

GRAPHOLINGUISTICS AND ITS APPLICATIONS

Grapholinguistics in the 21st Century—2024

/gʁafematik/
Proceedings

October 23–25, 2024, Venice, Italy
Yannis Haralambous (Ed.)

Part II

Fluxus Editions

Grapholinguistics and Its Applications 12

Series Editor

Yannis Haralambous, *IMT Atlantique & CNRS Lab-STICC, France*

Series Editorial Committee

Gabriel Altmann†, *formerly Ruhr-Universität Bochum, Germany*

Jacques André, *formerly IRISA, Rennes, France*

Vlad Atanasiu, *Université de Fribourg, Switzerland*

Nicolas Ballier, *Université de Paris, France*

Kristian Berg, *Universität Oldenburg, Germany*

Chuck Bigelow, *Rochester Institute of Technology, USA*

Stephen Chrisomalis, *Wayne State University, USA*

Florian Coulmas, *Universität Duisburg, Germany*

Joseph Dichy, *Université Lumière Lyon 2 & CNRS, Lyon, France*

Christa Dürscheid, *Universität Zürich, Switzerland*

Martin Dürst, *Aoyama Gakuin University, Japan*

Keisuke Honda, *Imperial College and University of Oxford, UK*

Shu-Kai Hsieh, *National Taiwan University, Taiwan*

Terry Joyce, *Tama University, Japan*

George A. Kiraz, *Institute for Advanced Study, Princeton, USA*

Mark Wilhelm Küster, *Office des publications of the European Union, Luxembourg*

Gerry Leonidas, *University of Reading, UK*

Dimitrios Meletis, *Universität Zürich, Switzerland*

Kamal Mansour, *Monotype, USA*

Klimis Mastoridis, *University of Nicosia, Cyprus*

Tom Mullaney, *Stanford University, USA*

Martin Neef, *Technische Universität Braunschweig, Germany*

J.R. Osborn, *Georgetown University, USA*

Cornelia Schindelin, *Johannes Gutenberg-Universität Mainz, Germany*

Virach Sornlertlamvanich, *SICCT, Thammasat University, Thailand*

Emmanuel Souchier, *Université de la Sorbonne, Paris*

Jürgen Spitzmüller, *Universität Wien, Austria*

Richard Sproat, *Google, USA*

Susanne Wehde, *MRC Managing Research GmbH, Germany*

Yannis Haralambous (Ed.)

Grapholinguistics in the 21st Century

/gʁafematik/

October 23–25, 2024 – Venice, Italy

Proceedings

Part II

Fluxus Editions

Yannis Haralambous (Ed.). 2026. *Grapholinguistics in the 21st Century. October 23–25, 2024. Proceedings* (Grapholinguistics and Its Applications, Vol. 12). Brest: Fluxus Editions.

This title can be downloaded at:

<http://fluxus-editions.fr/gla12.php>

© 2026, The respective authors

Published under the Creative Commons Attribution 4.0 License

(CC BY 4.0): <http://creativecommons.org/licenses/by/4.0/>

ISBN: 978-2-487055-12-4

e-ISBN: 978-2-487055-13-1

ISSN: 2681-8566

e-ISSN: 2534-5192

Cover illustration: Votive offering from the Sanctuary of Asklepios on the south slope of the Athenian Acropolis (350–300 BC, Acropolis Museum, EAM 15244): a marble face, its eyes inlaid in coloured stone, set into a niche carved in a limestone pillar. An inscription, still legible when the pillar was excavated in 1876, read: “ὑπὲρ τῆς γυναικὸς // εὐξάμενος // Πραξίας Ἀσκληπιῶ” (on behalf of his wife, having made a vow, Praxias [dedicated this] to Asklepios) (*IG* II² 4372). She was suffering, we may assume, from a disease of the eyes. Praxias could have contented himself with writing “I thank the god for healing my wife’s eyes.” Instead, he inscribed the rock with her face. Here writing is pushed to an extreme: the stone is the page, and the face—placed, framed, and addressed to a reader, the god—is the grapheme. Between the sentence carved in letters and the face carved in marble there is no break, only a continuum of graphic acts. It is this continuum, in all its breadth, that grapholinguistics takes as its object.

Cover design and typesetting: Atelier Fluxus Virus

Main fonts: William Pro by Typotheque Type Foundry, Computer

Modern Typewriter by Donald E. Knuth, Source Han Serif

by Adobe Systems, Amiri by Khaled Hosny

Typesetting tools: LuaL^AT_EX, bibl_{at}ex+biber (authoryear-icomp style), xindex

Fluxus Editions

38 rue Émile Zola

29200 Brest, France

www.fluxus-editions.fr

Dépôt légal: septembre 2026

κγζκς

Table of Contents

<i>Preface</i>	ix
<i>List of Participants at the Grapholinguistics in the 21st Century 2024 Conference</i>	xi

PART I

FLORIAN COULMAS. – The Linguistic Landscape: What we can learn from it	1
PHILIPPA M. STEELE. – The Visual-Cultural Fit of Writing Systems	15
MARY C. DYSON & DAVID BŘEZINA. – Do we process characters as shapes, nothing special?	47
DENNIS REISLOH & TATJANA SCHEFFLER. – On the linguistic status of emojis	65
DAVID A. ROBERTS. – Multilinear featurality in Roman script African orthographies	95
JONAS ROMSTADT. – Looking for the crucial point(s) – Forms and functions of punctuation units in handwritten German school exams	123
ALEXANDRE SOLCÀ. – Un court manuel du minoen proto-gréco- anatolien	159
ADELI V. BLOCK. – Inscribing Multilingualism: Lifemaps and “Trans- scripting” Among Moroccan Amazigh Youth	163
SPYROS ARMOSTIS & MARILENA KARYOLEMOU. – Creating a writ- ing system for an endangered language: the graphisation of Cypriot Arabic	181

JOSEPH DICHY. – Written languages and the Mental Lexicon: a crucial aspect of grapholinguistics, exemplified by agglutinative word-form recognition in Arabic and Biblical Hebrew	209
GUY BOURSIER. – Writing Egyptian Arabic: the case of a ‘dialectal’ Wikipedia	229
SINA FAKOUR. – Reviving Linear Elamite (2300–1880 BCE), The oldest known phonetic writing system.	247
YANNIS HARALAMBOUS. – Masoretic Graphemics and Graphetics: Challenges and Solutions	297
BEHNOOSH NAMDARZADEH & NICOLAS BALLIER. – Audio LLM subtokens as encapsulated knowledge: the case of Persian subtoken graphemic representations in Whisper	327
SAIYA L. KARAMALI. – The Developing Orthographic Conventions of Roman Hindi-Urdu	361

PART II

DONALD E. KNUTH, interviewed by YANNIS HARALAMBOUS. – The Grapholinguistic Model of T _E X, followed by an “All Questions Answered” Session	393
JAN KUČERA. – Tamil Orthography Reforms	417
VASANTA DUGGIRALA, RAJU SURAMPUDI BAPI & SOHAM G. KORADE. – Graphic Complexity and Orthographic Neighbors: Observations based on Telugu Writing System	443
PAUL D. UEDA. – Characters, Romanization, and Anti-Colonialism: Historical Development of Taigi and Vietnamese	469
HELEN MAGOWAN. – Towards reading in four dimensions	489
JAMES MYERS. – Synchronic and diachronic ordering in Chinese character form patterns	507
JANET GANON-DAVEY. – Beyond the alphabet, beyond the binary, maybe beyond “Chinese”? Exploring the emergence of gender-inclusive Chinese pronouns	533
NOAH HERMALIN. – The Efficiency of Spelling-Sound and Spelling-Meaning Mappings in Two Logographic Writing Systems . . .	551

GORDON G. BERTHIN & ROBERT SCHOCH. – The Antiquity and Timeframe of the Rongorongo Script on Rapa Nui (Easter Island)	597
ANTONIO PERRI. – Rethinking Unicode: how to digitally encode non-linear written artefacts? A tentative encoding of Codex Mendoza, folio 2r	633
ARVIND IYENGAR. – Braille as writing: Evidence and lessons for grapholinguistic theory	661
MICHAEL FILHOL. – AZVD as a Sign Language writing system proxy, and the potential evolution	689
MANGAS HECTOR AFONSO & PETER BILAK. – Enhancing Distance Reading for Low Vision: A Reading Acuity Experiment on Letter Width	709
TITUS NEMETH & MARTIN TIEFENTHALER. – Prima — An innovative type, designed for learning to read and write	713
SANTHOSH THOTTINGAL. – Parametric type design in the era of variable and color fonts	757
BOTH PARTS	
<i>Index</i>	α'

List of Participants

at the

Grapholinguistics in the 21st Century 2024

Conference

Ahlberg, Aija K.
Armostis, Spyros
Ashourinia, Kaveh
Auda, Iris
Avelino Corral, Esteban
Bacon, Bennett
Behnoosh, Namdarzadeh
Behrendt, Doris
Berthin, Gordon
Bianchini, Claudia Savina
Birk, Elisabeth
Block, Adeli V.
Bodor, Cristian
Boursier, Guy-Marie
Březina, David
Halverson, Colin
Cacciafoco, Perono
Candida, Fabiana
Capo, Daniele
Carlotti, Agnese
Cheminant, Anne-Claire
Circluede, Camille
Cockrum, Paul
Coulmas, Florian
D'Angelo, Antonietta
Danet, Claire
Dichy, Joseph
Dunlavey, Nicholas
Dürst, Martin Jakob
Dyson, Mary C.
Elta di Rodeano, Sveva
Fakour, Sina
Filhol, Michael
Fiona, Ross
Galli, Giulio
Ganon-Davey, Janet
Gardner, William L.

Gaultney, James V.
Gnanadesikan, Amalia
Groshi, Artur
Grzelec, Malgorzata
Guidotti, Marta
Guthrie, Tilly
Haralambous, Yannis
Harbour, Daniel
Hermalin, Noah M.
Hockett, Sara
Home, Eleanor
Honda, Keisuke
Huot-Marchand, Thomas
Iyengar, Arvind
Jindai, Keisuke
Joyce, Terry
Karamali, Saiya Layana
Khoury, Gretta
Khoury, Yara
Knuth, Donald E.
Krelaus, Leonie
Kučera, Jan
Lerbs, Meyer-Lothar
Magowan, Helen
Mastoridis, Klimis
Maurizio, Isabella
Meletis, Dimitrios
Mihaylov, Dimitri
Monaco, Sergio
Myers, James Tomlinson
Nemeth, Titus
Nevins, Andrew
Osgardy, David J.
Payne, Annick
Perondi, Luciano
Perri, Antonio
Polo, Ludovica

Raju S., Bapi
Roberts, David A.
Romstadt, Jonas
Schoch, Robert M.
Share, David
Shomer, Michal
Steele, Philippa M.
Strobel, Fabian

Szabolcs, Vátány
Terada, Yusuke
Thottingal, Santhosh R.
Tiefenthaler, Martin
Ugray, Gábor Laszlo
Vasanta, Duggirala
Verna, Didier
Xu, Duoduo

The Grapholinguistic Model of T_EX / “All Questions Answered” Session

Donald E. Knuth, interviewed by Yannis Haralambous

Abstract. This is the transcription of the interview and “All Questions Answered” session of Donald E. Knuth at the 2024 *Grapholinguistics in the 21st Century* conference, on October 24th, 2024. The text has been (slightly) edited and annotated with footnotes by the interviewer. In June 2026, Knuth read through the text and provided several remarks of his own, which have been incorporated into the footnotes and typeset in Xerox PARC’s Cream font to set them apart from the interviewer’s text.



1. The Grapholinguistic Model of T_EX

DEK (Donald E. Knuth): Okay. So you introduce me and so on, and then I just talk.

YH (Yannis Haralambous): Well, I’m not sure you need an introduction, but since you asked for it, Donald Ervin Knuth is one of the greatest computer scientists of the 20th century, and the beginning of the 21st, obviously.

Donald E. Knuth  0009-0000-8366-9524

Computer Science Department, Stanford University, USA

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 393–415. <https://doi.org/10.36824/2024-graf-knut>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

He wrote the *Art of Computer Programming* (TAOCP),¹ which is somehow the Bible of computer science. He is also the creator of the T_EX typesetting language, which is a programming language for producing beautiful documents of any kind, whether mathematics, dictionaries, or whatever you can think of. When he created T_EX, he noticed that the fonts were not optimal. So he created another programming language called METAFONT to describe fonts, going back to the parametric descriptions of typefaces in the Renaissance.² He used T_EX to typeset the code of METAFONT and METAFONT to create fonts for using with T_EX. So you have all of these tools and technologies combined, always with the goal of producing efficient and beautiful documents.

And they are used by millions of people today.

DEK: Okay. Gosh, I couldn't have improved on that. So are people watching me now? Can they see you?

YH: Yes. People are watching you.

DEK: Okay. Hello, everyone! The hardest thing when you're Zooming is that I don't have feedback as to what the audience is thinking, but I'm

1. This series of books (Knuth, 1968-) is DEK's magnum opus. He began working on it in 1962; the first volume was published in 1968, the second in 1969, and the third in 1973. In 1974, he received the Turing Award, whose citation honored the series as a whole, along with his foundational work on the analysis of algorithms. The most recent installment of TAOCP at the time of writing is Volume 4, Fascicle 7 ("Constraint Satisfaction"), published in February 2025, which will eventually be folded into the bound Volume 4C; Volume 4 has been appearing in parts (4A in 2011, 4B in 2022), and Volumes 5–7 are still planned to complete the series. Around 1977, he realized that if he wanted these books to be typeset properly, he would have to create his own typesetting tools. This marked the birth of T_EX and METAFONT, as well as Knuth's other legendary series of works: the series *Computers & Typesetting* (C&T), whose five volumes are, respectively, A a T_EX manual, B the T_EX source code, C a METAFONT manual, D the METAFONT source code, and E the source code for the Computer Modern typefaces, written in the METAFONT language. Here we witness the different scales of a single universe: the characters in TAOCP and C&T are generated by programs (in METAFONT); the works themselves are generated by a program (T_EX); and TAOCP explains how to write programs. Producing even a single comma in these works took a METAFONT program to draw it and a T_EX program to insert it into the text; C&T reveals these programs to us in their finest detail, and TAOCP teaches us how to understand these, and other programs, how to write them, and how to become a creator of universes just as DEK is. We live in an era where we see only the tip of the iceberg: most technologies are hidden from ordinary people, and soon, with the rise of LLMs in programming, the technology may even be hidden from the programmers themselves. TAOCP and C&T, on the other hand, are worlds where everything is open, explainable, and accessible—worlds in/on which humans have total control.

2. One of DEK's seminal texts, "Mathematical Typography," a J.W. Gibbs Lecture given on January 4th, 1978, and reprinted in his collection *Digital Typography* (Knuth, 2016), contains ruler-and-compass constructions for the letters B and S by Feliciano, Pacioli, Torniello, Palatino, Tory, and Jaugeon.

glad if you could wave and so on. I mean, if nobody laughs at my jokes, then I don’t know if anybody’s hearing me.

YH: Maybe we can start with the interview.

DEK: I only want to say one thing first, which is that Yannis did not tell me any of these questions in advance. Because I always think it’s better to have somebody stumble and give a bad answer, you get more information that way than if I had a canned presentation and was following a script. The mistakes I make might be more important than the correct answers I give.

YH: Okay. I wanted to call this part of the interview “the graphematic model of T_EX”. I sent you some definitions of what we could call a *grapheme*. It’s a distinctive unit for a given language system. A *graph*—I’m so sorry, this term has been used a lot, and is very polysemic—in this context, a graph is just a representation, the material support of a grapheme. We have people in the audience who are specialists in that. Functionally, the notions and concepts of grapheme and graph can be compared to Unicode characters and glyphs, even though the definitions are completely different.³ Graphemes and graphs are specific to a given language system, whereas Unicode nourishes the illusion of being universal.

Now, in T_EX, the T_EX source document uses characters. ASCII characters at the time evolved into Unicode characters today. These characters, when read by T_EX, become tokens and then nodes in a list. They end up being *set char* commands in a DVI file.⁴ These *set char* commands, as well as the nodes, are font-dependent. So they are just positions in a font and the font information. Then, to make this visible, you create bitmaps using METAFONT. You load them as bitmap files when printing

3. See Haralambous and Dürst (2019, pp. 139–145) for more details.

4. The distinction between “tokens” and “nodes” is reminiscent of Unicode’s dichotomy between “characters” and “glyphs” (Haralambous, 2007, pp. 54–58) in the sense that the former are abstract, more-or-less linguistic, entities while the latter are references to slots in a font, and therefore to images. DVI (“Device-independent”) is a static document format that is both minimalistic and very powerful. It is minimalistic since it contains only seven kinds of commands: (1) page initialization, (2) horizontal and vertical relative positioning, (3) nesting, (4) glyph setting (among which also the *set char* command mentioned in the text), (5) black box drawing, (6) font definition and activation, (7) “special” commands that have no semantics and the arguments of which are directly transmitted to the printer driver. The entire list of commands is explained in two and a half (!) pages of Volume B of C&T (Knuth, 1982a, §585). By way of comparison, the PostScript manual is a 912-page-long book (*PostScript Language Reference* 1999) and the PDF manual a 1310-page-long PDF file (*PDF Reference* 2006). Another feature of DVI is the fact that it is very precise since all calculations are done in the microscopical unit sp (a unit equal to 5.363 nm). Besides its extreme precision, DVI is powerful because it supports arbitrary nesting, enabling any kind of alignment between visual elements.

the DVI document. The only place where we still have some information on the identity of the glyph, in this case, is in the METAFONT code, where you have the name of the character.

My question is: What was the original idea behind an “electronic T_EX document”? Would it be just the source code that needs to be compiled? Would it be the source code plus DVI plus METAFONT? Or would it be these, plus the process of building the document, using also the format and all other resources?

DEK: Of course, I didn’t start out with the idea that I was making something extremely general. But I was faced with the problem of typesetting one book. My original idea was that I had just learned that there was good technology to print books that used pixels, you know, bits, instead of chemistry and metallurgy and photography and all that scary stuff. But the task of making beautiful books had turned out to be a computer science problem, which was just zeros and ones. I was faced with a situation where mathematicians and computer scientists were left behind because the printing technology had switched over, but we didn’t have anybody to figure out what the theory of it should be. So I needed something that would keep my own books from looking terrible. The drafts that I got from the proofs of volume two of TAOCP, well, you can find them in the Stanford archives,⁵ but I don’t recommend that anybody really look at them because it’s so painful to the eyes.

The shift from the quality typesetting of the 1960s to the unspeakable quality of the middle 1970s made me wonder whether I should ever write another book. So I had this problem: how to make my books look good again for the second edition. I found salvation when I learned that there were actually new machines that could print something that looked like real books using just zeros and ones.

Okay, I started out, and I didn’t have any idea about DVI or any of this stuff. All I know is I have a book, and I want to get it done. Well, I found out at that time what the state of the art was and what the best publishers of mathematics texts were doing. One of the main centers was in Belfast,⁶ and so they would compose onto paper tape, and they had skilled compositors who spent a lifetime composing mathematics. These people prepared things that went to paper tape, and then to another machine, and eventually a book would come out.

5. See https://archives.stanford.edu/catalog/sc0097_aspace_ref128_jpj, as well as footnote 8

6. The Universities Press in Belfast was a groundbreaking printing house using Monotype equipment, founded in 1959. It was dissolved in 2013.

So I learned what their system was,⁷ just so I could see what kind of basic functions need to be included. But I also knew about the system that Bell Labs had, and it’s one of the systems people used to access documents in electronic form. Those were only imitations. But this one in Belfast was state-of-the-art for real printers, and not toy experiments. I wanted something state-of-the-art, and I also investigated different machines being made for printing at the time, so that eventually I’d be able to send the zeros and ones to a good device.

Okay, so how did I start creating this model that you described? Well, it was simple. I looked at my book and found about eight pages’ worth of stuff, including all the different kinds of things that had to happen. I mean, I certainly needed ordinary text. I had to have equations. I had to have tables. I had to have computer programs. And line art for illustrations. In my book, I really didn’t need any photographs. But anyway, I made myself a mini-book consisting of eight pages, and I said, “Okay, now suppose this was my whole book. What language would I use? How would I enter this into a computer? What would I like to do?”

Then it remained to write a compiler that would compile for this little language into instructions for a machine. My test program is reproduced in full in my book, *Digital Typography*.⁸ So you can see the very first trial

7. The Universities Press in Belfast was using the Monophoto system (Boag, 2000), a transitional adaptation of the Monotype hot-metal composition caster. Reading the same punched paper tape from the keyboard as regular Monotype hot-metal machines, the Monophoto produced a high-quality film negative with the characters exposed on it instead of casting metal. See the beautiful documentary video <https://www.youtube.com/watch?v=DXfZjk9Mu9s>.

8. We can’t help but share the beginning of this test program—so different from the L^AT_EX code we’re used to—with the reader, both for the nostalgia it evokes and for the fabulous von Neumann quote it contains (Knuth, 2016, pp. 508–509):

```
\require ACPhdr
%Example TEX input related to Seminumerical Algorithms
\ACPages starting at page 1:
\titlename %This tells the page format routine not to put a page number on top
\runninglefthead{RANDOM NUMBERS}
\ljustline{\hexexpand 11 pt {\:p CHAPTER \hskip 10 pt THREE}}
\vskip 1 cm plus 30 pt minus 10 pt
\rjustline{\:q RANDOM NUMBERS}
\vskip .5 cm plus 1 pc minus 5 pt
\quoteformat{Anyone who considers arithmetical \cr
methods of producing random digits \cr is, of course,
in a state of sin. \cr} author{JOHN VON NEUMANN (1951)}
```

The attentive reader will have noticed the missing backslash before “author” on the last line. This is not an error. In fact, DEK writes in (ibid., p. 512): “The word ‘author’ which appears in this definition is not preceded by the escape character \ since it is scanned as part of the \quoteformat macro. Please don’t expect to understand this mess now, T_EX is really very simple; trust me.”

that I made as an input language that I thought I'd be able to handle. Then there was a second version a couple of months later. So anyway, that was where it started.

But there was this chicken-egg problem because we didn't have fonts, as you mentioned. First, I had to write something that would make fonts. But then, to have fonts, you needed something that would use them. So I had to do both things at once. There was a period of six months where I didn't have anything working. I just had ideas on paper.

Finally, I guess it was April of 78, when I spent every night from midnight to 10 o'clock, when the computer wasn't crowded, putting these systems together.

So anyway, it started with something I was designing for myself and my secretary, and it was supposed to solve problems I could foresee and that I'd be interested in. Well, but I was working at Stanford's AI lab, and there were about 100 people there, and it's very open, and everybody's watching, say, "What are you doing, Don?" So people said, hey, maybe we'd be interested to do it, too. Guy Steele⁹ was there, and he decided to port my system so that people at MIT could take a look at it. Eventually, I got to a point where 100 people were using it, and I had to write a manual.

Then there was a time when it reached 1,000 people, and every group had suggestions I hadn't included.

So it evolved over time: the idea of making things more and more universal at every stage, and a better understanding of which kinds of abstractions are going to be useful.

So I probably answered less than what you wanted or more than what you wanted, but I'll let you ask another question, and then I'll know.

YH: So you never had the dream of Project Gutenberg full of $\text{\TeX}$ documents, all books ever written in $\text{\TeX}$ on a server?

DEK: I didn't have this as a dream. That came later. I mean, that was too much to hope. I mean, I'm not that good at predicting the future. I'm not any good at predicting the future.

But I mean, my only dream at first was quality for at least one book.

YH: My next question is about spaces. Can I remind the public that in the DVI format, you have the *right* command,¹⁰ which is used both for

9. Guy Steele is the co-inventor of the Scheme programming language and one of the great language designers. He is the co-author of the 1983 edition of the *Hacker's Dictionary* (Steele et al., 1983), which is especially interesting to linguists since it describes language mechanisms that are specific to hackerese English (see also footnote 16), such as verb doubling, sound-alike slang, the -P convention, overgeneralization, spoken inarticulation, <anthropomorphization> and implicit comparatives.

10. See footnote 4 and (Knuth, 1982a, §585). The *right* command belongs to the category of DVI horizontal and vertical relative positioning commands.

spaces between words and for kerning. It’s the same command. There is no distinction between kerning between letters and spaces between words.

I’m asking because the role and function of spaces are hot topics in grapholinguistics. We had a very nice talk about that today.¹¹ I wanted to ask, was it a deliberate choice to match the two concepts, the concept of kerning and the concept of interword space, even though in the input file you have the space character between words and nothing between letters?

So was it a deliberate choice to merge these two concepts?

DEK: I think it’s independent. In the DVI, for all the same reasons as in PostScript, you just have this question of having to have coordinates where everything is being placed. So whatever commands you need to tell you how to go to a new x, y position, you could give full coordinates every time, or you could give relative coordinates, relative to where you are.

So there’s no difference among positioning commands. There’s no semantics in there. That’s specifically just to identify where to plant the next bit.

But in the input, I started out naively only knowing what normal Americans know about spaces. The main thing I thought about spaces was that I had seen a word processor where people used two spaces instead of one. By mistake, they wouldn’t know that they were inserting different amounts of space.

I was careful to say that if you have to type two spaces, it doesn’t get into your document unless you somehow say, “I meant this to be an extra space”. There’s also a question, you know, when you get to the end of a line, does that imply a space or not? I was careful to look at that. I didn’t know about kerning in those days. I picked that up a little bit later in my reading. I spent a lot of time in Stanford’s typography collection, looking at all the books I could find about how to do it well. That kind of spacing was not part of my original thoughts.

The spacing in mathematics was very, very strongly a part of my original quest because I studied and found what I call the standards of excellence in mathematical typesetting. I took a lot of measurements of how they did it. I also saw how the people in Belfast had manually said “Oh, here I’m inserting a thick space or a thin space in a mathematical formula”.

I knew what kind of primitives for that kind of space were going to be needed. But what actually goes into a DVI file has nothing to do with

11. Amalia E. Gnanadesikan, “Mind the Gap: Spaces and Boundaries in Spoken and Written Language,” <https://www.youtube.com/watch?v=sldNkvkyQlY>.

the meaning of space. The meaning of space in DVI is only about getting me from here to there.

YH: My third and last question is about the sentence ending full-stop. You are clearly distinguishing in the *T_EXbook*,¹² the sentence ending full stop and the abbreviation point, which is, a point followed by a backslash and a space. We talked about this today, and it's a syntactic distinction between the end of a sentence and an abbreviation point for staying in the same noun phrase. This distinction between the full stop and the abbreviation point exists only in T_EX. Unicode doesn't know about this. Even in TEI,¹³ you only have an XML element for abbreviations, but nothing specifically for the difference between the full stop, which in the typewriter will be followed by two spaces, and the abbreviation point, while the abbreviation point is followed by one space.

So my question is, do you believe that a typesetting system like T_EX should go beyond legacy encodings like Unicode or should it remain within the boundaries of universal standards?

In other words, if Unicode had existed in the early seventies, would you have based T_EX strictly on it, or would you have left some room for users and developers?

DEK: I'm thinking that standards grow. So, I mean, the Unicode standard wasn't there, but I certainly learned later about all kinds of standards that were enforced in different countries at different times.

I know that, for example, in France, putting an accent on a capital letter gets in and out of fashion every 20 years, and in Germany, they had strict rules for how you typeset the Roman numerals. They were extremely pedantic and awful. Just because something is a DIN standard meant nothing to me. I'm saying, what should the world really be

12. In Chapter 12 ("Glue") of the *T_EXbook* (Knuth, 1982c), DEK explains that the period after an abbreviation "doesn't count as a sentence-ending full stop." T_EX's method to mark this property is either by using a non-breakable space ~ or a _ command after the abbreviation period. The example `Proc.\ Amer.\ Math.\ Soc.` is commented as follows: "Granted that this input looks a bit ugly, it makes the output look right. It's one of the things we occasionally must do when dealing with a computer that tries to be smart." This text is followed by Exercise 12.4: *Explain how to type the following sentence:* "Mr. & Mrs. User were married by Rev. Drofnats, who preached on Matt. 19:3-9." The answer is `Mr.~\& Mrs.~User were married by Rev.~Drofnats, who preached on Matt.~19\thinspace:\thinspace3--9.` Using the ASCII tilde character for nonbreakable spaces is still part of a T_EX ist's most basic instincts.

13. The Text Encoding Initiative defines element <abbr> to contain abbreviations of any sort (Sperberg-McQueen, Burnard, et al., 2025, §3.6.5) but does not mention the change of behavior of the period included in the abbreviation. Here is an example given in the documentation: <abbr>Dr. M.</abbr> Deegan is the Director of the <abbr>CTI</abbr> Centre for Textual Studies. Nothing in this example serves to distinguish the role of the period character in the abbreviation from that of a regular full-stop.

like? Now, as far as full stops are concerned, the sentence also ends with question marks and exclamation marks. Then there are quite different conventions in France and America that I didn’t realize. We have something in America we call French spacing, which, I think, means that you don’t put extra space after a full stop, while in America we’re more accustomed to having more space at the end of a sentence, whether it’s a full stop or a question mark or whatever.

My original design was to make it look like American books, but later on, I learned that, for example, some books were banned in America because they were, you know, too sexually explicit.¹⁴ So they were typeset in France, and I found in the library that they used French spacing there.¹⁵

I learned later that in France they have this peculiar idea of putting a little space before a colon, which never occurred to me when I was designing things. The original thing was that I had read a lot of books, and I wanted my book to look like the ones I liked best. But it would make sense that, after the number of users went past 1,000, then 10,000, then 100,000, and spread to other countries, I learned about these other things and tried to adapt them.

In my original design, I had no idea I would do anything that would be used all over the world. I wouldn’t have dreamed of that. And actually, I had to decide, really, what I do best, and I decided that, like, what I do best is write TAOCP.¹⁶ So I had to go through a period when I had to

14. DEK is referring to books published by the Obelisk Press in the 1930s and the Olympia Press in the 1950s, both based in Paris. Obelisk was founded by the Manchester-born Jack Kahane; Olympia was founded by his son Maurice Girodias, who took his French mother’s maiden name and continued in his father’s line of work after the war. Books such as Nabokov’s *Lolita* and Beckett’s *Molloy*, both Olympia titles, were bought by American and British travelers and smuggled back into the US and the UK. [DEK: Actually I was thinking primarily of *Lady Chatterley’s Lover*, which indeed was published by Obelisk.]

15. French spacing is in fact a loss of linguistic information, since sentence endings are left unmarked. Preserving that information, however, comes at a cost: English spacing requires the typesetter to examine each period to decide whether it ends a sentence or marks an abbreviation point. This can amount to a great deal of effort when one considers that a book may contain thousands of periods (*Moby Dick*, for example, contains 7,385).

16. The importance of TAOCP is such that, as indicated in *The New Hacker’s Dictionary* (Raymond, 1991), in hackerese language, the term “Knuth” is used as a reference to TAOCP. Here is the entry for ‘Knuth’ in this dictionary: “**Knuth** [Donald E. Knuth’s *The Art of Computer Programming*] n. Mythically, the reference that answers all questions about data structures or algorithms. A safe answer when you do not know: “I think you can find that in Knuth.” Contrast **literature, the**.” And here is the entry for ‘literature’: “**literature, the** n. Computer-science journals and other publications, vaguely gestured at to answer a question that the speaker believes is trivial. Thus, one might answer an annoying question by saying, “It’s in the literature.” Oppose **Knuth**, which has no connotation of triviality.”

find an endgame. How can I leave the work on further refinements of typography to other people?

So I would wake up in the morning and not say, “What great new model should I have to improve, to get better and better ligatures in Tamil or something?” But I wake up in the morning and say, “How can I finish this project and get it over with?”

YH: OK, and one last question, very short. You know that in grapho-linguistics, we are very much interested in phenomena that are purely in the written modality of language. One of these phenomena is hyphenation. So you have worked a lot on hyphenation. You even had a PhD student¹⁷ to create a generator of hyphenation patterns.

My question is: In the Stanford Linguistics Department, was there ever a linguist interested in your work on hyphenation?

DEK: That’s a great question. I don’t think any of the people here, any of my colleagues, expressed special interest in that. So all these things are really important. I’m so delighted whenever I read your papers, in particular, to see how beautifully you’ve taken care of these details. The interesting thing is that they’ve evolved in so many different cultures and by so many different kinds of influences. So it’s a marvelous tableau to see people striving for beauty in different ways. It’s an endless quest. But it’s also that, that’s the point of life, to be engaged in these wonderful journeys.

YH: Thank you very much. So I will stop monopolizing you. We can start with the “All Questions Answered” session.

2. An “All Questions Answered” Session

GG (Giulio Galli): Good evening. Thanks for being here. So my question is, it seems to me, coming from typeface design education, that other than the content and the implications of both METAFONT and T_EX themselves, what also stuck very much in literature and mostly in people’s mind today is the debate between you and Professor Hofstadter,¹⁸ back

17. Frank Liang, “Word Hy-phen-a-tion by Comp-put-er,” 1983 (Liang, 1983), in which he considers hyphenation as a data compression problem and invents a new data structure, the *packed trie*, to efficiently store and search hyphenation patterns.

18. This “debate” may rest on a misreading of DEK’s original claims. In No. 1 of the 1982 volume of the *Visible Language* journal, DEK presented the parametric possibilities offered by the METAFONT programming language (Knuth, 1982d). In No. 4 of the same volume, Hofstadter characterized Knuth’s position as “falsely optimistic,” attributing to it two claims: “(1) that underneath all ‘A’s there is just one grand, ul-

in the 80s, about parametrizing typefaces. It is more often than not presented as a contrast. I even had a full module back in my master’s year titled “Knuth vs. Hofstadter”. But now, my personal takeaway, after reading both your and his articles, is that the overlap between your views may be greater than is sometimes communicated.

So I guess my question is: how do you reflect on that debate that seems to have struck a chord for you, and on the many more debates on the topic in the typographic community?

DEK: Let me introduce my colleague here, Luis Trabb Pardo. He was my right-hand man on T_EX in the early days.¹⁹ Can you see? No, you can’t see it, but they want to see you now, yes.

Okay, so anyway, Luis, did you understand his question?

LTP (Luis Trabb Pardo): I didn’t follow that particular question.

DEK: Okay, you mentioned Hofstadter? My favorite story is that Doug said at one point, “The most important question in artificial intelligence is, ‘What is the letter A?’ And I said, ‘Yes. And the second most important question about AI is: What is the letter I?’ ”²⁰ You don’t get it, but anyway,

timate abstraction that can be captured in a finitely parametrizable computational structure—a ‘software machine’ with a finite number of ‘tunable knobs’; and (2) that every conceivable particular ‘A’ is just a product of this machine with its knobs set at specific values” Hofstadter (1982, pp. 309–310). Hofstadter further argued that “to fill out the full ‘space’ defined by a category such as ‘chair’ or ‘A’ or ‘waltz’ is an act of infinite creativity, and that no finite entity (inanimate mechanism or animate organism) will ever be capable of producing all possible ‘A’s and nothing but ‘A’s” Hofstadter (ibid., p. 310). However, a close reading of DEK’s article does not straightforwardly support this attribution. DEK argued that any given typeface can be described by some METAFONT program, and that a single program can, with appropriate design, parametrize several typefaces simultaneously and generate interpolations among them. He did not claim that a single, universal program could generate *every conceivable font* solely by varying parameter values. Hofstadter’s critique, while philosophically substantial in its own right, appears to engage with a stronger claim than DEK actually advanced, which calls into question whether a genuine disagreement over DEK’s position ever existed.

19. Luis Trabb Pardo, originally DEK’s PhD student (Trabb Pardo, 1978) and then working on the T_EX project (with the title “Associate Director, T_EX Project”), is known for the TPK (Trabb-Pardo-Knuth) Algorithm (Knuth and Trabb Pardo, 1980), which allows programming languages to be compared. See also <https://www.tug.org/interviews/trabb-pardo.html>.

20. In fact, this exchange between Douglas Hofstadter and DEK is documented in the former’s essay “Waking Up from the Boolean Dream, or, Subcognition as Computation”: “I hereby make the following claim: The central problem of AI is the question: *What is the letter ‘a’?* Donald Knuth, on hearing me make this claim once, appended, “And what is the letter ‘i’?”—an amendment that I gladly accept. In fact, perhaps the best version would be this: The central problem of AI is: What are ‘a’ and ‘i’?” (Hofstadter, 1985, p. 633)

there are definitely, in all, I mean, the older I get, I see more different art forms, and font design is one of them, it covers more than one art form, and it involves so many different things about, you know, not only the optical illusions, but also a great deal more. I had fun reading Yannis' description from some years ago about emojis, and all these, okay, so, but your specific question is what?

GG: I just wanted to ask you, how do you see 40 years later, how do you reflect on that debate around the possible or not parametrization of typefaces, that debate you had with Professor Hofstadter back in those days?

DEK: Okay, well, I still believe that it's wise to think of parameters in every project you do, some projects are one-off, but other ones, you know that you have certain things that you can vary, and it's very important to focus on how you would vary the design, if your boss came in the next day and told you that he wanted it to be different.

If you understand this notion of parameter, that's great, but I don't think you're going to get to a point where we've universally decided what all the parameters are, that's like saying we've all decided what kind of novels can be written and what kind of statues can be made, or what kind of puzzles can be formed, or what kind of jokes can be told? Apparently, a best-selling book is coming out that says all literature falls into one of these seven plots or something.

DB (Doris Behrendt): Hello, my name is Doris. I have greetings from the German-speaking T_EX user group, by the way, and I wanted to ask for your opinion on the Comic Sans font.

It has a reason. The reason is that this year I saw a lot of famous people giving talks, and their slides were with Comic Sans. I just wanted to get your opinion on it, since it's going viral a bit.

DEK: Yeah, that could be a danger. But also, I was at a conference at MIT where several of the best talks were illustrated with Comic Sans. I first saw it, I think, probably in Christos Papadimitriou's graphic novel,²¹

21. This graphic novel is called *Logicomix*. It appeared first in Greek (Δοξιάδης, Παπαδημητρίου, Παπαδάτος, and Di Donna, 2008) and then in English (Doxiadis and Papadimitriou, 2009). It is the story of the lives and works of Georg Cantor, Ludwig Wittgenstein, G. E. Moore, Alfred North Whitehead, David Hilbert, Gottlob Frege, Henri Poincaré, Kurt Gödel, and Alan Turing, narrated by Bertrand Russell. Typographically, it is quite interesting, since the texts by characters from the present are typeset in all uppercase, while Russell's narration is always in mixed case. On page 54 (of both editions), Goethe's *Mailed* is even set in (badly kerned but otherwise correct) Schwabacher script.

Besides its other qualities, *Logicomix* is also interesting from a grapholinguistic perspective, for the following reason: On page 69, the young Russell uses Greek script

which talks about famous logicians. But in that work, it was only all-caps. I probably went through five or ten years seeing only the capital letters of Comic Sans.

But now, okay, we’re engaged in a project where a wonderful friend, Siobhan Roberts,²² is compiling a strange biography of me, where we’ve gone through all of my memorabilia, and we’ve photographed all kinds of ephemera from every period of my life, and letters written, and so on. But also, I kept a diary, a daily diary of technical things that I was doing. So, this book that she’s planning, we’re working on it, probably, hoping maybe in a year it’ll be done, but she’s going to be quoting a lot from my diary.

The question was, what font to use for the diary entries? I said immediately, “Comic Sans.” But now, if you say it’s going viral, it’s going to be too much a part of the furniture.²³ But certainly, I’m going to see the proofs of it next month. I don’t know the history of that font, or who created it. When I was working on T_EX in the 70s, we had a font that ev-

to transcribe the entries in his diary so that his tyrannic grandmother is unable to read them (the title on the diary’s cover being “Greek Exercises” for camouflage). The graphic novel shows a page of this diary, written in English transcribed phonetically into Greek. What is interesting is that the phonetic transcription of English *differs* between the Greek and English versions of *Logicomix*. In the former version, it adopts the modern pronunciation of Greek and the monotonic system (the monotonic system is an abomination that was introduced in Greece in 1982, many decades after Russell supposedly wrote those lines), and in the latter version, it adopts a more-or-less Erasmian pronunciation of Greek. So, for example, the words “humans behave” are transcribed “ὕμανς μιχαίηβ” (no breathings, a mu-pi digraph for the /b/ and a beta for the /v/) in the former, and “ὕμανς βιχαίηφ” (rough breathing on the upsilon to express the /h/, a beta for /b/ and a phi for /v/—even though a digamma would be more appropriate than a phi here) in the latter. This variation in the transcription scheme clearly demonstrates that transcriptions are not only linguistic but also cultural adaptations. But the comparison between the two transcriptions is even more interesting since it reveals failures, *quasi-Freudian slips*: on the one hand, in the English and supposedly polytonic version, many monosyllabic words (such as “Μοστ, μορ, το, κορς” for “Most, more, to, course”) are unaccented, something that would never happen in polytonic Greek; on the other hand, in the Greek version of *Logicomix*, an upsilon is used for the word “humans,” as a trace of the /h/, and an omega is used for the words “all” and “also,” as indicator of the length of the syllables. These linguistically sound practices were common before the 1982 monotonic reform (Haralambous, 2019), but quite seldom in as late as 2010. It would be interesting to determine the extent to which these phenomena are accidental versus intentional.

22. Siobhan Roberts is a Canadian author and science journalist, and a regular contributor to the *New York Times*. She authored “The Yoda of Silicon Valley,” a beautiful text on DEK in the Profiles in Science series (Roberts, 2018), which ends with a troubling quote about AI: “I am worried that algorithms are getting too prominent in the world. It started out that computer scientists were worried nobody was listening to us. Now I’m worried that too many people are listening.”

23. Quoting Siobhan Roberts (personal communication, June 5th, 2026): “the book is in the works. There is no publication date yet. I am still writing. I’d say it is uncertain as to whether Comic Sans will be used, but perhaps in some shape or form.”

everybody loved on our Xerox graphics printer. I can't remember its name now.²⁴ But it was rather similar to Souvenir. A lot of people know the font called Souvenir, and it was used so much.²⁵ Everybody loved it for 10 years, but all of a sudden, everybody started hating it. So, I don't know when the last book printed in Souvenir was, but there was a time when more than half of the publications used Souvenir.

LML (Lothar Meyer-Lerbs): Hi, my name is Lothar. The big question is, as you said, you have not planned T_EX and METAFONT to do all these things, but in hindsight, what would you add to these programs? What features are missing? What would you like to see in a version that's no longer yours? What should people put into these programs to make them better?

DEK: Now, let me first give a joke answer, you can look online for a talk that I gave called "An Earthshaking Announcement".²⁶ This was, in fact, I view that as my last technical paper of my life. I mean, there's going to have to be a last one. I decided that that was going to be the last one. Everything else will be a blog or something. It was a talk I gave at a T_EX user group meeting in San Francisco. It was in the same place where Steve Jobs used to announce the newest features for Apple products. I described the future *²⁷ project, the successor to T_EX, which is called iT_EX. But you had to pronounce it with tones. You also, if you did it correctly, should ring a bell as well. It had a special logo that included the

24. The interviewer searched in Stanford Artificial Intelligence Laboratory Operating Note 74 "Find a FONT" (Earnest, 1976), and it appears that the font that is visually closer to Souvenir was probably called Meteor. DEK: By chance, I was looking at Find a Font a few days ago, and I did NOT find the font that I was talking about. [With Gemini's help, I also found what is no doubt the most comprehensive list of font samples from that era, namely Christman (1980).] So I decided that the font in my mind must have been on the Dover printer, NOT the XGP. Sure enough, Gemini was able to help me identify it—the name was "Cream"—and to show me its actual bitmaps. Cream, designed by Bob Flegal, was wildly popular, adopted by Smalltalk for example, and is now available via KreativeKorp as "Parc Place.ttf" and "Parc Place Legacy.ttf". The thing that marries Cream to Souvenir is mainly the lowercase letters like e, v, w, y. (The fonts can be downloaded from <https://www.kreativekorp.com/software/fonts/index.shtml>.)

25. People think of Souvenir as a paradigmatic 70s font, but it was originally designed by Morris Fuller Benton for ATF in 1914. In 1971, Ed Benguiat redrew and expanded it for ITC, and it became ubiquitous. Quoting Jeremiah Shoaf, in his *Type-wolf* Web site, "Due to its rampant overuse in the 1970s, ITC Souvenir is notable as one of the most hated typefaces by designers active in that time period—I like to think of it as the Comic Sans of the 70s."

26. The talk can be viewed here: https://www.youtube.com/watch?v=eKaI78K_rgA and the transcription can be found in Knuth (2010) and in Knuth (2011, pp. 707–715).

27. Here and in Knuth (2010), the asterisk signifies that any phonetic (or synesthetic, see footnote 28) realization of this logo should include the ring of a bell.

bell. Anyway, you can see a video of this talk. It lasts half an hour. It was a satirical thing that essentially said I learned I have no talent for writing programs, so I should instead hire somebody to do the programming properly. They were going to use all of the techniques of software development that satisfy all the buzzwords. Not only did it include improvements to fonts and kerning and so on, but it also did three-dimensional things. It would include 3D printing. It would include music. It would also include, well, search features. It did mathematical computations.

Essentially, it was a combination of Google, Facebook, and Mathematica. I didn't have ChatGPT as part of it at the time, but I would have included it if it existed at the time. Anyway, the idea was that this successor to T_EX was going to be everything to all people, and it was only going to cost—of course, it had to be charged for, because that was one of my big mistakes, my biggest mistake was putting T_EX in the public domain—it was only to cost \$100 a month, but if you could get 10 other people to sign up, you could get it for nothing. So there was this Ponzi scheme associated with it as well. And so, you know, the other big mistake I made was using literate programming, etc. Actually, I sort of—this would be my final paper, because my first paper was a satire that was published in *MAD Magazine* when I was in high school.²⁸ Okay, now, we're

28. Here, DEK puts his two seminal texts into perspective: his incipit, the *MAD Magazine* article in which he presents his own system of measurement (one *potrzenie* corresponds to the thickness of issue 26 of *MAD Magazine* (1957), one *blintz* corresponds to the mass of a halavah cake with a volume of 1 cubic dekapotrzenie, etc.) and his own calendar (long before January 1st, 1970, which is the origin of the Unix calendar, DEK introduced October 1st, 1952, as the origin of the MAD calendar); and its excipit, the text of his presentation “An Earthshaking Announcement” published in TUGboat in 2010, in which he presents his supposedly new version of T_EX. Aside from his ability to satirize the spirit of the times, we notice a very strong commonality between the two texts: their human depth. The meter was, in the past, defined as one forty-millionth of the Earth's meridian—but how do you really calculate such a length? The *potrzenie* is a measure accessible to ordinary people, and fundamentally honest: its lack of precision is right there, before our eyes; there's no need to hide it behind pseudo-scientific rhetoric. The *potrzenie* is just as fragile as we are in the face of technological advances: how will we measure it on the day the last copy of MAD #26 is reduced to dust? DEK's * project reminds us that communication has always been multimodal (we can hear the rustling of a book's pages, we can smell it, we can even eat it like Gérard Philipe, cf. Cloux, 2007; Haddad, 1984) and that the simplification of transmitting only text (as defined by Unicode) is a historical aberration. His idea of ringing a bell every time the * logo is spoken, aside from the reference to Catholic liturgy or to the ASCII BEL character (0x07), creates a synesthetic experience, not to mention the symbolic aspect of this bell: “to ring a bell” means both “to physically ring a bell” and “to spark a previously forgotten memory.” He thus adds a psychoanalytic dimension to the sensory and synesthetic dimensions. To conclude this 1957/2010 comparison, the first article reveals a young mind who had already grasped that all formal systems rest on informal choices—his final article shows us that so-called progress increasingly consists of forgetting things: stability,

probably talking about more. The things that have come out in X_YT_EX and so on are probably the things that are—who is it, Jonathan Kew?²⁹ He knows a lot about many languages, and I think his insights were especially valuable for preparing for the future. I think it’s important to have something that can change, but it has to be archival. It should be that, for an important document somebody writes, you should be able to see it again 50 years later. If your conventions are changing all the time, because it depends on somebody’s rendering engine or something like that, that’s impossible. One of the most important things was to keep it small, well enough defined that you can say this is a permanent document, and not a trendy, ephemeral document. I mean, the World Wide Web has a subset of HTML that I can use, which they say they’re going to keep going forever.³⁰ I think that’s very important.

YH: Okay. There are many font designers in this room, so I cannot help but ask: When you started collaborating with Hermann Zapf, were you speaking the same language? I don’t mean German and English. I mean, between a computer scientist and a font designer, were there any terminological or perceptual hurdles?

DEK: I think Hermann and I hit it off rather well. I mean, he was thinking about using brushes and pens. And he, you know, he taught me what he

literate programming, the “do-it-yourself-to-better-understand” approach—all of this is disappearing in the era of LLMs, and DEK traces, with gentle precision, the outline of what is being left behind. Furthermore, both papers share a structural joke: they present absurdity in the form of rigorous technical specification. The Potrzebie System has conversion tables; * has pricing tiers and certification levels. The comedy in both cases comes from the mismatch between the seriousness of the form and the playfulness of the content—which is, of course, exactly what all of DEK’s serious work does in reverse: serious content in a form made as accessible and even playful as possible. The two satirical papers are his serious work seen in a mirror.

29. Jonathan Kew (SIL International) is the developer of X_YT_EX, an extension of T_EX that communicates with the surrounding operating system in order to render “complex” scripts such as Arabic, Hebrew, CJK, etc. (Robertson, Hosny, and Berry, 2025). Unfortunately, ever since 2020, X_YT_EX is considered unmaintained and has not seen any evolution. As of the writing of this text (June 2026), the most promising extension of T_EX is LuaT_EX, which uses an internal programming language (Lua) to access the various data structures inside T_EX in real time (Hagen, Henkel, Hoekwater, and Scarso, 2025).

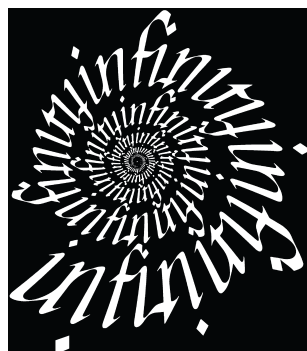
30. In 2004, the W3C founded the Web Hypertext Application Technology Working Group (WHATWG) to manage the evolution of W3C standards and tests. In their FAQ (<https://whatwg.org/faq>), they claim that their foundational principle is backward compatibility—parts of the standard that have matured and been implemented generally cannot be changed in ways that are backward-incompatible without extreme care. But they also say, more candidly, that “if the web is replaced by something better and dies, the HTML Standard will die with it,” which is a bit less optimistic.

meant by this. And our early discussions about the Euler typeface³¹ went through, you know, we had dreams that couldn’t be fulfilled because they were probably trying to do too much. So I dedicated METAFONT to Hermann, and I said, you know, “To Hermann Zapf: Whose strokes are the best.”³² I meant that in two senses. Not only the marvelously beautiful strokes that he would draw, but in English, there’s another meaning of strokes, which means “compliments”. Whenever I did something that he didn’t approve of, he would tell me right away. So I knew that when he did occasionally give me a compliment, it was real. I really appreciated the strokes that were slaps in the face, as well as the strokes that were saying, “Okay, Don. You’re starting to get it.”

YH: Any other questions?

GG: I have a very quick question. What is the poster behind you? Is that an ambigram?³³

DEK: That is by Scott Kim, one of my students,³⁴ yes. I’m glad it shows up. Let’s see that.



31. The Euler font family was commissioned by the AMS to Hermann Zapf. The first book entirely typeset in Euler was “Concrete Mathematics” (Graham, Knuth, and Patashnik, 1989), and, in a way, the font’s originality matches the originality of the contents, where “Concrete Mathematics” is used both as an antidote to “Abstract Mathematics” and as the contraction of “CONTinuous and disCRETE Mathematics.” As the authors explain in the Preface, “The underlying philosophy of Zapf’s design is to capture the flavor of mathematics as it might be written by a mathematician with excellent handwriting. A handwritten rather than mechanical style is appropriate because people generally create mathematics with pen, pencil, or chalk. [...] This new type family has been named AMS Euler, after the great Swiss mathematician Leonhard Euler, who discovered so much of mathematics as we know it today. We are especially pleased to be able to inaugurate the Euler family of typefaces in this book, because Leonhard Euler’s spirit truly lives on every page: Concrete mathematics is Eulerian mathematics.”

32. Dedicatory sentence on page ii of the *METAFONTbook* (Knuth, 1982b).

33. The concept of *ambigram* has been coined by Hofstadter. He defines it as “a visual pun of a special kind: a calligraphic design having two or more (clear) interpretations as written words. One can voluntarily jump back and forth between the rival readings, usually by shifting one’s physical point of view (moving the design in some way) but sometimes by simply altering one’s perceptual bias towards a design (clicking an internal mental switch, so to speak). Sometimes the readings will say identical things, sometimes they will say different things” (Hofstadter, 1987).

34. Scott Kim is a computer scientist, DEK’s PhD student (Kim, 1987, with Charles Bigelow in his thesis committee), puzzle and video game designer, artist, author, and recreational mathematician. He wrote one of the first books on ambigrams, called *Inversions* (Kim, 1981), with a foreword by Hofstadter and a backword by Jef Raskin.

By the way, I saw Scott last Sunday, and so he now has kids getting out of college, and he's having fun making some YouTube videos with one of his sons.

Were any of you at Stanford last year at the event that Tom Mullaney organized?³⁵ I mean, look, there were many shared interests. Like, I talked to the people who did the cuneiform fonts, for example, and Chuck Bigelow was one of the keynotes. Well, we had quite a few great speakers.

MD (Martin Dürst): Hello, Don, this is Martin Dürst. I have a question, a little bit less technical. You were extremely healthy and active and so on. I wanted to ask if there's anything that, well, that keeps you healthy and going?

DEK: Well, I've been lucky, although, okay, so a week ago, I had a cataract removed in my left eye. Next week, they're going to take the cataract off my right eye. At the moment, I don't see, I mean, I see differently with different eyes. I'm trying to learn how to stay healthy. So I swim typically four days a week and ride a bicycle. But while I'm recovering from this eye surgery, I'm supposed to go a whole month without swimming, biking, or gardening.

But generally, I do think it's, you know, the human body was designed to do certain things. So I look for opportunities to walk rather than to ride. Let's sort of put it that way. My balance is getting worse. I'll have to do some more exercises to improve my balance. Who knows what's ahead? But if some illness hits me, I'm not going to be angry about it. I'll be thankful for all of the good health I have had.

While I stay healthy, I'm going to do my best to continue producing, producing more of TAOCP that's sitting in my files, waiting to be written.

The book is printed in a square format so it can be turned at a right angle without compromising symmetry. The ambigram on DEK's wall is called *Infinity* and appears in Kim (1981, p. 35). In the comments, we discover that using a circle avoids loose ends and that stacking the lines solves the problem of extra dots: the dots hanging below one layer now become part of the next layer. On his blog (<https://www.scottkim.com/post/infinity-circle-1981>), Kim gives further technical details on a circular one-layer version of *Infinity*: "I programmed this design originally in JaM, the predecessor to PostScript. The mathematical transformation from straight to circular lettering was programmed by John Warnock, the co-creator with Martin Newell of JaM, and co-founder with Charles Geschke of Adobe Systems."

35. Thomas S. Mullaney (author of the very interesting *The Chinese Typewriter: A History*, Mullaney, 2018), is the director of SILICON (Stanford Initiative on Language Inclusion and Conservation in Old and New Media) and organizer of the *Face/Interface 2023* conference at Stanford (<https://digitalhumanities.stanford.edu/face-interface-2023/>), which is the event DEK is referring to (see also Veytsman, 2024).

Some of you might know this novel by Laurence Sterne from the 1700s called *Tristram Shandy*.³⁶ It’s a story of the life of Tristram Shandy. The first ten chapters cover the first week of Tristram Shandy’s life. So then he starts to realize he’s not going to get through the whole story. But the next year, the second volume or something of Tristram Shandy came out, and Laurence Sterne said, “You know, I plan to just come to my publishers and deliver more copy as long as I can.”

Somebody asked me, “What do you do, Don?” And I said, “Well, I eat, sleep, and write content”.

YH: Since we are asking less technical questions, in the T_EXbook, you say to the reader, *GO FORTH and create masterpieces of the publishing art*.³⁷ Nowadays, ChatGPT is also doing T_EX. And so theoretically, it can also do masterpieces of typesetting art, and even inspect T_EX’s code.

So my question is, what will you do if you receive a bug report coming from an artificial intelligence?

36. Besides its diary-like process of content production, *Tristram Shandy* is extremely interesting to (typo)grapholinguists due to the very innovative use of the typographic medium (see, e.g., Voogd, 2018 and Barchas, 2003). A precursor in typographic methods (see Haralambous, Landragin, and Handa, 2020) Sterne used an entirely black page to express mourning of Yorick, and even a pair of contiguous black and marbled pages he commented as “you will no more be able to penetrate the moral of the next marbled page [...] than the world with all its sagacity has been able to unraval the many opinions, tranfactions and truths which ftill lie myftically hid under the dark veil of the black one”. A ubiquitous feature of his work is the use of variable-width dashes (ranging from a few points to a complete line of text), sometimes 4–5 of them on the same line. I would like to compare his use of dashes with the way emphasis was given on the harpsichord (see, e.g., Couperin, 1716). Indeed, Sterne’s page and the harpsichord meet the same constraint and resolve it the same way: denied any control over intensity, each manufactures emphasis out of time. The harpsichord’s plucked action fixes a note’s loudness, whatever the force of the touch, so the player privileges a note not by striking it harder but by isolating it temporally—the agogic accent, to borrow Riemann’s later term, produced through articulation and the slight silence that, falling before an onset, makes the ear register it as stressed. Sterne’s typography works under an analogous poverty. The mid-eighteenth-century page possessed no instrument of graded emphatic weight—nothing answering to boldface—and italics signaled only difference of kind, a name or a foreign word or an altered voice, rather than difference of degree; emphasis proper had therefore to be constructed, as in music, from duration and silence. This is the work of the Shandean dash, and of the calibrated lengths Sterne assigns it: not a louder word but a suspended one, a withholding that loads the phrase to come exactly as the micropause loads the note to come. The parallel is finally historical as much as structural, since both temporal expedients are dissolved by the same order of invention—the fortepiano restoring intensity to the fingers and so retiring the agogic detour, the latter economy of boldface lending the page a direct typographic stress that the dash had until then been obliged to counterfeit in time.

37. This is the “final exhortation,” at the end of “Chapter 27: Recovery from Errors” in Knuth (1982c, p. 303).

Will you pay the hexadecimal dollar?³⁸ And to whom?

DEK: Oh, whoever sent it, if it's a valid correction, the reward is justified.³⁹

A month ago, the publisher said, "We're going to reprint volumes 1, 2, 3, and 4A". Every time a new printing comes out, I go through all of the error reports that have come in. So, since February, it turned out that there were more than 150 separate issues that people had raised. I would say only about 30 of them were really, really bad or not worthwhile. Even when someone thought there was an error, but the text was okay, I could still improve it so that a person wouldn't think there was an error. So I went through these 150 things, and each one is independent of the others, so it took me more than two weeks. That was only for four of the books that I have in print. So I've got a big stack of mail to answer after I finish the next thing.

But my current project is: I'm hoping to finish volume four, fascicle seven, which, if all goes well, will be printed in December.⁴⁰ I'm writing the last 10 pages now, and next week I'll start on the index to it.

But certainly, these Large Language Models are tremendous fakers, and so they're so good at saying plausible things, and if I get something like a distributed denial of service attack with reports, then I'll have to figure out how to cope with that. But right now, I would check whether the comment is plausible. Boy, I hope nobody tries it, though. Long ago, in the 60s, Joshua Lederberg made a model of what constitutes a viable protein, and so then there was a question of whether you could write a computer program that would come up with a million viable proteins, and the question is, well what if he sends them all to the US patent office to get a patent on it?⁴¹ To me, all connections with money are the least important in my life, but I know that it's not true for everybody.

38. DEK awards checks for finding technical, typographical, or historical errors, or making substantial suggestions for his publications (the interviewer is the proud recipient of two such checks). Since 2008, these checks have been issued by the Bank of San Serriffe (https://hoaxes.org/archive/permalink/san_serriffe) in the country's national currency, namely the *hexadecimal dollar*.

39. DEK: Incidentally, when I issue the next round of checks in a week or so (e.g., in mid-June 2026), one of them will be to Claude... at the request of the man who was the go-between.

40. And indeed, TAOCP, Volume 4, Fascicle 7, *Constraint Satisfaction* has been released on February 5th, 2025.

41. Joshua Lederberg was a molecular biologist, winner of the 1958 Nobel Prize in Physiology or Medicine, professor at Stanford, and founder of Stanford's Department of Genetics. This appears to refer to ideas circulating around Lederberg's DENDRAL project (1964–), a program capable of systematically enumerating all possible molecular structures satisfying given constraints. The patent thought experiment DEK describes does not appear to correspond to a published text; it may derive from personal conversations at Stanford, where both men were colleagues.

YH: I think we’re finished.

DEK: I appreciate you guys staying up late to watch this.

ALL: Thank you very much,⁴² Don, and bye! (Applause.)



References

- Barchas, Janine (2003). *Graphic Design, Print Culture, and the Eighteenth-Century Novel*. Cambridge University Press.
- Boag, Andrew (2000). “Monotype and phototypesetting”. In: *Journal of the Printing History Society* 2, pp. 57–77. URL: <https://apmub.wordpress.com/wp-content/uploads/2014/01/monotype-and-phototypesetting-andrew-boag.pdf>.
- Christman, David P. (1980). *The Last Whole XGP Font Catalog*. Tech. rep. MIT AI lab working paper 197.
- Cloux, Patrick (2007). *Mon libraire, sa vie, son œuvre*. Le Temps qu’il fait.
- Couperin, François (1716). *L’art de toucher le clavecin*. Paris: Foucaut.
- Doxiadis, Apostolos and Christos Papadimitriou (2009). *Logicomix: An Epic Search for Truth*. Bloomsbury, New York.
- Earnest, Les (1976). *Find a FONT*. Tech. rep. Stanford Artificial Intelligence Laboratory Operating Note 74 <https://archive.computerhistory.org/resources/access/text/2017/06/102774987-05-01-acc.pdf>.

42. The interviewer would like to take this opportunity to thank DEK for bringing beauty and humanity to his, and to so many other people’s, lives. Expressing one’s gratitude to DEK (see also Haralambous, 2018) is a never-ending task, a task that makes you introspect and think about what is important in life, and what your GO FORTH targets are. May the last words of the unusually long series of 42 (not just any number!) footnotes be another attempt to transmit gratitude, von Herzen zu Herzen, φιλίας ἔνεκεν. Thank you Don!

- Graham, Ronald L., Donald E. Knuth, and Oren Patashnik (1989). *Concrete Mathematics*. Addison-Wesley.
- Haddad, Gérard (1984). *Manger le livre : rites alimentaires et fonction paternelle*. Grasset.
- Hagen, Hans et al. (2025). “LuaTeX Reference Manual”. <http://mirrors.ctan.org/systems/doc/luatex/luatex.pdf>.
- Haralambous, Yannis (2007). *Fonts & Encodings. From Advanced Typography to Unicode and Everything in Between*. Sebastopol, CA: O’Reilly, pp. xx+1018.
- (2018). “TeX as a Path, a Talk Given at Donald Knuth’s 80th Birthday Celebration Symposium”. In: *TUGboat* 39.1, pp. 8–15.
- (2019). “Phonocentrism in Greece: Side Effects of Two Centuries of Diglossia”. poster presented at *AWLL12*, Cambridge, UK, <https://hal.archives-ouvertes.fr/hal-02480230>.
- Haralambous, Yannis and Martin Dürst (2019). “Unicode from a Linguistic Point of View”. In: *Proceedings of Graphemics in the 21st Century, Brest 2018*. Ed. by Yannis Haralambous. Brest: Fluxus Editions, pp. 167–183. DOI: <https://doi.org/10.36824/2018-graf-hara1>.
- Haralambous, Yannis, Frédéric Landragin, and Kenichi Handa (2020). “Graphemic and Graphetic Methods in Speculative Fiction”. In: *Proceedings of Grapholinguistics in the 21st Century, 2020*. Ed. by Yannis Haralambous. Vol. 4. Grapholinguistics and Its Applications. Brest: Fluxus Editions, pp. 259–359. DOI: 10.36824/2018-graf-hara2.
- Hofstadter, Douglas R. (1982). “Metafont, Metamathematics, and Metaphysics: Comments on Donald Knuth’s Article “The Concept of a Meta-Font””. In: *Visible Language* 16.4, pp. 309–338.
- (1985). In: *Metamagical Themas: Questing for the Essence of Mind and Pattern*. Basic Civitas Books.
- (1987). *Ambigrammi. Un microcosmo ideale per lo studio della creatività*. Hopefulmonster.
- Huot-Marchand, Thomas (Apr. 2022). “Knuth vs. Hofstadter”. In: *Systèmes : logiques, graphies, matérialités*. Ed. by Kim Sacks and Victor Guégan. Design Art Media.
- Kim, Scott Edward (1981). *Inversions*. Byte Books.
- (1987). “Viewpoint: Toward a Computer for Visual Thinkers”. PhD thesis. Stanford University.
- Knuth, Donald E. (1968-). *The Art of Computer Programming*. Addison Wesley.
- (1982a). *TeX: The Program*. Vol. B. Computers and Typesetting. Addison Wesley.
- (1982b). *The METAFONTbook*. Vol. C. Computers and Typesetting. Addison Wesley.
- (1982c). *The TeXbook*. Vol. A. Computers and Typesetting. Addison Wesley.
- (1982d). “The Concept of a Meta-Font”. In: *Visible Language* 16.1, pp. 3–27.

- (2010). “An Earthshaking Announcement”. In: *TUGboat* 31, pp. 121–124.
- (2011). *Selected Papers on Fun & Games*. Vol. 192. CSLI Lecture Notes. CSLI Publications/Center for the Study of Language & Information.
- (2016). *Digital Typography*. Vol. 78. CSLI Lecture Notes. CSLI Publications/Center for the Study of Language & Information.
- Knuth, Donald E. and Luis Trabb Pardo (1980). “The Early Development of Programming Languages”. In: *A History of Computing in the Twentieth Century*. Ed. by N. Metropolis, J. Howlett, and Gian-Carlo Rota. San Diego: Academic Press, pp. 197–273.
- Liang, Franklin Mark (1983). “Word Hy-phen-a-tion by Com-put-er”. PhD thesis. Stanford University.
- Mullaney, Thomas S. (2018). *The Chinese Typewriter. A History*. MIT Press.
- PDF Reference (2006). Adobe Systems Incorporated.
- Pearson, Neil (2007). *Obelisk: A History of Jack Kabane and the Obelisk Press*. Liverpool University Press.
- PostScript Language Reference (1999). Adobe Systems Incorporated.
- Raymond, Eric, ed. (1991). *The New Hacker’s Dictionary*. The MIT Press.
- Roberts, Siobhan (2018). “The Yoda of Silicon Valley”. In: *The New York Times*. Appeared in the *New York Times* edition of Dec. 17th, 2018, <https://www.nytimes.com/2018/12/17/science/donald-knuth-computers-algorithms-programming.html>.
- Robertson, Will, Khaled Hosny, and Karl Berry (2025). “The X_YT_EX Reference Guide”. <http://mirrors.ctan.org/info/xetexref/xetex-reference.pdf>.
- Sperberg-McQueen, C.M., Lou Burnard, et al. (2025). *TEI P5: Guidelines for Electronic Text Encoding and Interchange*. The TEI Consortium.
- Steele, Guy et al., eds. (1983). *The Hacker’s Dictionary. A Guide to the Computer Underground*. Harper & Row.
- Trabb Pardo, Luis (1978). “Set Representation and Set Intersection”. PhD thesis. Stanford University.
- Veytsman, Boris (2024). “Face/Interface 2023 conference: Global type design and human-computer interaction”. In: *TUGboat* 45.1, pp. 7–10.
- Voogd, Peter de (2018). “A singular stroke of eloquence: Tristram Shandy’s typography”. In: *Nordic Journal of English Studies* 17, pp. 74–84.
- Δοξιάδης, Απόστολος et al. (2008). *Logicomix*. “Ικαρος”.

Tamil Orthography Reforms

Jan Kučera

Abstract. In this paper, we look into two Tamil orthography reforms, one attributed to Constanzo Beschi, who wrote a Tamil grammar in 1728, and one attributed to E.V. Ramasamy, which was implemented by a government order in 1978. We evaluate their contributions to the reforms and introduce them in the contemporary historical and political context. This includes topics of *pulli*, distinguishing short and long vowels, and alternative forms of letters.

1. Introduction

The Tamil script is used to record the Tamil language in India, Sri Lanka, Malaysia, Singapore, and Mauritius, but also other countries with Tamil diaspora. Apart from the Tamil language, it has also been used to write other languages, such as Arabic or various minority languages in the area (e.g., *baḍagu*, *irula*, *kōtta*).

Two successful orthography reforms have taken place during the development of the modern Tamil script. The first one is associated with the Italian Jesuit priest Constanzo Beschi (1680–1747), a missionary in South India. He is typically credited with introducing grapheme *ē* for long vowels *ē* and *ō*, typographically differentiating *ra* from *-ā*, and marking the lack of implicit vowels in this abugida by using what is known as *pulli*.

The second orthography reform was enacted by a government order in 1978. It is generally credited to a popular Indian activist E.V. Ramasamy, also known as Periyar, and it was introduced for the centenary of his birthday. The reform involved unifying the orthography of syllables with long *ā* and *ai* (i.e., *ṇā* became *ṇā*, *ṇai* became *ṇai* etc.).

Jan Kučera  0000-0002-0251-3227

Institute of Asian Studies, Faculty of Arts, Charles University, nám. Jana Palacha 2,
116 38 Praha 1, Czech Republic

E-mail: jan.kucera@ujca.cz

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 417–441. <https://doi.org/10.36824/2024-graf-kuce>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

These two reforms could not be more different. While the former was practically single-handedly introduced owing to the small number of printers established by missionaries at the time, the latter spanned over 50 years of public discussion, conflicting interests and philosophies. In this paper, we look into the background and aftermath of these two reforms and recount the contributions of the people attributed as their creators.

1.1. Overview of the Tamil Script

The Tamil script has a long history developing from two branches of *brāhmī*. Some letters were taken from the *vaṭṭeḷuttu* script, which emerged from the Tamil-Brahmi variant, and some letters were taken from the *grantha* script, which developed from the Southern Brahmi variant. The modern letterforms started to take shape in the 14th century; see Figure 1.

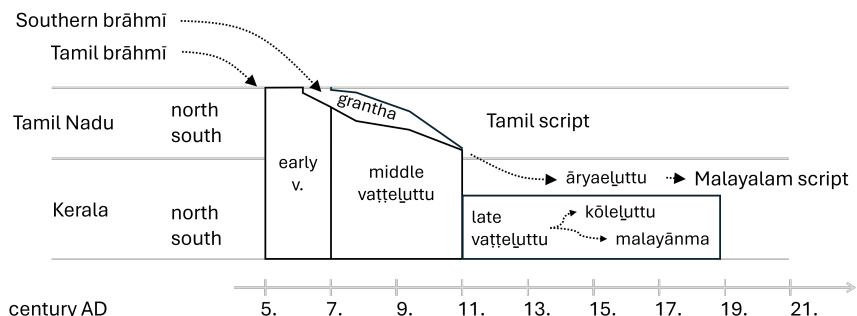


FIG. 1. Variants of *vaṭṭeḷuttu*¹

Like other scripts developed from *brāhmī*, the Tamil script is a typical Indic abugida, where unmarked consonants represent syllables with an inherent vowel, and syllables with different vowels are marked using mostly consistent vowel marks, for example: pa pā pi pī pu pū pe pē po pō pai pau . Pure consonants, i.e., consonant without any vowel, are marked by a dot above (*pulli*): p .

However, Tamil does not have aspirated or voiced consonants like *pba*, *ba*, *bba* etc., so the number of letters is significantly lower than in

1. Dating after Mahadevan (2021), Vielle (2008), 𑌕𑌕𑌕𑌕85, Sām (2006). The ratio of inscriptions written in *vaṭṭeḷuttu*, *grantha* and the Tamil scripts within the area of Tamil Nadu between 6th and 10th century AD after Govindaraj (1994, p. 14).

other Indic scripts.² Unlike other Indic scripts, the Tamil script also does not form conjuncts—pure consonants are always fully represented (e.g., க்க *kka*). The only exception is the conjunct க்ஷ *kṣa* from the *grantha* script used in words of foreign origin.³

1.2. Printing Until 18th Century

Tamil is at the very beginning of the history of printing press in India. The first book printed in any Indic script, *Doctrina Christam en Lingua Malauar Tamul*, was printed in 1578 in Goa by the Portuguese Jesuit missionaries.⁴ This printer was moved to Cochin (*kocchin*) shortly thereafter and ceased printing in a few years. In the 17th century, the Jesuits founded a Syrian press that eventually ended up in Ambalakad (*am-palakkātu*) as the only printer printing in Tamil at the time (Kalapura, 2007, pp. 445–7, சம்பந்தன் [Campantaṇ], 1980, p. 48). Finally, a Danish missionary established a printer in Tranquebar (nowadays *tarankampāṭi*) at the beginning of the 18th century. Its first publication in Tamil was a part of the New Testament printed in 1714, see Figure 2.

Figure 2 is a good example of the Tamil orthography in practice shortly before the changes introduced by Constanzo Beschi. Even though the letters have been slightly updated from the first prints in the 16th century, the orthography remained the same as in the early prints. The first row of green rectangles in Figure 2 is pointing out the lack of *pullis* to mark the pure consonants. In modern orthography, the line would read ஏகக்கிறிஷ்த்து *ēcukkiriṣttu*. The blue rectangle in the following row is marking two different letters that look identical, the first one being *ra* and the second one being the vowel mark *-ā*. In modern orthography, the line would read நாதரானவர் *nātarāṇavar*. Finally, the two red rectangles at the bottom denote vowels of different length. The first one is short, and remains ொ in modern texts, while the second one is long and is now written as ோ. These ambiguities alone mean that reading the text requires non-trivial language knowledge. According to Burnell, the orthography in this publication is identical to the one used in Tamil inscriptions of the 15th and 16th centuries (Burnell, 1968, p. 45).

2. On the other side, Tamil adds 4 letters of its own: ழ *ḷa* ள *ḷa* ழ *ḷa* ழ *ḷa* and ன *na*. For imported words, additional 4-5 *grantha* letters are usually listed as part of the modern Tamil alphabet.

3. There is also a fixed syllable ழ் *ṣṛi*. Note that Tamil used to join letters in the past, not only in handwritten manuscripts, but also in printed publications. Burnell (1968, p. 46) suggests mostly in the 16th century, rarely in the 17th century, but we can also see them later, e.g., on Figure 4 from 1809.

4. Available at <https://iiif.lib.harvard.edu/manifests/view/drs:53909112>. For the fascinating story of the early years of printing press in India see Priolkar (1958)

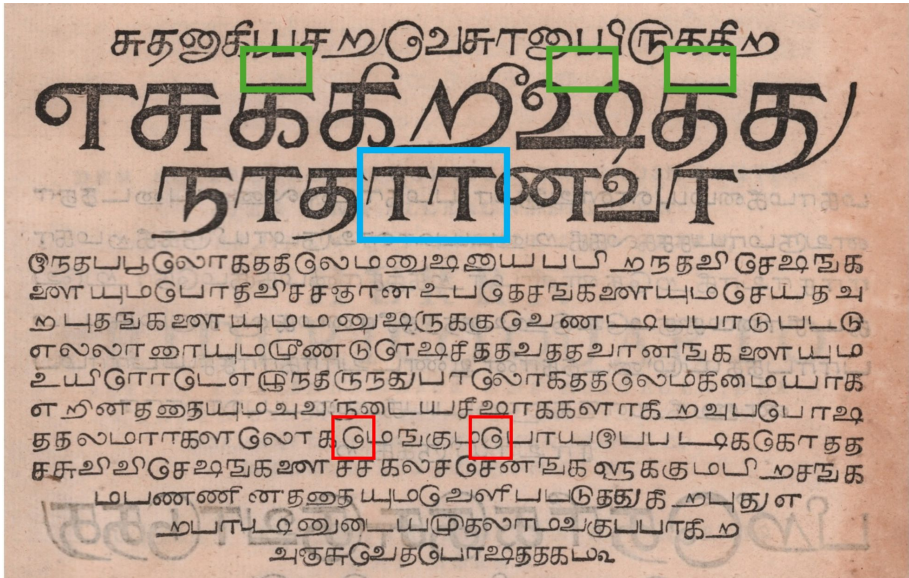


FIG. 2. The title page of New Testament, the first book of Protestant mission in Tranquebar (1714). From Tai (2021, p. 20) (cropped and annotated)

2. The Reform of Constanzo Beschi

Constanzo Beschi (Tamil name *vīramāmunivar*) was an Italian Jesuit who arrived in India in 1710 and eventually settled not far from Tranquebar (Blackburn, 2003, p. 45). In 1728, he composed a Latin-Tamil grammar, which also includes an introductory chapter on the number and form of Tamil letters. It was published in print in 1738:

1. To express *a* short, they add nothing to the consonant, and the same figure, viz., க, expresses both the simple consonant *k*, and the syllable *ka*; and so of the rest; which certainly cannot be approved, and will give no light trouble to beginners.

2. To express *ā* long, they add the figure ஁. [...] Yet since the said figure ஁, may also be the letter *ra* it is liable to become equivocal [...]; wherefore some to distinguish them, write ற, when the figure expresses *ā* long; but when it is to be taken for *ra*, they after [Sanskrit] fashion, slightly bend up the anterior stroke and write ர.

But in their Grammar called நன்னூல் [*nanṇūl*], as well to distinguish *ā* long from the letter *ra*, as the simple consonant form the consonant joined with *a* short, they teach certain marks to be written over them, which they call புள்ளி [*puṇṇi*]; [...]. As regards the second æquivocation, if this figure ஁ is to signify *a* long, nothing will be superscribed; but if it is to express the short syllable *ra*, the mark is to be superscribed; e. g. the word தரம் without any mark you may read *tām*; with this mark தரம் you may read *taram*. [...]

In the same way when the figure expressing *e* short and *ē* long, *o* short and *ō* long, is the same, for the sake of distinction they direct that mark [˘] to be superscribed over the short letters, the long being left unmarked. Thus மெய்° is read *mēy* long, [...] மெய் is read *mey* short [...].⁵ Nevertheless, excepting in some few expressions, I have no where seen these marks superscribed; which certainly would be very useful, especially to beginners, an omission arising perhaps from the laziness of transcribers. I also state that I have devised another and easier way of distinguishing *ē* and *ō* long from *e* and *o* short: viz., when the letter ட called *kombu* serves for both, if this is written in its simple form it will be *e* short and *o* short: but if it be turned in into the upper part, as I shall mention below of *i* long, in this way ே, it will be *ē* and *ō* long. Thus மெய், *mey* short; but ேமய் long. [...] Which plan has been approved by many persons who have not disdained to follow it. (Beschi, 1738, pp. 5–8), English translation by Mahon (Beschi, 1848, pp. 6–7), modern transliteration)

It should be noted that matters of non-standard orthography are very unreliably preserved in printed editions. Figure 3 shows several editions of this work, all using different type and different marks, in some of the cases making the text completely incomprehensible. Even more interestingly, important parts of the quoted text are not present in the handwritten manuscript of 1728 and appear only in print in 1738, as pointed out below.

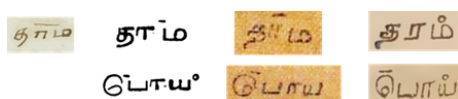


FIG. 3. Different editions of Beschi's introductory chapter. The first row shows the word *taram* in the text quoted above. The second row shows *pey* from the part explaining *pulli*. Note the different positions of the marks, the lack or addition thereof, and the modern form of ர at the top right. Right to left: English translation (Beschi, 1848), Latin reprint (Beschi, 1813), first edition (Beschi, 1738), original manuscript from 1728⁶

2.1. (Re)introducing *pulli*

Depending on the background of authors, Beschi is often said to have introduced or reintroduced the *pulli* into the Tamil script. There are several Tamil inscriptions already in both *brāhmī* and *vaṭṭeḷuttu* that use *pulli* for marking pure consonants, so there is no question about this practice

5. In the Latin edition of 1738, the marks are indeed printed right to the letters, with the only exception of ர (Beschi, 1738, p. 8).

6. Available at <https://gallica.bnf.fr/ark:/12148/btv1b10029450z/>.

predating Beschi by many centuries.⁷ The *pulli* is usually not present on palm-leaf manuscripts, likely to avoid damaging the palm leaves with holes, and this concern is not applicable to printed publications.

A more interesting observation is what *pulli* means to Beschi. The word *pulli* can be translated not only as a dot, but also as a mark in general. Beschi is referring to a system of marks described in *nannūl*, a Tamil grammar from around the 13th century. As can be seen from the examples in the quoted text (which are present in the first printed edition but not in the hand-written manuscript), it not only includes the dot for marking pure consonants, but it also includes the line above to mark syllables with short *a*. Moreover, these marks are to be written if and only if there is a possibility of ambiguity, so even the dot is not used as often as in modern texts. We can see this system in practice, for example, in the Fabricius' Tamil-English dictionary published in 1809; see Figure 4.

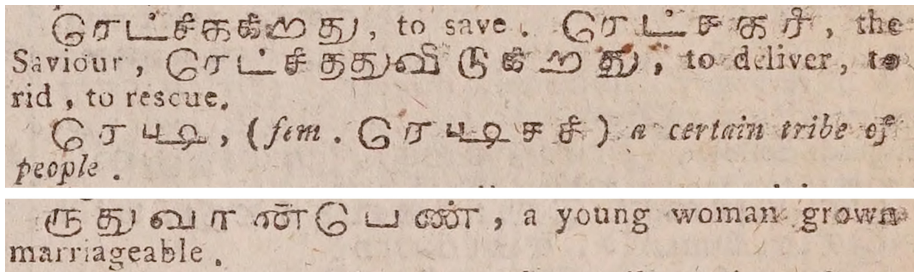


FIG. 4. Examples from the second edition of Fabricius' Tamil-English dictionary published in 1809 (Fabricius and Breithaupt, 1809, p. 169)

Note that the double consonants such as க்கி *kki* or த்து *ttu* do not carry dots, but ட்சி *ṭci*, as well as the final ர் *r* in the first row and the final ன் *n* in the bottom entry are marked.⁸ The bottom entry also shows the line above ன் *na* explicitly marking the short *a*: *rutuvāṇapeṇ*, not *rutuvānpēṇ*.

Hence, Beschi's mention of this system does not seem to account for the modern usage of *pulli* as a dot on every consonant without an implicit vowel. Beschi himself notes that he has not seen this system used apart from a few exceptions, and while recognizing its potential for learners of the language, he rarely utilizes it in his grammar himself.

7. For a good reference on early Tamil inscriptions, see Mahadevan (2003).

8. Interestingly, only the letter ர் *ra* uses the ring form of the mark rather than a simple dot. We see a similar difference in treatment of ர் *ra* already in the 1738 edition of Beschi's grammar. As a sidenote, the second entry shows an example of a Tamil ligature of ட்சி *ṭci* in print as late as 19th century.

2.2. Distinguishing *ra* and *-ā*

It is true that Beschi in his grammar systematically distinguishes *ra* and *-ā* by using ர and ா, respectively. He also clearly states that some to distinguish them, write [...], suggesting this had already been the practice of others before, and he should not be considered the inventor of the altered shape.

Some fonts include the bent anterior stroke only when the identity of the letter is unclear. When the *pulli* or some vowel marks are attached (such as in the case of ரி *ri* ரீ *rī*), it is clear the letter cannot be a vowel. Beschi does not seem to be consistent in this regard and the printed edition does not always match the handwritten manuscript; see Figure 5 for an example.

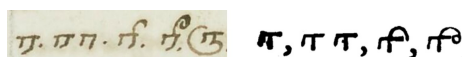


FIG. 5. Syllables ர *ra*, ரா *rā*, ரி *ri*, ரீ *rī* from a list of syllables. Left: Beschi's handwritten manuscript from 1728. Right: First printed edition in 1738 (Beschi, 1738, p. 10)

The *ra* vs. *-ā* pair was not the only ambiguity in the script. There is also ள, which can be either *la* or the right part of the vowel mark for *-au*: கௌ *keḷa* (especially with the pure consonants unmarked, *keḷ*) but also கௌ *kau*. Beschi comments on this:

For the diphthong *au* they place ூ before each letter, and ள after: thus கௌ *kau*, தௌ *tau*, &c. But it might be read also *kēl*, *bear*; and *tēl*, *a scorpion*; wherefore this way of writing is seldom used; but in the place of the diphthong they write *a* short and add the consonant *v*. Thus the noun *kauvai* they seldom or never write கௌவை, but கவ்வை [*kavvai*]. (Beschi, 1848, p. 7, modern transliteration)

Consequently, no system was proposed to disambiguate this case by Beschi, but as we will see later, it became a point of discussion, a spelling reform and its retraction in the 20th century.

2.3. Distinguishing Short and Long Vowels *e/o*

The change clearly attributable to Beschi is the introduction of the grapheme ே to denote long vowels *ē* and *ō* (the *o* vowel consists of the vowel mark for *e* to the left and the vowel mark for *ā* to the right of the consonant). As quoted above, Beschi states he invented this distinction. More interestingly, there is no word to that effect or any usage of it in his 1728 handwritten manuscript; it appears only in 1738 in print.

Special attention should be paid to his explanation: if it be turned in into the upper part, *as I shall mention below of ī long [...]*. In the Tamil script, the long *ī* is usually distinguished by a curl at the end of the stroke: கி *ki*, கீ *kī*, நி *ni*, நீ *nī*, தி *ti*, தீ *tī* etc., but also ரு *ru*, ரூ *rū*, து *tu*, தூ *tū* etc. It is therefore quite natural to use the same idea of prolongation on the vowel mark for *ē*.

The modern form of *ē* has masked this origin with both loops being identical,⁹ but with the above note, it is clear that while the lower loop constitutes the core identity of the vowel, the upper loop is just the prolongation curl. And indeed, the original shape of the long *ē* reflects this imbalance visually, except that not all printed editions managed to preserve it; cf. Figure 6.

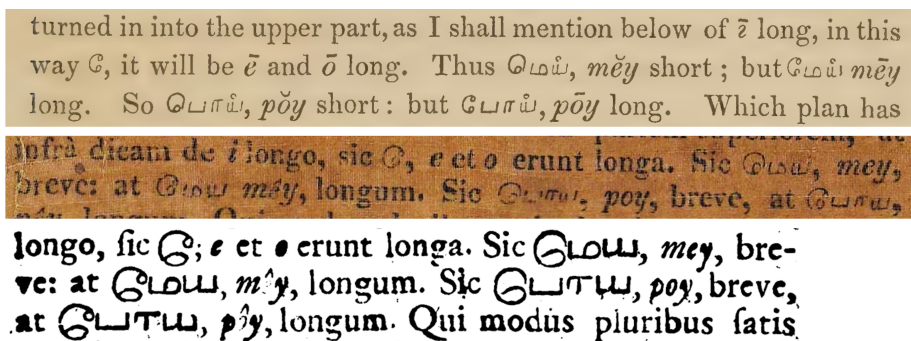


FIG. 6. Excerpt from the quoted text introducing *ē* in three different editions. Notice the different relative sizes of the upper and lower loops. Top: Beschi (1848, p. 7). Middle: Beschi (1813), Bottom: Beschi (1738, p. 8)

A similar topic re-emerges during the 20th century reform with regards to the initial vowel for *ī*. Tamil currently uses quite an unexpected *ī* form coming from the *grantha* script, but an alternative form exists that applies the same principle of a prolongation curl: இ *i*, இ *ī*. This form, sometimes claimed to be the native Tamil form, was occasionally used in publications in the 19th century. For an example, see Figure 7.

9. Such shape is shown in a type specimen as early as 1854 from the Vepery mission (Marr, 1969, p. lviii).

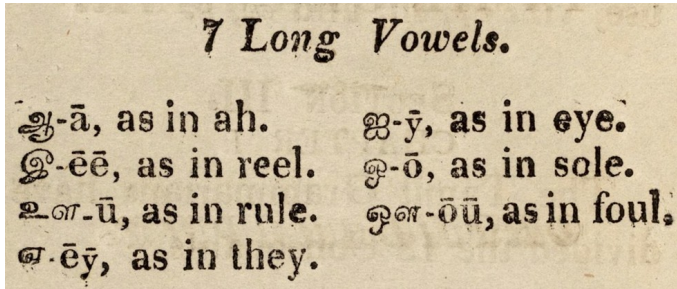


FIG. 7. An example of a publication using an alternative form of long *ī* (Rhenius, 1838, p. 2)

3. The Reform of E.V. Ramasamy

3.1. Political Background

The 20th century was a fairly busy period for what is now Tamil Nadu, with many social and nationalist movements taking place. At the end of the 19th century, the classical Tamil works known as *Sangam literature* were rediscovered (Zvelebil, 1992, p. 46). That elevated the Tamil language to historical significance and resulted in Tamil becoming the second Indian language declared a classical language (after Sanskrit). That way the Tamils gained a sense of belonging to a literary, linguistic and religious past, which separates them from other Indians—especially Brahmins, who represent the northern Aryan culture, and who put Sanskrit and its importance above Tamil (Kailasapathy, 1979, p. 24).

In 1915, Vedachalam Pillai (*vētācalam*) founded a pure-Tamil movement with the goal of getting rid of any foreign words from Tamil, especially the Sanskrit ones. In the same year, a political party called Justice Party (*nītik kaṭci*)¹⁰ was created with the goal to protect and promote the political interests of non-Brahmin Hindus. The movement and the party complemented each other in trying to become free from Sanskrit influences (*ibid.*, p. 29). The concept of clean Tamil applied to the script too: the Tamil letters are completely adequate to express all the required phonemes; therefore, there is no need for the *grantha* letters or any reforms introducing new letters.

In 1925, E.V. Ramasamy (*ī. ve. irāmacāmi*), also known as Periyar (*periyār*),¹¹ launched the Self-Respect Movement (*cuyamariyātai iyakkam*), fighting for equality of all castes. This was later merged with the Jus-

10. South Indian Liberal Federation at the time (*teṇṇintiya nala urimaic caṅkam*).

11. Literally Great Man, a title given to him by a conference of Tamil Women while he was in prison (Kandasamy, Smarandache, and Kandasamy, 2005, pp. 108–109).

tice Party and renamed to Dravidar Kazhagam (*tirāviṭar kaḷakam*). The Indian National Congress came to power in 1937, establishing Hindi as a mandatory language in schools, resulting in wide protests in Tamil Nadu¹² led by Periyar until the decision was retracted (i.e., 3 years). A similar situation repeated in the 1960s after India gained independence and Hindi was again to become the only official language of India. Periyar proclaimed that the only way to stop the attempts of Hindi domination was a separate country—originally Tamil Nadu, later Dravidistan, a country for all Dravidians—which became the main purpose of this movement (Hardgrave, 1965, p. 27).¹³

3.2. Early Attempts

Between around 1930 and 1980, discussions about Tamil script reform were taking place in Tamil Nadu as well as other countries with Tamil population, most notably Malaysia and Singapore. Eventually, the government enforced the reform on the 19th October 1978 by a governmental order No. 1875.

Even before proposals to change individual letters and syllables, some called for adjusting the script for functional reasons. In his 1914 book *The System of Writing and Pronunciation in Tamil* (*tamiḷil elutumuraiyum uccarippu muraikum*) M. Rangasarya proposed to add three vowels to the Tamil script to record phonemes of the northern languages (பாலகந்தரம் [Pālacuntaram], 1982, pp. 2–3). Even Subramania Bharati, a prominent Tamil writer, wrote in 1915 that as the communication with the world increases, many new letters will be needed to write foreign names (சண்முகம் [Caṇmukam], 1978, p. 3). Since then, the society was split into those asking for new letters, mostly from the *grantha* script, and those like in the pure-Tamil movement, arguing that the current set is more than enough and preferring to remove letters.

The Tamil script reform as we know it today started in the 1930s. While it is usually connected to the name of Periyar who was trying to enact it and at whose centenary the government issued the order, we can find calls for these changes even before Periyar became involved.

The editor of the *Kumaran* weekly newspaper published an article *Reform in Tamil Letters* (*tamiḷ eluttil tiruttam*), in which he points out several difficulties involved in learning the Tamil script: the differences between short and long initial vowels, the irregularity of forming syllables using *-ai* and *-ā*, and also the irregular form of the syllable கூ *kū*. He proposed

12. The state of Madras at the time.

13. The separatist tendencies diminished after the reorganization of India based on languages in 1956 and were eventually outlawed by the 16th amendment to the constitution in 1963 (Kothari, [1970?], p. 331).

a regular formation of syllables according to Table 1, and encouraged scholars, writers and editors to consider his proposal and publish their thoughts (முருகப்பா [Murukappā], 1930). The title page of that newspaper issue was published using the newly proposed orthography.

TABLE 1. Changes to the Tamil script proposed in the *Kumaran* weekly (1930)

	before	after		before	after
<i>nā</i>	ண	ணா	<i>no</i>	னெ	னொ
<i>rā</i>	ற	றா	<i>ro</i>	றெ	றொ
<i>nā</i>	ன	னா	<i>no</i>	னெ	னொ
<i>nai</i>	னை	னா	<i>nō</i>	னே	னோ
<i>lai</i>	லை	லா	<i>rō</i>	ரே	ரோ
<i>lai</i>	ளை	ளா	<i>nō</i>	னே	னோ
<i>nai</i>	னை	னா			

Half a year later in 1931, almost a full-page article was published in the same newspaper, titled *Letters and Their History* (*eluttukkaḷum avarriṇ carit-tiramum*) on writing scripts throughout history, supporting reforms as a natural part of their developments (ரத்னம் [Ratnam], 1931). The history of the Tamil script itself was the subject of essays of A.C. Suppaiya (*cuppaiyā*) published at the beginning of 1933 in a Singaporean weekly *Progress* (*munṇērram*) (பாலசுந்தரம் [Pālacuntaram], 1982, p. 8, சுப்பையா [Cuppaiyā], [1935], p. i).¹⁴ Apart from the irregular syllables with *-ai* and *-ā*, complete abolition of the *ai* and *au* vowels was proposed, replacing them with *ay* and *av* respectively, effectively proposing a spelling reform as well. Finally, the author pointed out a still contemporary practice of using the old form of initial *ī* (i.e., இ instead of ஈ), not coincidentally, in textbooks for children (பாலசுந்தரம் [Pālacuntaram], 1982, Kandiah, 1986, p. 20). Even though the proposed changes were not motivated by technological reasons at this point, the author assured readers that on typewriters, space for any new letters can always be created by similar changes towards regularities in the script (சுப்பையா [Cuppaiyā], [1935], p. 36).¹⁵

The first discussions about a possible reform of the Tamil script took place at a conference of Tamil scholars at the Pachaiyappa's College in

14. Periyar published them later in a book called *The Study of Tamil Letters* (*tamiḷ varivaṭṭiva āraṇycci*), which became the first book on this reform of the Tamil script (சுப்பையா [Cuppaiyā], [1935]).

15. This recommendation came from Kuthoosi Gurusamy (*kuttūci kurucāmi*) who had already tried to suggest it on the previous conference in Trichy in 1932 and had been rejected (குருசாமி [Kurucāmi], 1935b in வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989, p. 85). Some sources suggest a report from this committee was published in the weekly *Rationality* (*pakuttarivu*) on 12th of December 1934. However, the issue number 16 was published on 9th of December and number 17 was published a week later, on 16th of December.

Madras on the 23rd and 24th of December 1933 under the auspices of the Ministry of Education (Kandiah, 1986; வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989).¹⁶ One of the outcomes of the conference was the establishment of a committee to consider and report on the superfluous and missing letters (வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989, p. 52). A year later, an article called *The Reform of Letters* (*eḷuttīl cīrtiruttam*) appeared in the weekly of the Self-Respect Movement *Rationality* (*pakuttarivu*)¹⁷, in which the author describes how the languages and scripts around the world are developing, while in his country a religion of scholars turned letters into gods, so the nation is proud of pronouncing Vishnu as Vittnu or Vindu. He also reminded readers of an older form of *i* from about 70–80 years ago and mentioned that syllables with *-ai* and *-a* formed regularly would save 7 printing blocks and the need for children to remember the irregular forms.

Despite the need for many changes in the Tamil script, for now it is possible to make use of these small changes. This way of letters can be used in the next issue of *The Republic*.¹⁸ (குருசாமி [Kurucāmi], 1934, p. 12)

A relatively noticeable announcement was published in the same weekly on the 6th of January 1935: not only would the upcoming, delayed issue of *The Republic* be using the regular *-ai* and *-ā* vowels, but several books would be published that way too (குருசாமி [Kurucāmi], 1935a). Indeed, one week later on the 13th of January 1935 the publication of *The Republic* was resumed using regularly formed syllables. Kuthoosi Gurusamy, who authored the previous articles in *Rationality*, praised the editors, pleased that someone was finally adopting his ideas and considered it a complete success (குருசாமி [Kurucāmi], 1935b in வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989, p. 86).

The first time Periyar himself commented on the Tamil script reforms was in the following issue of *The Republic* on 20th January 1935:

A long time ago, many have come to the conclusion that many changes are needed in the matters of Tamil script.

Like comrade Gurusamy wrote, many amongst great scholars have been speaking about the matters of script reform for a long time.

We have no doubts that, in the matters of Tamil letters, several changes need to be done, however the worthless scholars¹⁹ philosophize about it. The older and more sacred the language, shapes [of letters] and other matters are, the more necessary changes they need. That is a true philosophy.

16. These conferences were not always peaceful; see reports from the meetings ibidem.

17. The editor of this newspaper was E.V. Krishnasami, brother of Periyar.

18. The publication of Periyar's weekly *The Republic* (*kuṭi aracu*) was planned to resume on the 6th January 1935 after an involuntary interruption.

19. அழுக்கு மூட்டைப் பண்டிதர்கள்

[...] (இராமசாமி [Irāmacāmi], 1935 in வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989, p. 87)

The article then continues on how the religion and some fanatics impede progress. The script needs to be adapted to the modern ways of writing (i.e., paper and print as opposed to engraving into stones and palm leaves). The argument to make it easier for children to learn to read and write falls into background as just another advantage of the reform. Periyar also proposes to unify the way syllables with *u* and *ū* are formed, e.g., கு *ku* and கூ *kū* (instead of கு *ku* and கூ *kū*, after ஜு *ju* and ஜூ *jū* and other similar syllables involving *grantha* consonants). Apart from making syllables with *-ai* and *-ā* regular, he also mentions replacing *ai* and *au* with *ay* and *av* (இராமசாமி [Irāmacāmi], 1935 in வேலு [Vēlu] and செல்வராஜி [Celvarāji], 1989, p. 93).²⁰

Since then Periyar started publishing books and newspapers with regular syllables as per Table 1. The Justice party's biweekly *Freedom* (*viṭutalai*) which started in 1935 was printed using the new syllables, hence the new regular forms of letters are sometimes called the letters of freedom (*viṭutalai eluttukkaḷ*) (Kandiah, 1986, p. 6).²¹

3.3. Governmental Committees

Between the mid-1930s and the independence of India, the public discussions about script reforms subsided.²² A Tamil literary conference was held in Madurai on the 18th and 19th January 1941, where it was agreed that a committee for the Tamil script reform will be formed (குழந்தை [Kuḷantai], 1968, p. 6). There do not seem to be any records of such a committee. On 14th and 15th of February 1948, the World Tamil Conference took place in Madras, which also adopted resolutions to lower the number of Tamil letters and to establish a committee for the Tamil script reform. Based on the decisions of this conference, the

20. In this article Periyar points out that *kau* and *kav*, and *kai* and *kay* are pronounced the same and this change could lead to lower the number of necessary Tamil letters even more. When he returned back from prison in 1934 where he was contemplating the script changes, he told the publisher of Suppaiya's essays that while the changes are necessary, it will be difficult to adapt to them—in contrast to the unification of syllables with *-ai* and *-ā* which are easily understandable for readers, and which can be immediately put to use both in books and newspapers (கப்பையா [Cuppaiyā], [1935], pp. ii–iii).

21. Periyar himself took over *Freedom* in July 1937 and started publishing it daily.

22. There were more important problems to deal with during this period. In 1937 Hindi was made mandatory in schools, against which protests have been held until the decision was retracted in 1940. Periyar was imprisoned again and the calls for a separate Tamil country and later Dravidistan emerged. There is also the World War II and the events leading to the independence of India.

largest Tamil newspaper *Swadesamitran* (*cutēcamittiran*) started printing the vowel marks for *i*, *ī*, *u* and *ū* separately, without connection to the consonant (குழந்தை [Kulantai], 1968, p. 6).²³

Meanwhile, the government in Madras appointed its own Committee on Tamil in 1947, which prepared a preliminary report in February 1948 (Norman Brown, 1953, p. 4). The task of this committee was to prepare a reform of the Tamil script so that Tamil could be typeset on a new type of hot-metal press which could cast whole lines of text at once (until then, the typesetters had to manually place one character after another) ("Adapting Tamil Script for Lino Printing" 1948). The issue with these machines by Linotype Company (see Figure 8) was that they could only take 96 characters for fast typesetting (Ross, 1989, p. 129).²⁴

On the 8th October 1949, the Minister of Information and Publicity presiding over the 17th annual day celebrations of *Swadesamitran*, Press Worker's Union, said that the disadvantage of Tamil press when compared to the English one was that it was not possible to create a Linotype machine for the current cumbersome alphabet and it is therefore necessary to make changes to the script in the interest of the development of the Tamil journalism as well as the language itself ("Evolution of Tamil Linotype Machines: Minister emphasises need" 1949). The government, having the report of the 1948 committee, asked the Society for the Development of Tamil (*tamiḷ vaḷarccik kaḷakam*) to review the proposed changes ("Reform of the Tamil Script: Changes Recommended" 1949). The society organized a conference for this purpose on the 21st December 1949 in Madras, in which many changes to the script were proposed, some of which were unanimously agreed upon.²⁵ The board of the society discussed the resolutions on the 11th January 1950 and decided to recommend to the government to implement a reform that would consist of switching to regular syllables with *-ai* and *-ā*, as well as detached vowel marks for *-i* and *-ī*, which would not interact with the consonants, as can be seen in Figure 9 ("Tamil Script Reform" 1950).

Based on the recommendations, the government expanded its committee, which eventually prepared its second and final report dated 16th August 1950.²⁶ The report states it is necessary to reform the Tamil script, both in the interests of mechanical efficiency and in the light of educational psychology. The proposed changes all pertained to the

23. This newspaper was often testing readers with various changes in the script.

24. In exchange for lower speeds and increased costs, this limit could be raised to 200. All these characters must also be available on the keyboard.

25. Including the letter *f* is one of the suggestions that were postponed. This conference also resolved to adapt the international (Arabic) numerals ("Reform of the Tamil Script: Changes Recommended" 1949).

26. Neither the preliminary report from 1948 nor the final report from 1950 were published. However, a summary of the second one was published in *The Hindu* on 13th July 1951 (Norman Brown, 1953, p. 4).

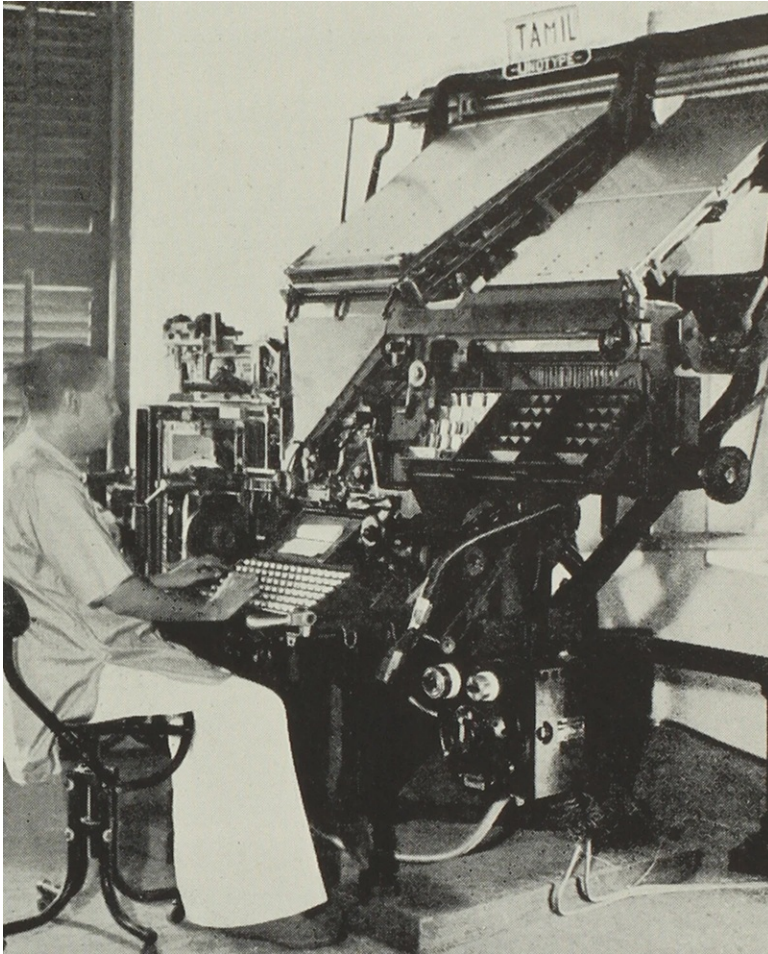


FIG. 8. The first Linotype machine for Tamil in the Linotype Company Madras office, 1936. From the private collection of Vaibhav Singh (L&M News, December 1936 in: Contextual Alternate, 2022)

vowels: the regular formation of syllables with *-ai* and *-ā* as in Table 1, detached *-i* and *-ī* as in Figure 9 and then two changes in initial vowels—the older form of initial *ī* and distinguishing the grapheme used for *la* and *au*; see Table 2 (Norman Brown, 1953, p. 5).

The committee was aware of the irregularities with *-u* and *-ū*, but it was also aware of potential controversy caused by any suspicion of trying

To separate the symbols ீ for all
consonants like க ீ க ீ த ீ த ீ

FIG. 9. Proposed separate *i* and *ī* vowel marks (“Tamil Script Reform” 1950)

TABLE 2. Changes to the initial vowels recommended by the governmental committee in 1950

	before	after		before	after
<i>ī</i>	ஈ	இ	<i>keḷa</i>	கௌ	கௌ
<i>au</i>	ஒள	ஒர	<i>kau</i>	கௌ	கௌ

to sanskritize the script, even if unfounded.²⁷ Since the above changes were technically enough to run the Linotype machine in fast mode, there was no reason to risk the reform failing due to unnecessary controversies (Minakshi Sundaran, 1953, p. 34). Similarly, amongst the considered barriers for children was the fact that some of the vowel marks are written to the left of or on both sides of the consonants. The committee also decided to avoid changing this practice, for the same reason that prevents them from switching to the Latin script:

any remedy will be only worse than the disease; because there is the great danger of making the handful of our literates in Tamil, illiterates, by introducing revolutionary changes. (ibid., p. 35)

3.4. Worldwide Adoption

The government accepted the recommendations of this committee in 1951 (Norman Brown, 1953, p. 5; Kandiah, 1986, p. 21).²⁸ *Swadesamitran* started to print part of its content according to these recommendations. On 28th October 1951 the Singaporean daily *Tamil Drum* (*tamiḷ muracu*) published an article in full support of the reform and noted that apart from the *Lady Tamil* (*centamiḷ celvi*) newspaper and another monthly magazine there were no articles against the reform (திருநாவுக்கரசு [Tirunāvukkaracu], 1951).²⁹

In May 1952, a new government came into power that was not in favour of the reform. This could have been due to a large stock of already printed textbooks in the current orthography (Norman Brown,

27. The marks for ு -*u* and ூ -*ū* come from the *grantha* script used for Sanskrit.

28. It is worth pointing out that the proposed changes do not include replacing the diphthongs *ai* and *au*.

29. However, it does point out a disagreement in Malaysia. This newspaper printed the full recommendations of the committee (Kandiah, 1986, p. 21).

1953, p. 5). In any case, in July 1952, the government announced that due to a strong opposition to the reform it was leaving it up to the public to implement the changes that it considers necessary (Minakshi Sundaran, 1953, p. 28) and did not pursue the matter further.

Once again the script reform receded into the background, until the end of the 1960s.³⁰ In 1969, Singapore celebrated 150th anniversary of its foundation. For this occasion, the Tamil schools created a commemorative publication with an article about the Tamil script reform, in which they stated that even if Tamil Nadu did not unanimously accept the changes, it would not be a problem—once a student becomes versed in Tamil, they can learn the old letters and then study books in the old orthography too (Kandiah, 1986, p. 22). At both the 2nd world conference of Tamil studies in Madras 1969 and the 4th one in Sri Lanka 1974 the reform of the Tamil script was studied (பாலசுந்தரம் [Pālacuntaram], 1982, p. 23). Again the need for reform was put forward (இளந்திரையன் [Iḷantiraiyan], 1979, p. 16), and resolutions of support came from the Symposium of Tamil teachers of Indian universities (*intiyap palkalaik kaḷakat tamiḷācīriyar maṇṇa karuttaraṅku*) in Puducherry on 3rd June 1974 and a group of Tamil scholars (*tamiḷakap pulavar kulu*) on 2nd February 1975, including the reform of syllables with *-u* and *-ū*. In 1977, The Annamalai University organized a symposium on the script reform (பாலசுந்தரம் [Pālacuntaram], 1982, p. 23). June 1977 also holds elections in Tamil Nadu, and the DMK promises to introduce the reform in a way that everyone would accept it (**tam10**).³¹

In August 1977, the Prime Minister of Tamil Nadu and the Minister of Education received a letter calling for implementing the reform. It stayed unanswered, so the author tried again in January 1978 (இளந்திரையன் [Iḷantiraiyan], 1979, pp. 9, 15). In July that year, an article *The Tamil Government Seriously Considers Tamil Script Reform* was published. Furthermore, the government was preparing for celebrations of Periyar's centenary and the reform of the script is one of the reforms Periyar was pushing for (ibid., p. 18).

Finally, on the 19th of October 1978, the government issued an order number 1875, in which it implements Periyar's script and spelling reform (on request of the committee for Periyar's anniversary).³² The new orthography was supposed to be used in the government, governmental organizations and schools with immediate effect. The government also

30. Meanwhile, the states of India were reorganized according to the language in 1956, resulting in the creation of the Madras state with Tamil as its official language. During 1963–1965, another wave of protests against Hindi were taking place as it was supposed to become the official language of India. Consequently, a faction of Dravidar Kazhagam, the DMK party, won 1967 elections in Madras.

31. The DMK was defeated in these elections.

32. For full text of the order, see e.g., இளந்திரையன் [Iḷantiraiyan] (1979, pp. 118–120), for commentary see சண்முகம் [Caṇmukam] (1978, pp. 218–234).

recommended that publishers follow the system in this order in Tamil newspapers, other periodicals and books. The substance of the reform is summarized in Table 3.

TABLE 3. Changes to the Tamil script and spelling as per the government order from 1978

	before	after		before	after		before	after
<i>ai</i>	ஐ	அய்	<i>nai</i>	நை	னை	<i>ro</i>	ரெ	றா
<i>au</i>	ஔ	அவ்	<i>lai</i>	லை	லை	<i>no</i>	னெ	னா
<i>nā</i>	நா	ணா	<i>lai</i>	லை	ளை	<i>nō</i>	நே	னோ
<i>rā</i>	ரூ	றா	<i>nai</i>	நை	னை	<i>rō</i>	ரே	றோ
<i>nā</i>	நா	ணா	<i>no</i>	னெ	னா	<i>nō</i>	நே	னோ

It is apparent that the government decided to ignore the conclusions of both the expert committee and the government of the 1950s and went for a populist acceptance of a Periyar's reform.³³ The government received due criticism, also caused by the fact that it justified the reform by the request for Periyar's anniversary, not mentioning anything about the long history of the reform and discussions with the public, professionals and scholars. The dissenting voices were mostly regarding abolishing the *ai* and *ay* diphthongs and replacing them with *ay* and *av* without affecting pronunciation. Eventually the government ceded and issued another order on 15th of January 1979 in which it allowed the old spelling using diphthongs (பாலசுந்தரம் [Pālacuntaram], 1982, p. 23).

The government was in no rush to implement or promote the proposed changes either. In a survey of almost 2,000 adults at the end of January 1979, almost 55% respondents said they had not heard anything about the government-proposed changes (see Figure 10). Governmental magazines, calls and signs in public spaces remained in the original orthography even a year after the changes were announced.

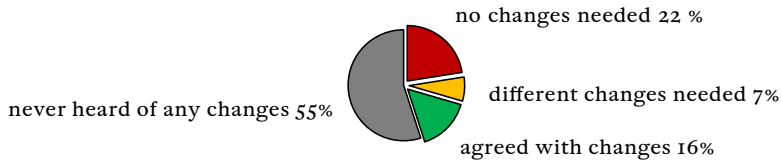


FIG. 10. Public poll of opinions on the Tamil script reform in 1979 (data after Siromoney and Bala, 1979)

33. One of the readers noted that we should be thankful for at least one Periyar's reform being accepted (இளந்திரையன் [Iḷantiraiyan], 1979, pp. 76–77).

In October 1979 the Association of Tamil teachers in Singapore (*ciṅkappūrt tamilāciriyaṛ caṅkam*) expressed their support in the *Voice of Tamil Teachers* magazine (*tamilāciriyaṛ kural*) for the Tamil Nadu government accepting the Periyar's suggestions. The Singaporean government announced in a circular from 26th September 1983 that starting with January 1984, the changes should be implemented for all educational purposes. The changes were to be implemented gradually up to 1987 when the new orthography would be expected of students during exams (Kandiah, 1986, pp. 25–26).

In Malaysia, a committee for consideration of the proposed changes was established in the 1980s, but it was not possible to come to a consensus (*ibid.*, p. 22). The government officially adopted the new orthography (as amended, i.e., keeping the *ai* and *au* in 1994 (Nedumaran, personal correspondence)).

Even though the situation improved in Tamil Nadu during 1980s (the government, universities and various associations started using the new orthography), the private sector, despite being the one who initiated the changes, lagged behind (Shanmugam, 1983, p. 99; Kandiah, 1986, p. 24). Many concrete proposals for changes in orthography were published during this 50-year history (see the supplementary material). Paradoxically, a considerable number of them only after the reform was accepted. As Periyar himself stated, this was just the beginning. At the start of the 1980s, the government established a new committee that would propose further changes to the script (Shanmugam, 1983, p. 99).

4. Conclusion

We have seen two different reforms of the Tamil script. One devised by a single person whose main interest was to make Tamil easier to learn, where there was no authority to regulate the script usage, no way for the public to express their opinions, and all that was needed was the one printer to adopt the changes. Yet still, no changes deemed unnecessary were made. On the other hand, we have decades of discussions, ideological arguments and politics playing a role. Expert committees were established that prepared carefully balanced recommendations, only for everything to be thrown away, and replaced by a 40-year-old suggestion for political points, to honor a person whose all other reforms were too radical to implement.

During the course of history summarized in this paper, we can see four arguments being put forward for a script reform:

1. *educational*, trying to make it easier to learn to read and write;
2. *technological*, trying to make it simpler, faster or cheaper to typeset and print;

3. *social*, where the script does not meet the society needs, either for business or cultural reasons;
4. *functional*, where the script does not meet the language needs.

These types of arguments closely correspond to the criteria for optimal writing systems discussed in Meletis (2018): the psychological/cognitive fit, the technological fit, the sociocultural/ideological fit, and the linguistic fit.

As for contributions of C. Beschi and E.V. Ramasamy, both had the means to realize their ideas in print and get their publications to readers. The one change we can attribute to Beschi is the distinction between long and short *e* and *o* vowels, which he must have devised between 1728 and 1738. We learned that rather than inventing a new glyph, he used the traditional Tamil means of prolongation, i.e., ending the existing short glyph with a loop, and this difference was still visible in early prints.

The situation with Periyar is slightly more complicated. He was an activist, he fought for the changes and promoted them. However, he did not invent any of the particular changes, and he was no longer alive when the government issued the order. Furthermore, the first governmental order contained changes that even Periyar later in his life argued should not be done.

It should be pointed out that some of the other countries were willing to progress without waiting for India. This is even more prominent after digitalization, where Tamil Nadu was very reluctant to move to Unicode, while countries like Sri Lanka and Singapore had practically no other choice if they wanted to support all their scripts simultaneously, and adopted Unicode first.

With the onset of digital technologies and modern printing methods, the technological needs for changes in script and orthographical reforms diminish.³⁴

References

- “Adapting Tamil Script for Lino Printing” (Mar. 26, 1948). In: *The Indian Express*.
- Beschi, Constanzo Giuseppe (1738). *Grammatica Latino-Tamulica Ubi de Vulgari Tamulicæ Linguae Idiomate கொடுந்தமிழ் dicto*. Trāngambariāe: Typis Missionis Danicæ.
- (1813). *Grammatica Latino-Tamulica in qua de Vulgari Tamulicæ Linguae Idiomate கொடுந்தமிழ் dicto*. Madraspatnam: Typographeum Collegium.

34. Rather, it gives rise to ideological voices calling for changes in how script is internally represented in such technologies, without any visible effect for readers.

Overview of proposed changes to the Tamil script

Authors:

1.	raṅkācārya also proposed ர ங க ா ச ர்ய	9.	cirampāṇ paramānantam
2.	periyār, porkō, irā kiruṣṇamūrtti, vē. kalaimaṇi	10.	kulāntaicāmi
3.	koṭumuṭi caṇmukam, koṭumuṭi caṇmukappirakatam	11.	nallatampi
4.	namaccivāya mutaliyār	12.	mu. varatarācaṇ
5.	te. po. mī.	13.	pulavar kulantai
6.	tirumalai muttu cuvāmi	14.	vē. tillaināyakam
7.	porkō	15.	i. jē. cuntar
8.	pēṇā ṭṭi	16.	irācakōpālaṇ

Initial vowels:

	a	ā	i	ī	u	ū	e	ē	ai	o	ō	au
1.	அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	ஐ	ஓ	ஔ	ஒள
2.	அ	அ	இ	இ	உ	உ	எ	எ	அய்	ஓ	ஔ	அவ்
3.	அ	அ	இ	இ	உ	உ	எ	எ	ஐ	ஓ	ஔ	ஒள
4.			இ	ஈ								
5.			இ,	ஈ								ஓள
6.	அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	ஐ	ஓ	ஔ	அவ்
7.	அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	அய்	ஓ	ஔ	அவ்
8.	அ	அ	இ	ஈ	உ	உ	எ	எ	அய்	ஓ	ஔ	அவ்
9.	அ	அ	ஆ	ஆ	உ	ஊ	எ	ஏ		ஓ	ஔ	
10..	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
11.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
12.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
13.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
14.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
15.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்
16.	அ	அ	அ	அ	அ	அ	அ	அ	அய்	அ	அ	அவ்

Authors:

1. periyār	7. porkō	13. cu. makātēvaṇ
2. mu. va.	8. kuḷantaicāmi	14. ātittar
3. nallatampi	9. cirampāṇ paramānantam	15. te. po. mī.
4. pōṇā ṭṭṭi	10. vē. tillaināyakam	16. ṇṇāṇatēmā
5. tirumalai muttu cuvāmi	11. i. jē. cuntar	17. koṭumuṭi caṇmukam
6. pulvar kuḷantai	12. irācakōpālaṇ	18. vi. kē. tillaināyakam

Vowel marks:

	ka	kā	ki	kī	ku	kū	ke	kē	kai	ko	kō	kau
1.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
2.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
3.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
4.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
6.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
7.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
8.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
9.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
10.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
11.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
12.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
13.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
14.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
15.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
16.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
17.	க	கா	கி	கீ	கு	கூ	கெ	கே	காய்	கொ	கோ	கவ்
18.					க	கூ						

After: Pālacuntaram 1982, p. 120-123, without typography edits.

- Beschi, Constanzo Giuseppe (1848). *A Grammar of the Common Dialect of the Tamul Language, called கொடுந்தமிழ்*. Trans. by George William Mahon. Madras: Reuben Twigg. Trans. of *Grammatica Latino-Tamulica Ubi de Vulgari Tamulicæ Linguae Idiomate கொடுந்தமிழ் dicto*. Trangambariae: Typis Missionis Danicæ, 1738.
- Blackburn, Stuart (2003). *Print Folklore, and Nationalism in Colonial South India*. Delhi: Permanent Black.
- Burnell, A. C. (1968). *Elements of South-Indian Palæography from the Fourth to the Seventeenth century A.D. Being an Introduction to the Study of South-Indian Inscriptions and MSS*. Varanasi: Indological Book House.
- Contextual Alternate (2022). *Picturing practice: people, places, and print artefacts in South Asia*. URL: <https://www.contextualalternate.com/collection02>.
- “Evolution of Tamil Linotype Machines: Minister emphasises need” (Oct. 9, 1949). In: *The Sunday Indian Express*.
- Fabricius, Johann Philipp and Johann Christian Breithaupt (1809). *A Malabar and English Dictionary*. Vepery: English Missionaries at Madras.
- Govindaraj, R. (1994). *Evolution of Script in Tamil Nadu*. Tamil Nadu Archaeological Society.
- Hardgrave, Robert L. (1965). *The Dravidian Movement*. Bombay: Popular Prakshan.
- Kailasapathy, K. (May 1979). “The Tamil Purist Movement: A Re-Evaluation”. In: *Social Scientist* 7, pp. 23–51.
- Kalapura, Jose (2007). “India Inscribed: Development of Printing Technology in India, 16-18 th Centuries”. In: *Proceedings of the Indian History Congress* 68, pp. 436–463.
- Kandasamy, W.B. Vasantha, F. Smarandache, and K. Kandasamy (2005). *Fuzzy and Neutrosophic Analysis of Periyar's Views on Untouchability*. Phoenix: Hexis.
- Kandiah, A. (1986). *Modification of Tamil Scripts*. Tech. rep. Nawala.
- Kothari, Rajni ([1970?]). *Politics in India*.
- Mahadevan, Iravatham (2003). *Early Tamil Epigraphy: From the Earliest Times to the Sixth Century A.D.* Chennai: Cre-A.
- (2021). *Early Tamil Epigraphy: From the Earliest Times to the Sixth Century C.E.* Ed. by Third Edition. Vol. I. Chennai: Central Institute of Classical Tamil.
- Marr, J. R. (1969). “Some manuscripts in Grantha script in Bangkok”. In: *Bulletin of the School of Oriental and African Studies* 32, pp. 281–322.
- Meletis, Dimitrios (2018). “What is natural in writing?” In: *Written Language & Literacy* 21.1, pp. 52–88.
- Minakshi Sundaran, T. P. (Jan. 1953). “Tamil Script Reform”. In: *Tamil Culture* II. Ed. by taṇināyakam aṭikaḷār taṇināyakam, pp. 28–35.
- Norman Brown, W. (1953). “Script Reform in Modern India, Pakistan, and Ceylon”. In: *Journal of the American Oriental Society* 73, pp. 1–6.

- Priolkar, Anant Kabra (1958). *The Printing Press in India: Its Beginnings and Early Development*. Bombay: Marathi Samshodhana Mandala.
- “Reform of the Tamil Script: Changes Recommended” (Dec. 22, 1949). In: *The Sunday Indian Express*.
- Rhenius, G. (1838). *Abridgement of the Rev.d G. Thenius’s Tamil Grammar*. Madras: Examiner Press.
- Ross, Fiona (1989). “Form Metal Type to Digital Letterforms – a Straightforward Transition for Indian Scripts?” In: *Matrix* 9, pp. 128–136.
- Sām, En. (2006). *Kēraḷattile prācīna lipimāṭṛkakaḷ*. Tiruvananthapuram: Saṁsthāna purārēkhāvakuppū kēraḷasarūkkārū.
- Shanmugam, S. V. (1983). *Aspects of Language Development in Tamil*. Annamalai-nagar: All India Tamil Linguistics Association.
- Siromoney, Gift and S. Bala (Sept. 1979). “Public opinion survey on prohibition, Tamil script reform and declaration of emergency”. In: *Madras Christian College Magazine* 48, pp. 16–17. URL: https://www.cmi.ac.in/gift/Surveys/surv_emergency.htm.
- Tai, Sophia (2021). *Visual analysis of Tamil character*. Tech. rep. Reading.
- “Tamil Script Reform” (Feb. 1, 1950). In: *The Indian Express*.
- Vielle, Christophe (2008). *Manuel de Malayāḷam*. Bruxelles - Louvain-la-Neuve: Societas Belgica Indiae Orientalis - Institut orientaliste de Louvain.
- Zvelebil, Kamil (1992). *Companion Studies to the History of Tamil Literature*. Leiden: E.J. Brill.
- இராமசாமி [Irāmacāmi], ஈ. வெ. [Ī. Ve.] (Jan. 20, 1935). “தமிழ் எழுத்துச் சீர்திருத்தம் [Tamil script reform]”. In: குடி அரசு [Kuṭi Aracu], pp. 10–11.
- இளந்திரையன் [Iḷantiraiyan], சாலை [Sālai] (1979). *எழுத்துச் சீர்திருத்தம் களத்திலே கடிதங்கள் [Letters from the field of script reform]*. சென்னை [Chennai]: தமிழ்ப் புத்தகாலயம் [Tamilp Puttakālayam].
- கிருஷ்ணமூர்த்தி [Kīruṣṇamūrtti], இரா. [Irā.] (1985). *பிற்காலத் தமிழ் வட்டெழுத்து [Later Tamil Vatteluttu]*. சென்னை [Chennai]: இரா. கிருஷ்ணமூர்த்தி [Irā. Kīruṣṇamūrtti].
- குருசாமி [Kurucāmi], குத்தூசி [Kuttūci] (Dec. 30, 1934). “எழுத்தில் சீர்திருத்தம் [Reform in the script]”. In: *பகுத்தறிவு [Pakuttarivu]*, pp. 11–12.
- (Jan. 6, 1935a). “(ஞ, ற, ன, லை, லே, லை எழுத்துக்கள் மாற்றம் [Changing the letters ṇā, rā, ṇā, ṇai, lai, lai, ṇai]”. In: *பகுத்தறிவு [Pakuttarivu]*, p. 11.
- (Jan. 13, 1935b). “தமிழ் எழுத்திலும் புரட்சியா? [A revolution in the Tamil script too?]” In: *குடிஅரசு [Kuṭiaracu]*, pp. 12–13.
- குழந்தை [Kuḷantai], புலவர் [Pulavar] (1968). *தமிழெழுத்துச் சீர்திருத்தம் [Tamil script reform]*. வேலா பதிப்பகம் [Vēlā Patippakam]: ஈரோடு [Erode].
- சண்முகம் [Caṇmukam], செ. வை. [Ce. Vai.] (1978). *எழுத்துச் சீர்திருத்தம் [Script reform]*. அண்ணாமலைநகர் [Annamalainagar]: அனைத்திந்தியத் தமிழ் மொழியியல் கழகம் [All India Tamil Linguistics Association].

- சம்பந்தன் [Campantan], மா. சு. [Mā. Cu.] (1980). *அச்சம் பதிப்பும் [Printing and publishing]*. சென்னை [Chennai]: தமிழர் பதிப்பகம் [Tamilar Patip-pakam].
- கப்பையா [Cuppaiyā], அ. சி. [A. Ci.] ([1935]). *தமிழ் வரிவடிவ ஆராய்ச்சி [Re-search on the Tamil letter-forms]*. ஈரோடு [Erode]: பகுத்தறிவு நூற்பதிப்புக்கழகம் லிமிட்டெட் [Pakuttarivu Book Publishing Society Ltd.]
- திருநாவுக்கரசு [Tirunāvukkaracu], வை. [Vai.] (Oct. 28, 1951). “எழுத்துச் சீர்திருத்தத்தால் ஞாலமெலாம் பரவும் [Through script reform it will spread over the whole world]”. In: *தமிழ் முரசு [Tamil Muracu]*, p. 4.
- பாலசுந்தரம் [Pālacuntaram], இரா. [Irā.] (1982). *தமிழ் எழுத்துச் சீர்திருத்தம் [Tamil script reform]*. திருச்சி [Tiruchi]: பொன்னம்மை பதிப்பகம் [Ponnam-mai Patippakam].
- முருகப்பா [Murukappā] (Sept. 1930). “தமிழ் எழுத்தில் திருத்தம் [Reform in the Tamil script]”. In: *குமரன் [Kumaran]*, கக [11].
- ரத்னம் [Ratnam] (Mar. 1931). “எழுத்துக்களும் அவற்றின் சரித்திரமும் [The letters and their history]”. In: *குமரன் [Kumaran]*, p. 21.
- வேலு [Vēlu], சு. [Cu.] and சொ. [Co.] செல்வராஜி [Celvarāji], eds. (1989). *தமிழ் எழுத்துச் சீர்திருத்தம் உண்மை வரலாறு [Tamil script reform: the true history]*. வேலூர் [Vellore]: குத்தூசி குருசாமி பதிப்பகம் [Kuttūci Kurucāmi Patippakam].
- ஸாம் [Sām], എൻ. [En.] (2006). *கேரളത്തിലെ പ്രാചീനലിപിമാതൃകകൾ [Ancient script specimens of Kerala]*. திருவனந்தபுரம் [Thiruvananthapuram]: സംസ്ഥാന പുരാവേഷവകുപ്പ് കേരളസർക്കാർ [Kerala State Archives Department, Govt. of Kerala].

Visual Complexity of *Akṣaras* and Orthographic Neighbors

Observations Based on the Telugu Writing System

Vasanta Duggirala, Surampudi Bapi Raju & Soham Korade

Abstract. The present study was designed (1) to examine aspects of graph and grapheme complexity associated with Telugu *akṣaras* in the script that is currently in use, and (2) to estimate quantitatively, the impact of grapheme complexity on the Orthographic Neighborhood (ON) size in 200 two-syllabic words that were part of the 1000 most frequently occurring printed words listed in a Telugu-text corpus. For all the graphs and graphemes in the Telugu script, four aspects of their visual complexity, viz., Perimetric Complexity (PC), Disconnected Components (DC), Connected Points (CP), and Simple Features (SF) were measured. With the help of an algorithm, ONs for the 200 bi-syllabic words were generated by substituting entire *akṣara* or by altering its sub-components without changing the position of the *akṣara* in the target word. The lexical status of each ON was verified using an online dictionary. Statistical analysis of the results revealed that the complexity values for the PC and DC components were strongly negatively correlated with ON, suggesting that greater visual complexity of graphemes is associated with fewer ONs in Telugu. The implications of these results are discussed briefly, and some topics for future research are mentioned in this paper.

1. Introduction

Considerable research on writing systems reported to date has been driven by the idea that learning to read in any script depends primarily on how the minimal units of writing (graphemes) map onto linguistic units such as phonemes, syllables, and morphemes. This idea about

Vasanta Duggirala  0009-0005-2139-3581

Retired Professor of Linguistics, Osmania University, Hyderabad, India

E-mail: vasantad@gmail.com

Surampudi Bapi Raju  0000-0003-2204-0890

Cognitive Science Lab, International Institute of Information Technology (IIIT), Hyderabad, India

E-mail: raju.bapi@iiit.ac.in

Soham Korade  0009-0005-2518-0313

Student of Engineering, IIIT, Hyderabad, India

E-mail: soham.korade@students.iiit.ac.in

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 443–468. <https://doi.org/10.36824/2024-graf-dugg>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

representational mapping informed existing major typologies of writing systems, viz., alphabets (representing both vowel and consonant phonemes as in English), abjads (consonants only as in Hebrew), alphasyllabaries/abugidas (*akṣaras* as in Hindi), syllabaries (syllables /*morās* as in Japanese), and morphosyllabaries (morphemes as in Chinese). The terms for the typologies of writing systems were directly applied to all scripts in each type. Thus, scripts associated with all Brahmi-derived Indic languages, including Telugu, were referred to as alphasyllabaries or abugidas since the minimal orthographic unit across all these scripts is *akṣara*, an orthographic CV syllable with an inherent vowel that is assumed to have similar functional value. Details about the origin of Brahmi-derived writing systems and the cultural contexts in which scripts associated with an abugida and an abjad can come into contact in India are provided by Ramanujan and Weeks (2019).

The dominant discourse around the principles of representational mapping also animated much published psycholinguistic research on how reading takes place in *akṣara*-based writing systems (see, e.g., Nag (2014; 2017); Padakannaya, Pande, Saligram, and Shruthi (2016) for Kannada; Bhuvaneshwari and Padakannaya (2014) for Tamil; Duggirala (2019) for Telugu; Chatterjee-Singh and Sumathi (2019) for Hindi; Nambiar, Kishore, and Bhargava (2023) for Malayalam).

In recent years, there has been a realization that the multilingual, multiscriptal ethos of India poses many challenges to existing discussions of representational mapping. Some of these challenges include: (1) the arrangement of *akṣara* and its components in writing (most Indic scripts have a non-linear, hierarchical arrangement of *akṣara*'s components around its base unlike letters in an alphabet) with the degree of non-linearity varying across different Indic scripts (2) differences in the extent of mapping between phonological features and orthographic units, and (3) level of graphic complexity of *akṣaras* and (4) the need to represent more than one language using the same script. Highlighting these challenges, some grapholinguistic researchers have pointed out that *akṣara*-based writing systems must be viewed as “fully vowelised *akṣarik* segmentaries” and that the syllable-*akṣara* mapping breaks down in the case of complex *akṣaras* (Gnanadesikan, 2017; 2021)). Others opined that writing-system typologies should consider factors such as linear/non-linear, integral/decomposed, complete/reduced, levels of graphic complexity, and semiotic heterogeneity arising from the use of graphemes from other languages (Fedorova, 2021). Iyengar (2023) pointed out that there is a need to examine the post-consonantal environments in categorizing vowelised segmentaries as abugidas or alphasyllabaries or abugidic-alphasyllabaries. Since the graphematic boundaries of an *akṣara* may not always align with the phonological syllable, one should use graphematic criteria in determining its functional value. In other words, while *akṣara* is associated with phonology, it should not

be decided by it (see Iyengar (2024) for a detailed discussion of this point).

In the past two decades of the 21st century, some grapholinguistic researchers have also argued that there is a need to go beyond representational mapping, which is assumed to be static across all scripts within a given writing-system typology. This should be done by conducting systematic research into the structural properties of graph/grapheme inventories, especially with reference to non-alphabetic writing systems, to specify graphetic and graphematic allography and graphotactic rules. This requires examination of visual complexity to identify which segmentable orthographic units have functional value within a given script, as argued by Meletis (2020a,b). Meletis and Durscheid (2022) commented further that future grapholinguistic research should uncover spatially based systematicity in graph inventories besides giving up on alphabet-specific definition of the construct ‘grapheme’ because in some writing systems, not all readily differentiated segments function as graphemes. Adopting a multi-modular writing system comprising a graphetic, graphematic (with connections to the language module), and orthographic modules, these researchers proposed the term ‘basic shape’ to denote a template corresponding to a given graph. Since Abugidas raised a number of questions for defining a grapheme, these researchers offered three distinct criteria for arriving at a universal definition of grapheme:

- (1) Lexical distinctiveness (that contributes to meaning differentiation),
- (2) Linguistic value (basic shape corresponds to a specific linguistic unit), and
- (3) Minimality (basic shape occupies exactly one segmental space).

Chang, Chen, and Perfetti (2018) proposed a multidimensional measure of visual complexity referred to as the ‘GraphCom’ that measures four different dimensions of visual complexity: (1) Perimetric Complexity (PC), (2) Disconnected Components (DC), Connected Points (CP), and Simple Features (SF). They have empirically demonstrated that a combined measure of graphic complexity enables comparison across writing systems, even those within the same typology. Their database consisted of 131 writing systems and the associated scripts (including the Telugu script). Measures such as the Graphcom will enable researchers to study the interaction between structural features and cognitive processes involved in reading and writing by allowing assessment of the orthographic processing abilities of beginning (bilingual) readers and/or those experiencing reading difficulties. Keeping these applications in mind, we have used the same four dimensions of graphic complexity as Chang, Chen, and Perfetti (ibid.) did to quantify the graph and grapheme complexity of Telugu akṣaras reported in this article.

One of the psycholinguistic variables affecting spoken and/or visual word recognition in alphabetic and non-alphabetic writing systems is the size and density of Orthographic Neighborhood (ON). Marian (2017) reported orthographic and Phonological Neighborhood (PN) databases for many European languages. It was also observed that lexical decision tasks are completed quickly and accurately for words with large neighborhoods (see Davis, 2005; Grainger, 2005; Peereman and Content, 1997). Other researchers reported that large ON will lead to relatively fast eye movements during reading (Yates, Locker, and Simpson, 2004). ON size reportedly affects reading recognition of words even in non-alphabetic scripts associated with languages such as Chinese (Chang, Welbourne, and Lee, 2016; Xiong, Zhang, and Ju, 2021; Zhao, Li, and Bi, 2012). We are not aware of any published research on the ON in relation to any *akṣara*-based Indic scripts, which motivated our study.

Drawing inspiration from some of the grapholinguistic and psycholinguistic research cited in this section, we have undertaken the present study to seek answers to two specific questions relating to the current-day Telugu script:

- (1) How does visual complexity distinguish Telugu graphs and graphemes?
- (2) What is the relationship between graphemic complexity and ON?

Meletis (2020a) offered definitions of a number of terms relating to both theoretical and applied grapholinguistics. We have used the terms ‘graph’, ‘basic shape’, and ‘grapheme’ in the sense he defined them. The *akṣara* is also referred to as ‘orthographic syllable’ and enclosed in <-> to distinguish it from the phonological syllable. While we acknowledge the fact that the term ‘writing system’ encompasses graphetic, graphematic, and sociolinguistic (orthographic) components, our discussion in relation to the Telugu writing system in this paper is restricted for the most part to the graphetic and graphematic components and not to the orthographic module specifying rules of spelling Telugu words correctly. We have adhered to ISO 15919 standards when providing transliteration of the Telugu data included in this paper. The rest of the contents of this paper are organized under the following main headings: Telugu Writing System §2; Graph and Grapheme Complexity §3; Grapheme Complexity and Orthographic Neighborhood size §4, and Implications and Directions for Future Research (§5).

2. The Telugu Writing System

Telugu is one of the four major literary languages belonging to the Dravidian family included in the 8th schedule. It is the official language in two southern states of India, viz., Andhra Pradesh and Telan-

gana. Many tribal languages, such as Gondi, Koya, Konda, and Kolami, use the Telugu script (see <https://scriptsource.org> for more details). The current-day Telugu writing system may be considered an abugida-alphasyllabary because, first, the main graphic unit ‘*akṣara*’ (CV₀) is an orthographic syllable with an inherent vowel <a>. Secondly, a series of vowel-modifying diacritics (*mātras*) is attached to the basic *akṣara* (CV₀), generating hundreds of orthographic syllables that function as graphemes (see Iyengar (2023) for a detailed discussion of this newly proposed hyphenated typological term). The commonly occurring graphic syllables in native Telugu words are V, Vṁ, CV, CCV, CCVṁ, CCCVṁ. In other words, while all native Telugu words end in open syllables or with a coda-nasal, words borrowed from other languages can have consonant sequences word initially or medially, and a pure consonant without a vowel word finally. Not all *akṣaras* in Telugu script correspond with phonological syllables.

2.1. Inventory of Graphs (Basic Shapes)

The direction of the Telugu writing system is left to right. Words are separated by spaces. All graphic syllables in Telugu are round, each constructed by circles, loops, hooks, and check marks.

In the Telugu script that is currently in use, there are 16 independent vowels, including short and long ones. Vowel length is phonemic in Telugu. Separate graphs are used to represent nasalization and aspiration features. The vowel muting symbol (*virāma* when applied to any consonant, kills the inherent vowel, resulting in a pure consonant that typically occurs in word-final positions in words borrowed from English or Sanskrit. The anuswara <aṁ> and aspiration marker <aha> appear linearly on the horizontal axis. The vowels are represented explicitly in their primary form in word-initial positions. In word-final position, and in borrowed words, they are subordinated to consonants since they are represented by vowel-modifying diacritics. The secondary symbols or diacritics corresponding to all the vowels are referred to as *mātras*. Each one has a specific name that is used during literacy instruction offered during primary school years. When these symbols are applied to basic shapes of <CV₀> *akṣaras*, the inherent vowel is suppressed, and the *akṣara*’s shape gets altered slightly.

There are 36 graphic symbols to represent basic shapes of CV- *akṣaras* (unaspirated and aspirated) in the Telugu script. In all these *akṣaras*, the inherent vowel /a/ is represented by a check mark, [v] referred to in Telugu as *talakaṭṭu* ‘head-stroke’. In the case of the graph <ఁ టa> it is indicated by a small vertical bar written on top of the left loop; The *akṣaras* corresponding to <ఙ ja>, <ఞ gna>, <ణ ṇa>, <బ ba> and <ల la> are devoid of overt symbol for the inherent vowel <a>. That is, the *talakaṭṭu* or check

A. BASIC SHAPES

అ	ఆ	ఇ	ఈ	ఉ	ఊ	ఋ	ౠ
a	ā	i	ī	u	ū	ṛ	ṝ
ఎ	ఏ	ఐ	ఒ	ఓ	ఔ	అం	అః
e	ē	ai	o	ō	au	am	ah
క	ఖ	గ	ఘ	ఙ			
ka	kha	ga	gha	ṅa			
చ	ఛ	జ	ఝ	ఞ			
ca	cha	ja	jha	ña			
ట	ఠ	డ	ఢ	ణ			
ṭa	ṭha	ḍa	ḍha	ṇa			
త	థ	ద	ధ	న			
ta	tha	da	dha	na			
ప	ఫ	బ	భ	మ			
pa	pha	ba	bha	ma			
య	ర	ల	వ	ళ			
ya	ra	la	va	ḷa			
శ	ష	స	హ	ఱ			
śa	ṣa	sa	ha	ṛa			

B. VOWEL MODIFIERS

ౌ	ఀ	ఁ	ం	౓	౔	ౕ	ౖ	౗	ౘ	ౙ	ౚ	౛	౜	ౝ
ā	i	ī	u	ū	ṛ	e	ē	ai	o	ō	au	am	ah	
కౌ	కి	కీ	కు	కూ	కృ	కె	కే	కై	కో	కొ	కం	కః		
kā	ki	kī	ku	kū	kṛ	ke	kē	kai	ko	kō	kau	kam	kah	

C. EXAMPLES OF AKṢARAS WITH LIGATURES FOR GEMINATES AND CLUSTERS

kka క్క, cca చ్చ, tta త్త, lla ల్ల, wwu వ్వు, rre రై
 dru ద్దు, kti క్తి, tsa త్స, tru త్తు, vy వ్య, tri త్రి

FIG. 1. Inventory of graphic elements in the Telugu script

mark is absent in them. In these and all other graphs, the inherent vowel /a/ can be deleted completely, turning them into pure consonants <జ్ j>, <ణ్ ṇ>, <బ్ b> <ల్ l> required for representing words from other languages especially English. The aspirated consonants and fricatives have entered modern-day Telugu through borrowings from Sanskrit, Persian-Arabic, and English. All these *akṣaras* serve as articulatory units during the acquisition of beginning reading.

The graphic forms associated with consonant sequences are referred to as *ottulu* in Telugu. These ligatures apply to *dvitvākṣarālu* (gemimates) or *samyuktākṣarālu* (clusters). They typically lie below the basic *akṣara* and are almost never attached to it, unlike the diacritics associated with the vowels. It should be noted that accurate representation in writing requires writing the primary graphs (basic shapes) first and then placing the secondary forms (ligatures) below them. *Akṣaras* made up of gemimates tend to occur word medially or word finally, never at the beginning of words. Most words borrowed from Sanskrit have complex onsets with two or even three consonants at the beginning of the word (CCCV). When a vowel is pronounced after a conjunct consonant (as in gemimates and clusters), its diacritic is attached to the first and not the second consonant, resulting in some degree of nonlinearity between spoken and written syllables.

2.2. Visuospatial Logic Governing Telugu *Akṣaras*

In the example *akṣaras* shown below, there is a non-linear relationship between spatial and temporal order conditioned by the placement of the vowel diacritic (shown in red color).

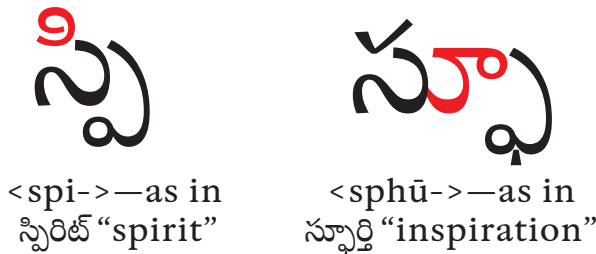
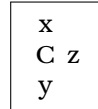


FIG. 2. Telugu *akṣaras* <spi> and <sphū>

The two orthographic syllables with clusters shown above correspond with two CV-phonological syllables, **spi-** and **sphū-** respectively. However, in the right *akṣara* <**sphū**> the orthographic syllable is visually

more complex because the vowel diacritic corresponding to <ū> and the ligature of <sph> occupy larger segmental space compared to the akṣara <spi> on the left. The visuo-spatial logic behind vowel modifiers and ligatures involved in representing geminates and clusters in Telugu was specified by Krishnamurti and Gwynn (1985) as under:



where the primary consonant is represented as C, which has three distinct positions (x, y, and z) around it:

- Position ‘x’ is exclusively fixed for vowel diacritics attached to the C.
- Position ‘y’ is fixed for ligatures corresponding to geminates and clusters
- Position ‘z’ for some secondary symbols of vowels and consonants.

Krishnamurti and Gwynn (1985, p. 34) stated that the positions x, y, z, as well as the degree of contiguity (fused vs. non-fused to the C), distinguish consonant and vowel *akṣaras* besides imposing a strict order in reading them in slow speech in Telugu. They added further that while hundreds of CV syllables and an equal number of Consonant + Consonant combinations are theoretically possible, about 400 different orthographic syllables are sufficient to represent most sounds and sound combinations in Telugu. Referring to the two complex *akṣaras* discussed earlier, viz., <spi> and <sphū>, the spatial location of diacritics for <spi> involves two positions x and y. Whereas, that for <sphū> involves, x (the inherent vowel <a>), y (secondary symbol for <ph>) and z (vowel diacritic for long <u>) attached to the basic akṣara <s> on the horizontal axis, contributing to higher level of visual complexity of akṣara <sphū> compared to that of <spi>. It should be noted that this logic works for a vast majority of *akṣaras* although there are some exceptions relating to fusion or non-fusion of *akṣara*’s components with the base as in these two words as well as words such as స్నేహం snēham ‘friendship’ in which the vowel modifiers in both the *akṣaras* are not attached to the base consonants, <స sa> and <హ ha> respectively in this case. Whether graph complexity varies depending on whether the vowel-modifying diacritics are fused with the base (CV₀) is one of the points we wish to probe in this study.

2.3. Graphemes in Telugu Script

This section provides information on how the basic shapes of individual graphs in the script inventory combine to form graphemes that make up meaningful Telugu words.

Monosyllabic meaningful words are extremely limited in Telugu: Some examples include:

<i>rā</i>	రా	'come'	<i>ā</i>	ఆ	'that'
<i>pō</i>	పో	'go'	<i>ī</i>	ఈ	'this'
<i>nā</i>	నా	'mine'	<i>ē(m)</i>	ఏం	'why'
<i>mī</i>	మీ	'yours'	<i>strī</i>	స్త్రీ	'woman'

It should be noted that in the first five words, the diacritic associated with long vowels is attached to the base CV-*akṣara*, whereas in the bottom two words, it is not. Since they do satisfy the criteria of mapping onto one phonological syllable, they are lexically distinctive and occupy one segmental space; we can treat them as 'graphemes.'

Most *akṣara*-based writing systems, including Devanagari associated with Hindi, have independent vowels appearing in word-initial position, and dependent vowels (diacritics) elsewhere. The independent vowels and their post-consonantal diacritics are to be treated as allographs since they are in complementary distribution and correspond with the same linguistic unit. The initial phase of literacy instruction in Telugu is always aimed at teaching children to practice pronouncing and writing the basic shapes of CV *akṣaras* listed in the *varnamāla* by applying various vowel-modifying diacritics or *gunintālu* as well as ligatures or *ottulu* even if they lack meaning. In fact, specially designed copyright booklets are given to children to fill in the basic shapes appearing with vowel diacritics and ligatures.

The basic shapes of *akṣaras* combine with each other to serve graphematic function in two-syllable meaningful words, as the examples listed below illustrate:

- <క ka> combines with <కీ ki> to become a meaningful word, కాకి *kāki* 'crow'.
- <కం kaṁ> combines with <ద da> to become the word, కంద *kanda* 'yam'.
- <కు ku> combines with <క్క kka> to become కుక్క *kukka* 'dog'.
- <కు ku> combines with <ట్ర tra> to become కుట్ర *kuṭra* 'conspiracy'.
- <కృ kru> combines with <షి ṣi> to become కృషి *kruṣi* 'effort'.

These examples illustrate that all basic shapes with vowel diacritics and those with ligatures can serve as graphemes in meaningful words, fulfilling the criterion of lexical distinctiveness. Each *akṣara* also corresponds to one phonological segment, and most of the *akṣaras* occupy one segmental space, with one exception, that of homorganic nasals indicated by a zero which lie next to the consonant on the horizontal plane (never attached to it) as in the word, కంద *kanda* 'yam' which aligns with the phonological syllables /kan/and /da/ or అందం *andam* 'beauty' with phonological syllables /అం am/ /దం dam/. It should be noted that in words with consonants appearing in coda position, a timing unit called

mora plays a role in processing and segmentation tasks. Mora is larger than a phoneme but smaller than a syllable. Patel (2007, p. 173) pointed out that the distinction between open and closed syllables and the concept of syllable quantity is implicit in the design of written *akṣaras*.

We reproduce below an excerpt from a Telugu newspaper to show different types of *akṣaras* that serve as graphematic syllables/words in the current-day Telugu script (each *akṣara* is separated by a period mark and each word by a hashtag #):

- (1) న. వ. తె. లం. గా. న. లో # స. రా. రీ # కో. లు. వు. ను. చే. జి. క్కిం.
 na. va. te. lam. gā. na. lō # sa. rkā. rī. # ko. lu. vu. nu. cē. ji. kkin.
 చు. కో. వ. డ. మే # ల. క్షం. గా # క. ప్ట. ప. డి చ. దు. వు. తు.
 cu. kō. va. ḍa. mē # la. kṣyam. gā # ka. ṣṭa. pa. ḍi ca. du. vu. tu.
 న్న. అ. భ్య. ధ్ధ. లు # ఎ. ప్పు. డె. ప్పు. డా
 nna. a. bhya. rdhu. lu # e. ppu. ḍe. ppu. ḍā

నవతెలంగానలో సర్కారీ కొలువును చేజిక్కించుకోవడమే లక్ష్యంగా కష్టపడి చదువుతున్న
 అభ్యర్థులు ఎప్పుడెప్పుడా

The aspirants studying hard with the primary goal of getting a government job in the newly formed state of Telangana are waiting

Among the three words in red, viz., *sarkāri* ‘government’ in the first line is a Hindi word, whereas *lakṣyaṃ* ‘goal’, in the first line, and *abhyard-bulu* ‘aspirants’ in the second line respectively are words borrowed from Sanskrit. These words have been assimilated into Telugu with certain modifications to the graphs to accommodate morphological-level information, such as plurality and case. When they are written in Devanagari script associated with Hindi, they appear as shown: सरकारी, लक्ष्य and अभ्यर्थी in direct correspondence with their phonological forms. The arrangement of graphemes in these two Indic scripts differs, suggesting differences in representational mapping. To elaborate, using the Hindi word *sarkāri*, while the Devanagari script represents <K> in its primary form, the Telugu script uses the secondary form of <k> in the second syllable. The Sanskrit word *lakṣyaṃ* is also modified from the original version in Sanskrit by replacing <a> with <aṃ> and adding the adverbial suffix *-gaa* in Telugu. The Sanskrit word, अभ्यर्थी, when written in Telugu, also gets modified by the addition of a plural marker *-lu* required in the context of this sentence. Thus, the arrangements of graphs belonging to languages other than Telugu appear to follow Telugu graphematic rules, sometimes even by violating phonotactic rules. The graphematic rules in the case of complex graphemes in Telugu are driven by spatial logic more than phonological information, a fact offering support to the suggestion that *akṣara* should be treated as a graphematic unit by Iyengar (2024).

In the sample of Telugu writing printed above, there are 43 different orthographic syllables (*akṣaras*) altogether. Of these, 30 have the prototypical V, CV(V), CVm structures, while the others containing ligatures representing geminates / clusters have C₁C₁V or C₁C₂V(m)-type structures. Looking at the example, ల. క్షం lakṣyam ‘goal’, it has the structure CV. C₁C₂C₃ m. The first akṣara <ల la> having a CV structure aligns with one phonological syllable. When it is replaced by <భ bha> another meaningful word, *bhakṣyam* ‘a sweetmeat’ obtains, and thus it is involved in lexical distinctiveness. It occupies one segmental space. Since it satisfies all three criteria specified for ‘grapheme’ by Meletis (2020a), it can be treated as a simple CV grapheme.

The second *akṣara*, <kṣyam>, on the other hand, demands a closer examination of the arrangement of basic shapes. The complex akṣara <kṣa> has a graphematic function by itself in that it appears in many meaningful words such as: *lakṣa* ‘hundred thousand’, *pakṣi* ‘bird’, *sikṣa* ‘punishment’, *mōkṣam* ‘liberation’, *rakṣaṇa* ‘protection’ *kṣaya* ‘Tuberculosis’ and so on. The primary form of <k> and the secondary form of <ṣ> are stacked vertically, and yet they occupy one segmental space, qualifying all the criteria to be considered as a complex grapheme. When it combines with the next akṣara, <yam>, it becomes a bound grapheme. The word *lakṣyam* can also be written as: లక్షము *lakṣyamū* or లక్షమ్ with three syllables. It is instructive to cite here the comments of Iyengar (2024, p. 431): “If *akṣara* is conceived as a written unit centered around one free graph, it follows that one can add or remove as many bound elements as graphematically permissible without impacting the *akṣara* count. More research is needed into the *akṣara*’s compositional transparency in Telugu script.”

2.4. Graphematic Features in Telugu Script

With a view to examining some graphematic relations governing the *akṣaras* in the Telugu script, we have selected 200 two-syllabic words from a text corpus. This corpus of over 3 million words of running text, covering modern fiction, short stories, novels, science writing, children’s stories, and journalese, was developed by the Central Institute of Indian Languages, Mysore, India (CIIL corpus, henceforth). A detailed analysis of the 1000 most frequently appearing printed words, orthographic syllables, and character sequences, along with their frequency counts in relation to the CIIL corpus, was reported in Uma Maheshwar Rao (2006). We have chosen 200 out of this list of 1000 words for our analysis of the visual complexity of *akṣaras*. In conducting this analysis, we drew on the spatial logic governing Telugu *akṣaras*, as discussed earlier in this paper, as articulated by Krishnamurti and Gwynn (1985). Specifically, the basic *akṣara*, <CV₀> has most of the vowel modifiers attached to it on top

(position X). Most ligatures representing consonant sequences (geminate and clusters) lie below the basic akṣara and are rarely attached to it (position Y). Homorganic nasals, aspiration marker (visarga) and vowel modifier corresponding to the grapheme <ఉ u / ఊ ū> lie on the horizontal plane next to <CV₀> at position Z. If we disregard the check-mark corresponding to the inherent vowel that is present in most akṣaras and classify them based on the position of other vowel modifiers and ligatures, ten different orthographic syllable types cover most of the 200 target words. The number of words belonging to a given akṣara type is indicated under N= in the first column in Table 1 below:

The following facts are evident from Table 1:

1. There are 25 words of the type V. CV / V. CVV such as ఒక *oka* 'one' and ఎలా *elā* 'how'. Such akṣaras are fully aligned with the phonological syllables and may be treated as simple akṣaras.
2. Words with homorganic nasal containing vowel modifier belonging to /u/ as in the word, మందు *mandu* 'medicine' (3rd word from top of the Table 1) corresponds directly to the phonological syllable *man.du*.
3. In contrast to types (1) and (2), the last row of Table 1 has only 9 words with akṣaras of the type, C₁C₂V. C₁C₂V (*m*) (e.g., వ్యక్తి <*vya.kti*> 'person'). This word is phonologically syllabified as /vyak/. /ti/ in compliance with the phonotactic rules of Telugu. However, it does not correspond with the orthographic syllable division.

One other fact that emerges from this analysis is that when the secondary graphs representing geminates or clusters that appear in position Y (bottom of the basic akṣara), the alignment between orthographic and phonological syllables breaks down as in words, అమ్మ *amma* 'mother', పెద్ద *pedda* 'big', చుట్ట *cutta* 'cigar' and those with clusters: రక్తం *raktam* 'blood', దృష్టి *druṣṭi* 'vision' and స్పష్టం *spaṣṭam* 'clarity' (listed in rows 5-10 of Table 1) suggesting that presence of ligatures seems to contribute to increase in visual complexity of Telugu akṣaras. This analysis, based on 200 two-syllable words, suggests that at least three major types of graphemes operate in Telugu script:

- (1) Simple (V(V), V_m, CV, CV_m, CVCV, CV_m.CV)
- (2) Complex (V.CCV, CV.CCV) and
- (3) Compound (CV. C₁C₂V; C₁C₂V_m. C₁C₂V; and C₁C₂V. C₁C₂V_m)

The third type has many bound graphemes. The graphotactic rules for the two-syllabic native Telugu words permit the following types of akṣaras:

- (1) Simple syllable alone as in for example, రా *raa* 'come'
- (2) simple syllable + ligature corresponding to a geminate as in అమ్మ *amma* 'mother' or అద్దం *addam* 'mirror'

TABLE 1. Arrangement of graphematic units within *akṣaras*

Orthographic syllable structure	Position of the V-diacritic and ligatures	Telugu Word with Transliteration	English Gloss	Status of Spatiotemporal alignment
V.CV(V) N=25	X in second syllable	idi ఇది	‘This one’	Present
Vm.CV N=14	Z in the second syllable	andu అందు	‘In it’	Present
CVm.CV N=25	Z in both syllables	mandu మందు	‘Medicine’	Present
CV(V).CV N=50	X in the 2nd syllable	pani పని	‘Work’	Present
V.C ₁ C ₁ V N=08	Y in the second syllable	amma అమ్మ	‘Mother’	Absent
CV.C ₁ C ₁ V N=15	X first syllable, Y in second syllable	pedda పెద్ద	‘Big’	Absent
CV.C ₁ C ₁ V N=10	Z in first syllable, Y in second syllable	cuṭṭa చుట్ట	‘Cigar’	Absent
CV.C ₁ C ₂ Vm N=25	Z and Y in the second syllable	raktaṁ రక్తం	‘Blood’	Absent
C ₁ C ₂ V(m). C ₁ C ₂ V N=16	Y in first syllable, X and Y second syllable	druṣṭi దృష్టి	‘Vision’	Absent
C ₁ C ₂ V.Vm N=09	Y in first syllable, Y and Z in second syllable	spaṣṭaṁ స్పష్టం	‘Clarity’	Absent

- (3) simple syllable + complex / compound syllables as in లక్ష *lakṣa* ‘hundred thousand’ or లక్ష్యం *lakṣyaṁ* ‘goal’.

Fedorova (2013) also made a distinction among simple, complex, and compound *akṣaras* and stated that the degree of complexity within these three types of structures varies across different abugida scripts, a point that needs to be probed in future research on Indic scripts. In a more recently published paper, Fedorova (2021) commented that vowels in an abugida act like different “garments” for consonants, sometimes they form the “soul” of a consonant “body” in an *akṣara*. We feel that this observation aptly captures the *akṣara*, *kṣyaṁ* in Telugu script because the heavy vowel <am> applies simultaneously to the three consonants: <k>, <ṣ>, and <y>.

Words borrowed from Sanskrit such as: దృష్టి *druṣṭi* ‘vision’ and స్పష్టం *spaṣṭam* ‘clarity’ with syllable structure C_1C_2V . C_1C_2V in both *akṣaras* are also to be treated as compound graphematic words with the greatest amount of graph/grapheme complexity compared to words with relatively simple orthographic syllable structure involving individual basic shapes, such as for example, ఋషి *ṛuṣi* ‘sage’ or పాతం *paṭam* ‘frame’ or శాపం *śāpam* ‘curse’ without ligatures. The visuospatial analysis of Telugu *akṣaras* discussed in this section suggests that modifications to the base form <CV₀> due to the presence of ligatures enhance the visual complexity of graphemes. This observation is substantiated by the quantitative analysis discussed in the next section. Characteristic features of the current day Telugu Script are listed in Appendix A.

3. Graph and Grapheme Complexity

This section provides quantitative information regarding graph and grapheme complexity (GC) as measured in our study.

3.1. Graph Complexity

As the programming code for estimating GC measures reported by Chang, Chen, and Perfetti (2018) is not available, nor are the actual estimated values for Telugu *akṣaras* reported by them, we reimplemented both in Python (available at the GitHub repository: <https://tinyurl.com/37y9ae2a>). We have used the same four graphic complexity measures proposed by Chang, Chen, and Perfetti (ibid.), namely, the number of Connected Points (CP), the number of Simple features (SF), the number of Disconnected Components (DC), and Perimetric Complexity. CP is defined as the number of intersection points between SFs. SF refers to

the number of loops, lines, dots, and curves. DC is taken as the number of disconnected points. Finally, PC is defined as the ratio of the squared perimeter of a graph (number of pixels) to the number of background pixels in the graph. Specifically, PC is $\frac{P^2}{A4\pi}$, where P is the sum of the inside and outside perimeters of the foreground (informally, it is the sum of the perimeters of the inked sub-regions of the akṣaras), A is the foreground area (Pelli, Burns, Farel, and Moore-Page, 2006; Watson, 2012). We illustrate how these measurements are performed using a single graph, <gha> ‘gha’, shown below in Figure 3.

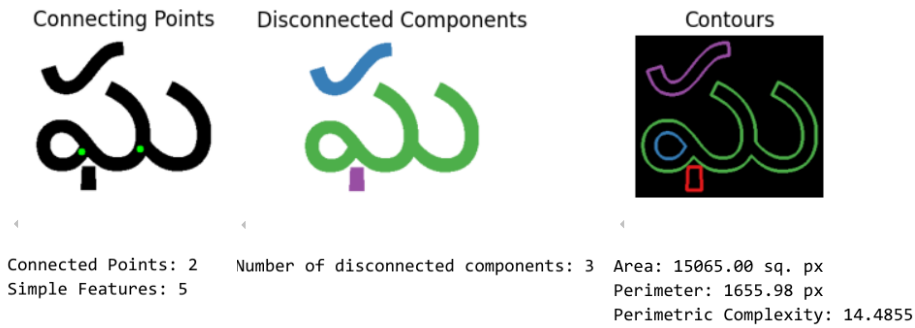


FIG. 3. Graphic complexity measures applied to the graph <gha>

The actual values for all basic shapes in the Telugu script are included in Appendix B. These four graphs show that for all the basic shapes of Telugu akṣaras,

- Simple Features (SF) range from 2-8;
- Connected Points (CP) range from 0-7;
- Disconnected Components (DC) from 1-3; and
- Perimetric Complexity (PC) ranges from 7.66 to 22.32.

Looking closely, one can discern a pattern according to which:

1. the visual complexity is the highest among vowels <ṛu>, <ṛū>, <am>, <aha>, <ū> and diphthong <au> followed by
2. aspirated consonants and then unaspirated consonants. It may be reasonable to argue that words containing aspirated consonants are visually more complex than those with unaspirated components because they contain more disconnected components due to the presence of the aspiration marker indicated below the base.
3. Graphs in which vowel modifiers are not attached to the top of the base CV₀, appear to possess greater graph complexity over those in which the vowel modifiers are attached.

We have validated our result for one graph with those reported by Chang, Chen, and Perfetti (2018) for the *akṣara*, <aha>, see Table 2.

TABLE 2. Graphic complexity values for <aha>

GC dimension	aha అహ Present study	aha అహ Chang et al. (2018) study
PC	16.70*	18.06*
DC	3	3
CP	2	2
SF	5	5

The perimetric complexity is the greatest for *akṣara* <aha> compared to all the other vowels, a finding in agreement with that reported by Chang, Chen, and Perfetti (ibid.) as shown in Table 2. It should be noted that the slight difference in PC values between the two studies is due to differences in the font types used. We have used the Noto Sans Telugu Regular font, whereas Chang, Chen, and Perfetti (ibid.) used the NATS font.

The *akṣaras* that do not have a checkmark on top have fewer connected points as well as fewer disconnected components (for example: <ల la> and <బ ba>). On the other hand, those that have a connected checkmark have fewer DCs but more CPs (for example, <గ ga, క ka, ఝ ra>) and vice versa for *akṣaras* with disconnected checkmarks (for example <ఎ ee>, <స sa>, <ప pa>).

The next table (Table 3) shows the changes in graphic complexity as the grapheme <క ka> gets modified when vowel modifiers and ligatures are added. As can be seen, all the GC measures tend to increase when a basic shape is transformed by modifiers.

TABLE 3. Graphic complexity values for <ka> with vowel diacritics and ligatures

Complexity Dimension	క <ka>	కొ <kō>	కక <kka>	కక్లా <kla>
PC	8.74	14.19	16.69	14.18
DC	1	1	2	2
CP	1	3	2	2
SF	2	5	4	4

Notice that the PC value increases to a greater extent when <క ka> appears as a double consonant <కక kka> compared to the cluster, <కక్లా kla>.

It could be related to the fact that the secondary form of <k> when it is doubled takes up more space, occupying position ‘y’ below the base consonant, and position ‘z’ on the horizontal axis. The secondary form (ligature) of <ల la>, however, remains below, but quite close to the base consonant graph. It is also relatively small, compared to that associated with the graph representing <క్క kka>. In actual writing, the exact position of the ligatures varies considerably. For example, the word, *druṣṭi* ‘vision’ can be written either as: దృష్టి or as ద్రుష్టి.

3.2. Grapheme Complexity

When the basic *akṣaras* join to form meaningful 2-syllable words, we have Grapheme Complexity. Grapheme Complexity is estimated by considering the image of two orthographic syllables written together and then estimating various GCs as defined in the previous section. As shown in Table 4. As grapheme complexity increases, GC values (particularly PC) also increase, as evidenced by three of the 200 target words listed in Table 4. However, it should be noted that DC, CP, and SF do not strictly follow this linear trend in several cases.

TABLE 4. Grapheme complexity values for three Telugu words with different syllable structure

GC Dimension	adi V.CV అది ‘that’	mūḍu CV.CV మూడు ‘three’	vyakti C ₁ C ₂ V.CV వ్యక్తి ‘person’
PC	20.66	33.97	35.12
DC	2	2	4
CP	5	12	5
SF	6	14	11

It should be noted that Telugu words with simple *akṣaras* (V.CV) have the least PC values compared to those with graphematic syllables <mū> and <ḍu> (CVV.CV) and those with even more complexity (C₁C₂V. C₁C₂V). It appears that the position of the vowel modifier also affects grapheme complexity. The next step is to examine the relationship between grapheme complexity and the size of orthographic neighbors for each target word.

4. Grapheme Complexity and Orthographic Neighborhood Size

A Telugu word's neighbors are those which differ from the target word in one entire *akṣara* or any of the sub-components of the *akṣara*, as the examples below illustrate:

- Substitution of an entire *akṣara* in the initial position of the word, గుల *gula* 'itch,' results in a new meaningful word, వెల *vela* 'price. This is an example of a phonological neighbor (PN).
- Deletion of the homorganic nasal from the word, తొండ *tonḍa* 'chameleon' results in తొడ *toda* 'thigh' is an example of ON.
- Addition of a segment (ligature corresponding to <గ ga> to the word, వరం *varam* 'boon' can result in వర్గం *vargam* 'group,' another example of ON.

This task was done using a specially designed algorithm applied to an online corpus. There were four main steps in the algorithm: (1) Analyze the input word's orthographic syllables, (2) Process each syllable, (3) Find matching words, and (4) Remove duplicate words and return the results. The lexical status of all the neighbors generated through these operations is verified using an online dictionary (<https://dsal.uchicago.edu/dictionaries.brown>). It should be noted that some dictionary entries belong to both old Telugu and Sanskrit.

With the help of this algorithm, all the 200 two-syllable words were subjected to substitution, deletion, and addition operations such that the result is yet another meaningful word that exists in the dictionary. It should be noted that if we had included words longer than two syllables, we could have obtained more information on orthographic neighbors, since deletion works better with three- or four-syllable words. Based on the data we have analyzed, we cannot specify the relationship among frequency, word length, and ON size, a topic that warrants further research.

A systematic comparison was made of all 200 words and their corresponding ONs. We have generated word clouds for words with simple, complex, and compound graphemes.

- Words such as ఆట *aaṭa* 'play' had 154 neighbors.
- Words such as రెక్క *rekka* 'wing' with a ligature had 93 ONs.
- Words such as పూర్వం *puurvam* 'past' had only 31 neighbors.

These results clearly show that as the visual complexity of *akṣara* increases, involving vowel-modifying diacritics or ligatures corresponding to consonant sequences, the grapheme's complexity increases. Some limitations of our study should be noted. We have used only 200 high-frequency two-syllable words and conducted all the analysis using only the CIIL corpus. However, the results need to be verified for the other

two-syllable words and extended for multi-syllable words. The code in the repository is useful for accurately estimating DC and PC, but needs further refinement to estimate SF and CP. The syllable structure extraction and generating ONs are scalable to multi-syllable settings. We faced considerable difficulty in finding a comprehensive, free-access text corpus and a contemporary online Telugu Dictionary with a lookup facility for the algorithm to verify whether the generated ON is a valid word.

Statistical analysis of our data revealed a negative relationship between grapheme complexity and ON size, as evidenced by the numbers, especially those corresponding to DC and PC, with the strongest negative correlation with the ON shown below. The scatter plot in Figure 4 below exhibits this relationship between PC and ONs:

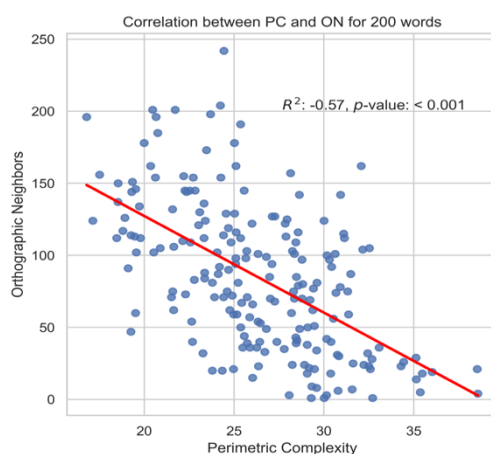


FIG. 4. Negative correlation between Perimetric Complexity and ON

The regression plot in Figure 4 shows a negative correlation between perimetric complexity and orthographic neighborhood size, such that the greater the graphemic complexity of orthographic syllables (*akṣaras*), the smaller the size of ON for Telugu.

Researchers have argued that grapheme complexity is strongly and positively associated with learning difficulties, and that the extent of this difficulty varies depending on whether the writing system is associated with the native language or a later-learned second language. Perfetti and Verhoeven (2022) argued that the visual complexity of graphs / graphemes is a prime candidate for a non-mapping factor that could make a difference to reading ability.

5. Implications and Directions for Future Research

We conducted this study to address two main questions: (1) How does visual complexity distinguish Telugu graphs and graphemes? And (2) What is the relationship between graphemic complexity and ON? Two of the four dimensions of graphic complexity we measured, viz., Perimetric Complexity (PC) and Disconnected Components (DC), demonstrated variation in both graphic and grapheme complexity across the entire inventory of akṣaras in the Telugu script. We have also shown that, for two-syllable words in Telugu, the higher the grapheme complexity, the smaller the size of the orthographic neighbors containing those akṣaras. Both these findings have many implications, both theoretical and clinical.

As mentioned earlier, the literacy learning environment in multilingual India is vastly different from most other countries in the Northern hemisphere. Depending on their socioeconomic status and parental education, children have varying degrees of exposure to oral languages and access to print materials at home. Yet, when they enter school, they are required to learn almost simultaneously one or two akṣara-based Indic scripts, along with English, which is associated with an alphabet. While there is a consensus among second language writing system researchers that specific combination of writing systems (and their scripts) has differential effect on literacy acquisition in general, and development of metalinguistic knowledge in particular (see Cook and Bassetti (2010), there is scant published works on how exactly children develop knowledge about the relationship between spoken units of a language and the graphic symbols especially with reference to Indic scripts. Empirical evidence regarding children's orthographic processing abilities across multiple scripts is virtually nonexistent. Most assessment tools are either adapted versions of English-based tests or rely on researchers' insights into the graphic complexity of akṣaras. In this context, there is a danger of misdiagnosing developmental dyslexia among Indian children. The results of our study, when bolstered with further studies involving larger text corpora and longer target words for estimating phonological and orthographic neighbors (density and frequency), will have tremendous implications for gaining better insights about language-script learning, language education practices, and language disorders.

Recent research on writing system diversity involving groups with different cognitive abilities (see, for e.g., Harris and Hirshorn (2022) revealed considerable individual differences in reading abilities at both behavioral and neural levels. The earlier finding that the Visual Word Form Area (VWFA) in the left hemisphere plays a crucial role in skilled word reading is now reported to be restricted to readers of alphabetic writing systems. Readers of non-alphabetic writing systems tend to exhibit bilateral engagement of VWFAs in both hemispheres, perhaps due

to the system's demand for more complex orthographic units characterized by greater visual complexity and stronger connections to semantics rather than only phonology. Since the development of reading strategies depends on specific writing systems, instructional material must be language-specific. There is an urgent need to determine the precise nature of the internal complexity of orthographic representations stored in the lexicon and the orthographic processing abilities of different populations to enhance our understanding of how bi-literacy acquisition works. The graph and grapheme complexity values we report for Telugu can provide much-needed guidance for designing graded reading tests for children with developmental dyslexia and adults with acquired dysgraphia. Some topics awaiting future research aimed at understanding the cognitive consequences of literacy in multiple languages/scripts in the Indian context include:

- Development of tests such as *akṣara discrimination*, word recognition, lexical decision that will allow researchers to manipulate sub-components of Telugu akṣaras, such as vowel modifiers, homorganic nasals, ligatures, etc., that will facilitate measurement of akṣara processing abilities.
- Designing behavioral and eye-tracking studies of word recognition when target words are presented in sparse vs. dense neighborhoods for words that appear in school textbooks.
- Future grapholinguistic research in relation to abugidic alphasyllabaries will also benefit from data relating to graphemic frequencies and phototactic patterns in various Indic scripts.
- Systematic studies that permit comparison among scripts associated with languages that have similar graph/grapheme inventories, such as Telugu vs. Kannada or Tamil vs. Malayalam.
- Development of computational models of *akṣara* naming / discrimination
- Analysis of word reading speeds/accuracies among children with congenital hearing loss, developmental dyslexia, acquired dyslexia, and dysgraphia following brain damage
- Application of graph/grapheme complexity measures to analyze writing impairments in individuals diagnosed with Parkinson's Disease.

Acknowledgments

We thank Arvind Iyengar for sharing with us some of the published papers on this topic and offering useful comments on an earlier version of this paper.

Appendix A

Characteristic Features of Current-Day Telugu Script (as per the Codes Specified in ScriptSource.org)

1. Language	: Telugu [tel], Family: Dravidian
2. Script	: Telugu [Telu]
3. Id.	: te-Telu-IN (Telugu script used in India)
4. Direction	: Left to Right
5. Type	: Fully vowelised akṣarik segmentary
6. Basic akṣaras	: <CV ₀ > # 35
7. Inherent vowel	: <a>
8. Independent vowels	: Yes, in word initial position
9. Dependent vowels	: In post consonantal position after <CV ₀ >
10. # of vowel akṣaras	: 16
11. Vowel modifiers	: Mostly fused with <CV ₀ > on top
12. Dominant graph	
In conjunct akṣaras	: C1 to which vowel modifier is attached
13. Ligature for geminates	: non-fused with <CV ₀ > at the bottom / stacked
14. Ligature for clusters	: non-fused with <CV ₀ > at the bottom / stacked
15. Obligatory virama (vowel killing sign)	: Yes, mostly used with borrowed words
16. Nasality	: Full form for <m>, <n>, zero post consonantal
17. Visarga	: Yes, mostly with Sanskrit words
18. Non-sanskrit akṣaras	: Yes <fa> written as <pha> and <za> as <Ja>
19. Aspiration sign	: Vertical line below <CV ₀ >
20. Word spacing	: Yes
21. Syllable marking	: No
22. Geminate sign	: No
23. Top mark on akṣaras	: yes, check mark on some, absent in others
24. Complex and compound Graphemes	: Yes
25. Grapheme-phonology Mapping	: Syllable and mora

Appendix B

Distribution of Graphic Complexity Values for All the Basic Akṣaras in the Telugu Script

Distribution of Simple Features (SF)

SF values	<i>akṣaras</i>
2	ఎ, ఒ, క, గ, న, బ, ర, ల, స
3	అ, ఏ, ఐ, ఓ, జ, ఠ, డ, ప, వ
4	ఆ, ఇ, ఋ, అం, ఙ, చ, ట, డ, ణ, ధ, ఫ, భ, మ, య, ఆ, ళ, శ, ష
5	ఈ, ఉ, ఔ, అః, క్ష, ఖ, ఘ, చ, ఝ, ఢ, త్ర, థ, హ
6	ఋ, ఌ
8	ఉః

Distribution of Connected Points (CP)

CP values	<i>akṣaras</i>
0	స
1	ఎ, ఏ, ఒ, క, గ, ర, న, వ, ఘ, బ, ర, ల
2	అ, ఆ, ఇ, ఐ, ఓ, అం, అః, ఖ, ఘ, జ, ధ, డ, ధ, భ, వ, శ, ష
3	ఋ, క్ష, ఙ, చ, ఝ, ట, డ, ణ, మ, య, ఆ, ళ, హ
4	ఈ, ఔ, ఇ, త్ర
5	ఉ, ఋ
7	ఉః

Distribution of Number of Disconnected Components (DC)

DC values	<i>akṣaras</i>
1	అ, ఆ, ఇ, ఈ, ఉ, ఉః, ఋ, ఌ, ఎ, ఐ, ఒ, ఓ, ఔ, క, గ, జ, చ, జ, ఇ, ట, డ, ణ, త్ర, ధ, న, బ, మ, య, ర, ఆ, ల, ళ, వ, శ
2	ఏ, అం, క్ష, ఖ, చ, ఝ, ర, డ, ధ, ప, భ, ష, స, హ
3	అః, ఘ, థ, ఫ

Distribution of Perimetric complexity (PC) values

PC range	<i>akṣaras</i>
7-9	ఎ, ఒ, ర, ల
9-11	ఆ, ఇ, ఏ, ఐ, ఓ, క, ఖ, గ, బ, చ, జ, ట, ర, ణ, త్ర, ధ, న, ప, బ, వ, శ, స
11-13	అ, ఉ, ధ, ఇ, డ, ఢ, ధ, ధ, ప, భ, ఆ, ళ, ష

13-15	కె, మ, హ
15-17	ఈ, క్ష, షు
17-19	ఊ, ఋ, లః, య, య
19-21	అం
21-23	ఋ

References

- Bhuvaneshwari, B. and P. Padakannaya (2014). "Reading in Tamil: A more alphabetic and less syllabic akshara-based orthography". In: *South and Southeast Asian Psycholinguistics*. Ed. by H. Winkset and P. Padakannaya. Cambridge: Cambridge University Press, pp. 192–201.
- Chang, Y. N., S. Welbourne, and C. Y. Lee (2016). "Exploring orthographic neighborhood size effects in a computational model of Chinese character naming". In: *Cognitive Psychology* 91, pp. 1–23. DOI: 10.1016/j.cogpsych.2016.09.001.
- Chang, Li-Yun, Yen-Chi Chen, and Charles Perfetti (2018). "GraphCom: A multidimensional measure of graphic complexity applied to 131 written languages". In: *Behavioral Research Methods* 50, pp. 427–449.
- Chatterjee-Singh, Nandini and T. A. Sumathi (2019). "The role of phonological processing and oral language in the acquisition of reading skills in Devanagari". In: *Handbook of Literacy in Akshara Orthography*. Ed. by R. Malatesha Joshi and Catherine McBride. Springer Nature, pp. 261–278.
- Cook, Vivian and Benedetta Bassetti (2010). *Second Language Writing Systems*. New Delhi: Viva Books.
- Davis, C. J. (2005). "N-watch: A program for deriving neighborhood size and other psycholinguistic statistics". In: *Behavioral Research Methods* 37.1, pp. 65–70.
- Duggirala, Vasanta (2019). "Akshara processing in Telugu depends on syllabic and phonemic sensitivity". In: *Handbook of Literacy in Akshara Orthography*. Ed. by R. Malatesha Joshi and Catherine McBride. Springer Nature, pp. 119–138.
- Fedorova, Ludmila L. (2013). "The development of graphic representation in abugida writing: The akshara's grammar". In: *Lingua Posnanien-sis*, pp. 49–66.
- (2021). "On the typology of writing systems". In: *Grapholinguistics in the 21st Century. 2020 Proceedings*. Ed. by Y. Haralambous. Brest: Fluxus Editions, pp. 805–824.
- Gnanadesikan, Amalia E. (2017). "Towards a typology of phonemic scripts". In: *Writing System Research* 9.1, pp. 14–35.

- (2021). “Brahmi’s children: Variation and stability in a script family”. In: *Written Language and Literacy* 24.2, pp. 303–335.
- Grainger, J. (2005). “Effects of phonological neighborhood and orthographic neighborhood density interact in visual word recognition”. In: *The Quarterly Journal of Experimental Psychology A* 58.6, pp. 981–998.
- Harris, Lindsay N. and Elizabeth Hirshorn (2022). *Culture is not destiny for reading: Highlighting variable routes to literacy within writing systems*. Tech. rep. 3. CISLL. URL: <https://huskiecommons.lib.niu.edu/ctrcisle-publication/3>.
- Iyengar, Aravind V. (2023). “More matters of typology: Alphasyllabaries, abugidas and related vowelised segmentaries”. In: *Written Language and Literacy* 26.1, pp. 30–56.
- (2024). “The akshara as a graphematic unit”. In: *Grapholinguistics in the 21st Century Proceedings. Grapholinguistics and its Applications*. Ed. by Y. Haralambous. Vol. 10. Brest: Fluxus Editions, pp. 419–436.
- Krishnamurti, Bh. and J. P. L. Gwynn (1985). *A Modern Grammar of Telugu*. New Delhi: Oxford University Press.
- Marian, Viorica (2017). “Orthographic and phonological neighborhood databases across multiple languages”. In: *Written Language and Literacy* 20.1, pp. 7–27.
- Meletis, Dimitrios (2020a). *The Nature of Writing: A Theory of Grapholinguistics*. Vol. 3. Grapholinguistics and its Applications. Brest: Fluxus Editions.
- (2020b). “Types of allography”. In: *Open Linguistics*. DOI: 10.1515/opli-2020-0006.
- Meletis, Dimitrios and C. Durscheid (2022). *Writing Systems and their Use: An Overview of Grapholinguistics*. Berlin: De Gruyter Mouton.
- Nag, Sonali (2014). “Akshara-phonology mappings: The common yet uncommon case of the consonant cluster”. In: *Writing Systems Research* 6, pp. 105–119.
- (2017). “Learning to read languages of South Asia”. In: *Learning to Read Across Languages and Writing Systems*. Ed. by Ludo Verhoeven and Charles Perfetti. Cambridge: Cambridge University Press, pp. 104–126.
- Nambiar, Krithika, Kiran Kishore, and Pranesh Bhargava (2023). “The effect of script reform on level of orthographic knowledge: Evidence from alphasyllabary Malayalam”. In: *PLoS ONE* 18.8. DOI: 10.1371/journal.pone.0285781.
- Padakannaya, Prakash et al. (2016). “Visual orthographic complexity of aksharas and eye movements in reading: A study in Kannada alphasyllabary”. In: *Writing Systems Research* 8.1, pp. 32–43.
- Patel, Purushottam G. (2007). “Akshara as a linguistic unit in Brahmi scripts”. In: *The Indic Scripts: Paleographic and Linguistic Perspectives*. Ed. by P. G. Patel, P. Pandey, and D. Rajgor. New Delhi: D.K. Printworld (P) Ltd., pp. 167–213.

- Peereman, Ronald and Alain Content (1997). "Orthographic and phonological neighborhoods in naming: Not all neighbors are equally influential in orthographic space". In: *Journal of Memory and Language* 37, pp. 382–410.
- Pelli, D. G. et al. (2006). "Feature detection and letter identification". In: *Vision Research* 46, pp. 4646–4674.
- Perfetti, Charles and Ludo Verhoeven (2022). "Writing systems and global literacy development". In: *Global Variation in Literacy Development*. Ed. by L. Verhoeven et al. Cambridge: Cambridge University Press, pp. 241–264.
- Ramanujan, Keerthi and Brenda Weeks (2019). "What is an Akshara?" In: *Handbook of Literacy in Akshara Orthography*. Ed. by R. Malatesha Joshi and Catherine McBride. Switzerland: Springer Nature, pp. 43–54.
- Uma Maheshwar Rao, G. (2006). "Analysis of the Telugu corpus: Some preliminary findings". In: *Corpus Linguistics: Study Material for Diploma in Computer Applications in Indian Languages*. Ed. by G. Uma Maheshwara Rao. Hyderabad: University of Hyderabad.
- Watson, A. B. (2012). "Perimetric complexity of binary digital images: Notes on calculation and relation to visual complexity". In: *Mathematica Journal* 14, pp. 1–41. DOI: 10.3888/tmj.14-5.
- Xiong, J., Y. Zhang, and P. Ju (2021). "The effect of orthographic neighborhood size and the influence of individual differences in linguistic skills during the recognition of Chinese words". In: *Frontiers in Psychology*. DOI: 10.3389/fpsyg.2021.727894.
- Yates, Mark, L. Locker, and G. B. Simpson (2004). "The influence of phonological neighborhood on visual word perception". In: *Psychonomic Bulletin and Review* 11, pp. 452–457.
- Zhao, J., Q-L. Li, and H-Y. Bi (2012). "The characteristics of Chinese orthographic neighborhood size effect for developing readers". In: *PLoS ONE*. DOI: 10.1371/journal.pone.0046922.

Characters, Romanization, and Anti-Colonialism: Historical Development of Taigi and Vietnamese

Paul Ueda

Abstract. When one considers the necessary ingredients for a social revolution, the written language would not always be at the top of the list. Yet, this situation can change in the circumstances where the written language itself carries a colonial legacy. Examples of this in history have been numerous as the world transitions to a post-colonial era and grapples with its aftereffects. However, these struggles do not occur in a vacuum—especially in the modern age of information. To this extent, the present paper conducts a comparative analysis of the historical and modern Romanized Taigi movement (Cockrum, 2023; Heylen, 2014; Klöter, 2005) and historically similar movements, such as the *Quốc ngữ* romanization movement of Vietnamese (Lo Bianco, 2001; Phan, 2013). This exploration reveals that the similar trajectories of colonialization experience by Vietnam and Taiwan present implications on how language activists should proceed—particularly with regards to the issue of acceptance in the language standardization process as described by Haugen (1966).

1. Introduction

Writing has always held a powerful position in society in both the definitions of the physical manifestation of words as well as referring the one's ability to record language that uses graphs. In Chinese history, an entire class of intelligentsia that held prominent status throughout history are commonly referred to by the term 'literati' (Tsien, 1962, p. 7). This term 'literati' make explicit that the most salient trait of these individuals is their ability to read the written word, as well as their ability to write, albeit to a lesser extent, as it comes from the Latin *litteratus* meaning 'one acquainted with letters.' History, law, philosophy, and even art, in the form of poetry, are all recorded with the vehicle of writing. Given the ubiquitous and powerful nature of these topics, it is not unreasonable to say the mere act of writing is powerful. Indeed, as the adage goes, "The

Paul Ueda  0000-0003-2317-8816

The Ohio State University, Department of East Asian Languages and Literatures, 398 Hagerty Hall, 1775 College Rd., Columbus, OH 43210, USA
E-mail: ueda.18@buckeyemail.osu.edu

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 469–488. <https://doi.org/10.36824/2024-graf-ueda>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

pen is mightier than the sword.” However, he controls what forms the pen writes can be said to be more powerful than either pen or sword, as their influence is cemented in such a way that most do not even notice their adherence. It is precisely this power—the control of what the written word looks like—that is the central focus of the present essay. Focusing on just the Localist Camp of Taigi, one of the three orthographic camps described by Cockrum (2022), we shall discuss the role of writing in both social revolution and sociopolitical identity construction.

For some societies, the transition to a post-colonial entity is coupled with the creation of a new nationalist identity, coupled with the construction of an *imagined community* (Anderson, 1983) that reflects the new identity that the country wishes to project. For example, Sebba (2007, p. 81) describes how Moldova, a member of the soviet bloc in the 20th century, transitioned the Moldovan writing system from Cyrillic to the Latin alphabet after gaining its independence. This transition was intended as a symbolic move of rejecting its previous soviet membership. Similarly, Schieffelin and Doucet (1994, p. 186) describe the sociolinguistic struggle between independent and colonial identities that occurred in Haiti during the standardization of Haitian Creole (Kreyòl).

In East Asia, this transition has played out differently for some societies. Due to its historical prominence, several East Asian countries—including Korea, Japan, Taiwan, and Vietnam—at one point employed Chinese characters as the primary orthography of their respective languages. Yet this relationship was not necessarily one of admiration, as in the case of Vietnam, which was colonized for a millennium by China and then for a century by France (Chiung, 2007; DeFrancis, 1977). After gaining independence in 1945, the government led by Ho Chinh Minh and his contemporaries struggled with how to reform the Vietnamese language as to “cultivate national pride” and to “re-affirm confidence in the great possibilities of the mother tongue,” as described by contemporary political figure Le Kha Ke, (cited in DeFrancis (1977, p. 246)). To this end, the Vietnamese government implemented *chữ Quốc ngữ*—a romanization system with its roots in colonial Vietnam but, to that point, had failed to gain widespread acceptance. After a period of intensive promotion, *chữ Quốc ngữ* was used widely by the population, and its promoters celebrated its ability to instill national pride, promote the national language, and to create a post-colonial Vietnamese identity (*ibid.*, p. 259).

Turning to Taiwan, the situation for Taigi is not so clear cut. Klöter (2005) describes the situation of Taigi in the 20th century succinctly as being in a state of “polyorthographia”—a language with multiple and mixed orthographies being used to represent the language. For Taigi, this is primarily defined by the usage of the Latin alphabet, Chinese characters, and even Japanese Katakana. This state is a result of the period of colonialization by the Japanese from 1845-1945, then followed by

intensive “re-China-ization” (Shih, 2021) by the Kuomintang nationalist government of the Republic of China. Repressive language policies were continuous until the end of martial law in 1987, after which Taigi served as a contested symbol of anti-colonial and anti-nationalist government policies (Khoo, 2021, p. 59). However, as Chiung (2007, p. 112) notes, this process of decolonialization is still ongoing on multiple levels in Taiwan. Today, several different groups employ Taigi as a tool for creating a local identity, including the modern democratic government. Cockrum (2023) described the sociolinguistic situation as being captured by a Three Camp Framework, in which the orthography employed by these various groups reflected their sociopolitical outlooks of Taiwan. One of these camps, the Localist Camp, is defined by its preference to use *Péb-ôe-jī*, a romanization system originating from the missionaries working in Fujian Province in southern China, and in Taiwan (Klöter, 2005, p. 90). Despite its missionary origins, this Romanized Taigi developed into a broader tool for the promotion of the Taiwanese people and society, particularly during the Japanese Colonial Period, spearheaded by activists such as Chhòa Pêh-hóe (Cai Peihuo 蔡培火; Heylen (2014, p. 53)). Even today, some language activists such as a YouTuber Ayo (Tâi-lâm muē-á kàu lí kóng tàigí [Tainan Little Sister Teaches You to Speak Taigi]) promote the adoption of *Péb-ôe-jī*, claiming that it serves as a gateway to learn other—namely western—languages (Tâi-lâm muē-á kàu lí kóng tàigí [台南妹仔教你講台語], 2020).

Given this parity between Vietnamese and Taigi, why did Vietnamese shift to a Latin alphabet while Taigi remained in an unstable state of polyorthographia (Klöter, 2005, p. 249)? For the case of Vietnamese, there was a wide social upheaval that allowed for radical departures in policy and for revolutionary concepts. Meanwhile, in Taiwan, one round of colonialism was followed by a second. The second round was not a radical upheaval, but instead a changing of policy while maintaining the same government structures that enforced colonial policies in the first place. For that reason, one could argue that Taiwan has never left the state of being colonized at all—and indeed local language activists do take such a position. While Vietnam was able to usher in a radical revolution for the vastly monolingual population, Taiwan was grappling with the identity politics and power struggle between the *benshengren* 本省人 and *waishengren* 外省人, a fundamentally fragmented understanding of the national identity.¹ While Vietnamese may be able to serve as a model for the Localist Camp language activists wishing to switch to *Péb-ôe-jī*, activists are forced to reckon with the effects of a contested identity due

1. This *bensheng* and *waisheng* distinction arose based upon the familial status during the wave of migration from China during the Chinese Civil War, which ended in 1949 with the retreat of the Nationalist Party (KMT) led by Chiang Kai-shek to the island of Taiwan.

to the perceived kinship with China. This identity conflict is navigated, in part, through these respective societies' relationship with the written language—underscoring the utility of writing for the social and historical analysis of societies.

The present paper will be organized into three primary sections. First, we will briefly discuss the linguistic and political history of China and Taiwan that has given rise to the Localist Camp and some of the sociopolitical ideological underpinnings that dictate its views. Afterwards, we will shift considerably to briefly recount the over two millennia of Vietnamese linguistic history, with particular emphasis placed on the colonial and post-colonial period. Finally, with the case of Vietnamese to serve as a point of comparison, we shall analyze some of the actors of the Localist Camp to understand how these ideologies are not novel or unique to Taiwan but are just one of the manifestations of post-colonial identity building that can be seen across East Asia.

2. From Oracle Bones to *Pê-ōe-jī*

The modern situation of written Taigi cannot be discussed without first discussing the role of Sinitic writing broadly within Chinese history. Broadly, there are four time periods that are of particular interest to the present discussion. The first is imperial China, which is from antiquity until the end of the Qing Dynasty in 1912. The second is the Republic of China (or Republican China) from 1912 until 1949. The third is the National Party Rule of Taiwan from 1949 to the end of martial law in 1987. Finally, the final time period is the ongoing democratic Taiwan. Dating back to at least as early as the middle of the second millennium B.C.E (Boltz, 1994, p. 11), the ancestor of the present Chinese script was utilized in several official purposes, with one major being divination, such as the writing found inscribed on the Oracle Bones, from which the orthography of this period derives its name (Tsien, 1962, p. 32). Later passing on to media such as clay, stone, bronze, bamboo, silk, and paper, for most of its history, writing has been a treasured part of Chinese heritage. Indeed, the form of characters still used today, known as *kaiti* 楷體, was introduced prior to the 4th Century (ibid., p. 203). Arguments over orthography date back to even the Han Dynasty, in which conflicting versions of the Confucian classics, written in different scripts known as *guwen* 古文 'old text' and *jinwen* 今文 'current text', were discovered that led to an ideological debate that still was raging as late as the Qing Dynasty (1644–1912) with the advent of the *kaozheng* 考證 school (Nylan, 1994, p. 84). While this paper does not make any claims about the applicability of the term "*guwen*" which has still faced some debate, at heart is the idea that arguments over orthography, authenticity, and authority have a long-standing tradition in the Sinosphere. It was not only the

ideas contained within the writing that were esteemed culturally. The manifestation of the writing itself, a piece of paper with written characters, were items which were to be treated with respect, as told to children with the phrase *jing xi zi zhi* 敬惜字紙 ‘pay respect to your characters and paper’ (Zhao and Baldauf, 2008, p. 34). Fishman (2002) (cited in Zhao & Baldauf) even argued that written classical Chinese had been “sanctified” and given the status of a holy vessel, as reflected by the fact that writing was considered to be given to Chinese by mythological figures, typically attributed to either *Cang Jie* 倉頡 or *Fu Xi* 伏羲 (Boltz, 1994, p. 130). Indeed, Sullivan (1999) argued for the “three perfections” that a well-trained scholar would be expected to master: painting, poetry, and calligraphy. These complementary arts were often practiced in tandem: a classical Chinese painting was not truly completed until also inscribed upon a poem with a beautiful script. Given such a mythos around writing as an artifact of culture itself, it is not hard to see how political debates surrounding national identity and language necessarily included writing as one of the primary markers.

The importance of writing to successive dynastic structures has not gone understated. Confucius argued that one essential function of the rule was to perform the “rectification of names” *zhengming* 正名 (Cao Feng [曹峰], 2016, p. 148). Later, in the Han Dynasty (206 BCE – 222 CE), Xu Shen 許慎 presented the *Shuowen Jiezi* 說文解字 ‘Explaining Graphs and Explicating Characters’ to the imperial throne in 121 (Boltz, 1994, p. 150). With this manuscript, the Han Dynasty aimed to ‘rectify’ the names and unify the language and its people. By doing so, Xu Shen provided a piece of scholarship that is still studied to this day.

However, one does not even need to turn to antiquity to see how closely the ideas of language and national identity have been interrelated in the case of Chinese. In many regards, the May Fourth Movement of Republican China (Republic of China; 1912–1949 (China), ongoing in Taiwan) was a protest of all things old and expression of dissatisfaction with the perceived weakness of China in international relations (Weng, 2018, p. 616; Tam, 2020, p. 111). As part of this protest, there was a desire to “modernize” the writing system. Instead of using the historical Classical Chinese that was unreadable to modern speakers without training, writers and linguists during this time turned to the creation of a more representative writing—what was known as *baibuwawen* 白話文 ‘plain speech text’ (Zhang, 2013, p. 565). The *baibua* in *baibuwawen* is meant to convey the message of “clear [obvious] speech,” meaning that the writing was intended to represent the way people speak. But given the diversity of China’s linguistic make-up, which speech exactly does this choice represent? Such a choice was not so clear to contemporary scholars (Tam, 2020, p. 31). Eventually, this *baibuwawen* came to resemble more closely the Mandarin style of speaking, even being established in

the 1930s as the written corollary to the widespread national language *guoyu* that was being promoted at the time (Zhang, 2013, p. 565).

Although *baibua wen* eventually won out and was established as the official writing system of Chinese in Republican China and continues to be the official writing system in the People's Republic of China (PRC) and Taiwan, the fate of Chinese characters was not so ensured at the time. During the May Fourth movement, there were prominent reformers, such as Chen Duxiu 陳獨秀 (1879-1942), who argued for the replacement of Chinese characters with the Latin alphabet (DeFrancis, 1984, p. 243). Given the intensely political milieu, it is little surprise that something that writing, being so important in the culture, became the focus of such intense heated criticism. Indeed, such an outlook on language would continue throughout the rest of the twentieth century in China with the efforts to simplify characters (Chen, 1999, p. 152) and develop a romanization system, Hanyu Pinyin, the latter of which was seen by some such as Su (2001) to be an intermediary step towards replacing the Chinese character script altogether. Indeed, there are still some scholars such as William C. Hannas who see characters as a hindrance to East Asia and believe that to progress further, they must abandon characters (for the severity of such claims, see Hannas (1997, p. 285)). In Taiwan, sociopolitical motivations for controlling script have extended to the banning of simplified Chinese script *jiantizi* 簡體字 as a method of "protecting authentic Chinese heritage" (Sui, 2011). This simplified script takes some basis in historical calligraphic forms, but the usage of these simplified characters in printed was first enforced by the People's Republic of China after the 1950's. Taiwan temporarily banned these simplified characters in order to combat the perceived communist threat. Today, China and Singapore use simplified characters. Only Taiwan and Hong Kong continue to use traditional characters, although there is some threat to this in Hong Kong due to increasing political pressure from the PRC government.

As evidenced above, writing has continued to be a sensitive topic for much of Chinese history even for the standard, or socially-dominant, written language. How, then, was it to be expected that the so-called 'dialects' of Chinese were to develop and maintain a thriving written culture? Many scholars (Liu, 2011, p. 59; Heylen, 2014, p. 187; Taylor and Taylor, 2014, p. 42) assert that these varieties either are not written at all, or if they are, are not a different writing system from standard written Chinese, but instead just include some potentially "locally flavored" graphs. In doing so, the underlying argument is that these varieties—or "dialects"—are not independent entities. They all exist under a subsumed structure of "written Chinese." If distinctly varietal Chinese is used, it used to promote a distinctly local, youthful, or counter-culture identity, such as in the case of some Shanghainese websites explored by Liu (2011, p. 65).

With some of the history behind Chinese writing explored, we can now turn more specifically to the case of Taigi. Sebba (2007, p. 32) asserts that variation in spelling/writing, from a sociolinguistics perspective, can be used to convey social meaning. However, important in this process is the comparison—what is subject to variation and what is it varying *from*. In the case of Taigi, it is important to understand that, invariably, any novel or distinct motivation to represent Taigi would be seen a variation away from Standard Written Chinese. This is why any discussion of Taigi orthographic reform must first begin from a place of understanding the process of orthographic reform that took place for the Chinese script generally.

The earliest extant example of written Southern Min, the language variety from which Taigi is derived historically, is the *Lijing ji* 荔鏡記 “The Story of the Lychee and the Mirror” dating back to 1566 (Klötter, 2005, p. 59). However, this text is not uniformly representative of Southern Min, as there were both vernacular and literary layers that would have served different communicative functions (*ibid.*, p. 60). Additionally, such performance aids were not “unmediated” recordings of the way that people spoke, as they were written and rewritten for stage plays and to be a venue for scholars to show off their literary talent (Huang et al., n.d., p. 242). Not only were these not necessarily faithful adaptations, but these sources of writing were also disparaged by public officials as being crude or harmful to public morality (Klötter, 2005, p. 59). Similarly, the Taigi songbooks *kua-á-tsheb* 歌仔冊 are not even positively identified in which variant of Southern Min they represent, despite most modern lyrics and scholarship presuming readings based on contemporary Taigi (*ibid.*, p. 74).

The previous cases of the opera script and songbooks present an interest challenge to this socially meaningful variation, as proposed by Sebba (2007). Given that socially meaningful variation exists only in relation from that which it is varying from, we must first determine to what degree the authors even saw their work as variation. Unfortunately, such a task is near impossible for the modern researcher, as many of these manuscripts are anonymous, removing any insight into the social motivations of their authors. However, given the domain of these manuscripts—specifically made for oral performance—it can be concluded that there was less interest in the written representation of Southern Min for the sake of writing it by itself. Instead, these texts are motivated to represent Southern Min due to the inherent performance-based aspect of their creation.

It is not until the period of Japanese occupation of Taiwan, 1895–1945, that we see perhaps the first efforts to write Taigi for the sake of writing Taigi. Ignored by scholars for a long time, the Romanized Taigi Movement has recently received more attention as debates have continued about the status of Taigi as an independent language (Heylen, 2014,

p. 54). While ultimately unsuccessful, the Romanized Taigi Movement was the first time that there had been even semi-widespread formal activism to establish Taigi as an independent language, and therefore with its own orthography. The lead individual behind this activism was Cai Peihuo (Chhoà Pôe-hóe 蔡培火, 1889-1983), who has been deemed the “protagonist” of this movement (Heylen, 2014, p. 53). During this time, Chhoà promoted the usage of *Péb-ôe-jī* 白話字 (hereafter, POJ), a latinized orthography based on the system of “Church Romanization” that was developed by the missionaries who were proselytizing the Southern Min speaking areas of Fujian and Taiwan (Klötter, 2005, p. 130). While not overtly religious in the promotion, Chhoà himself has been converted to Christianity, where he first learned POJ (Heylen, 2014, p. 70). In 1925, Chhoà published his manuscript *Tsáp hāng kuán kiàn* 十項管見 [My humble opinion in ten points] that expanded upon his critiques of Chinese and Japanese culture, as well as his arguments for learning Taigi and its importance in Taiwanese society (ibid., p. 75). In this manuscript, he expressed views that would become staples of Taiwanese language activists later, such that romanized Taigi was not limited to religious contexts and can represent the language in a wide variety of contexts. For Chhoà, the linguistic romanization movement was directly a part of the political movement, even insinuating that the language was part of the underlying reason that the Taiwanese people were not motivated to push for their own advancement (ibid., p. 85).

Perhaps the best way to characterize the Romanized Taigi Movement would be to see it as the Taiwanese manifestation of the May Fourth Movement that was occurring nearly simultaneously in China. Heylen (ibid., p. 53) argues that the Romanized Taigi Movement was not only influenced by the May Fourth Movement in China but was brought about by the present political situation of colonial Taiwan. As such, the ideas of progress, modernization, and reform are central themes of the Romanized Taigi Movement. In many ways, the Romanized Taigi Movement was an attempt to establish a uniquely Taiwanese identity when Taiwan was facing a cultural identity crisis (ibid., p. 93).

It is precisely due to the grassroots nature of the Romanized Taigi Movement that its solution—POJ—would end up being central to the attitudes espoused by the Localist Camp nearly a century later. Cockrum (2022) analyzed published sources of Taigi and found that there were broadly three camps in which modern written Taigi could be classified: the Modernist Camp, Localist Camp, or the Etymologist Camp. Membership in these camps was primarily determined by the manifestation of how an individual wrote Taigi. However, through the process of classification, it was discovered that it was not only the character, but the rationale behind selecting characters as well as general language attitudes that could motivate camp membership (ibid., p. 111). Of these camps, the Localist Camp are those who are most interested in the lo-

cal history and tradition of Taiwan (*ibid.*, p. 64). One mark of this camp membership is the intense political rebuke of the period of Nationalist Party (or Kuomintang; KMT) colonization that occurred after the retrocession of Taiwan back to (then Republican) China. This second period of colonization can be given the tentative dates of 1945 to the end of martial law in 1987, however, it is important to note that the process of de-colonization is something that is continually occurring in Taiwan to this day, a fact which complicates the matter of linguistic reform (Chiung, 2007, p. 112). This rejection of the colonial identity is something that is unique to the Localist Camp. Why is it the case that these political ideologies figure so prominently within the Localist Camp's linguistic assertions? Why do they not figure prominently in the Modernist or Etymologist Camps? In order to better understand the Localist Camp, it is essential to fully explore how the anti-colonial and post-colonial mentalities affect their rationale behind language usage and how it impacts their language attitudes. However, in order to do so effectively, we must first consider another post-colonial society in the Sino-sphere—Vietnam. As to be explored in the following section, understanding Vietnam's history and progression from a Chinese vassal during the dynastic times, to French colony, to independent nation will be an important point of comparison for Taiwanese studies.

3. The Case of Vietnamese and Chu Nom

Located to the south of China, Vietnam has had a complicated history with China and the Chinese language. Having a marginal, if any, position within the Sinosphere, Vietnam has often been ignored by scholars of Chinese, with only a select few, such as Chiung (*ibid.*) and DeFrancis (1977) discussing its linguistic situation in depth. For the purposes of the present discussion, John DeFrancis' (1977) investigation into the history of Vietnamese will serve as the base. DeFrancis' investigation is considered one of the seminal works on Vietnamese orthography, and is cited widely in other scholar's works, even in recent times (Lo Bianco, 2001; Chiung, 2007 amongst others). With this a base, we will now briefly explore Vietnamese linguistic history as divided into four eras: the millennium of Chinese colonialism (111 BCE – 939 CE), Monarchial Independence (939-1861), French Colonialism (1861-1945), and National Independence (1945-present).

3.1. Millennium of Chinese Colonialism (111 BCE – 939 CE)

Vietnamese is originally part of the Mon-Khmer language family, which is reflected in the fact that approximately 94% of the population is of

Mon-Khmer ethnicity (Chiung, 2003, p. 123). While a Mon-Khmer language, which is also an isolating language, Vietnamese has received significant influence from Chinese. Nguyen (1944, p. 250), cited in De-Francis (1977, p. 8), estimates that a third of all Vietnamese vocabulary has Sinitic origin, a number which increased to over 60% in the formal written context. Hence, the extent of Chinese influence on Vietnamese has been sizable. This is likely due to Vietnamese coming under Chinese control during the Han Dynasty in 111 BCE (*ibid.*, p. 10). During this period, the Chinese government imported its bureaucratic structure, including the usage of classical Chinese as the official language of governance. During this time, there was reportedly little to no literary productions that could be said to be more representative of Vietnamese than that of Chinese. However, once Chinese control ended in 939, this situation would change, although not as rapidly as one might have expected.

3.2. Monarchial Independence (939–1651)

The era of monarchial independence saw the introduction of more truly Vietnamese writing. Due to the social power and influence of Buddhism, Chinese retained a strong presence in Vietnamese society. Furthermore, with the ruling dynasty being backed by Buddhist support, Chinese remained the language of officialdom (*ibid.*, p. 14). However, by this point, scholars believe that the Chinese, when read aloud, would have been more of a “Sino-Vietnamese” reading, as it diverged from what may have been read in China (*ibid.*, p. 15). While this was occurring, in more marginal domains there was the rise of so-called “demotic writing” (*ibid.*, p. 24) which would eventually give rise to the writing system known as *Chữ Nôm* 字喃 [lit. characters for southern ‘babble’] (for graphic simplicity, we will omit the tone markings in the term *Chữ Nôm* rendering it as *Chu Nom*, or even more simply as *Nom*) which employed modified Chinese characters, as phono-semantic compounds 形聲字, to represent Vietnamese (*ibid.*, p. 28). The usage of *Chu Nom* was relegated to marginal activities, used by people such as ordinary people, relegated mandarins, and some “ultra-anti-Chinese nationalist elites” (Chiung, 2003, p. 29). *Nom* was used for “popular literature” that was aimed at the masses, such as Buddhist scripture (*ibid.*, p. 29).

However, even though *Nom* was a more locally coded language that was considered vulgar, Chiung (*ibid.*, p. 32) points out that writing in *Nom* was actually more difficult than writing in Chinese characters. Chiung argues that since *Nom* was comprised of Han Chinese characters, one must first know Chinese characters before one could read the *Nom* script. Knowledge of Chinese characters was restricted by the bureaucrats who wished to retain their power and status. Indeed, although more

aimed at the masses, that does not mean that Nom was entirely accessible in its representation of speech, nor consistent in its manner of doing so. Phan (2013, p. 21) notes that Nom can rightfully be considered a regional alternative to “literary Sinitic,” implying that it was still composed in such a manner that would have favored its usage by the erudite class. However, DeFrancis (1977, p. 46) asserts that literature composed in Nom, when read aloud, would have still been understandable by illiterate members of society, although laden heavily with classical Chinese allusions.

Nearing the end of this period, Vietnam saw an increased presence of Christian missionaries in the region. The missionaries brought with them several aspects of Western society, one of these items being the Latin alphabet (*ibid.*, p. 60). While there is some debate, creation of a romanized writing system for Vietnamese is typically attributed to the French Jesuit Alexandre de Rhodes (*ibid.*, p. 58). The usage of this new romanized system was very limited during this time, as it was primarily seen as a tool to aid other European missionaries in their efforts to speak the language of the people they were attempting to convert.

3.3. French Colonialism (1861–1945)

It was during the period of French Colonialism that there was the most diversity of languages, both spoken and written, in Vietnam. The present section will only touch on some of the broad themes of the period, and the reader is heavily urged to seek out additional information as interest provides, as the story will necessarily be simplified to a great extent here. The first topic that we shall discuss during the period of French Colonization is the continued presence of Chinese. During this period, Vietnam was divided into three different regions: Tonkin in the north, Annam in the central area, and Cochinchina in the south. Of these regions, the northern area of Tonkin was considered the stronghold of Chinese, as it still was the language used at the puppet court as well as the language used by serious scholars (*ibid.*, p. 128). However, with the promotion and rise of both French and *Quốc ngữ* (hereafter *Quốc Ngữ*, literally translated as ‘National language’), Chinese was on a steep decline by the early twentieth century. Indeed, such an end was welcomed by some, such as the lecturer Phan Chu Trinh, who delivered a lecture at the Tonkin Free School where he berated the Chinese orthography, stating that “Vietnam cannot be saved without getting rid of Chinese characters” (*ibid.*, p. 167). Nom, due to its close association with the Chinese script, declined similarly alongside Chinese. Thus, after over two millennia of intense Chinese influence on the language of Vietnam, Chinese finally was cast aside as a relic of antiquity, viewed as a Vietnamese

analogue to how western civilizations view Ancient Greek or Latin (DeFrancis, 1977, p. 205).

With the decline of characters, it is natural to ask what would rise to serve as its replacement. During the French colonial period, the answer to this question was not clear. As mentioned in the previous paragraph, there were individuals from both sides of the conflict, both colonizer and colonized, that wished to rid Vietnam of the influence of Chinese characters. However, there was significant disagreement as to what should instead take its place. From their role of a colonizer, the French desired the French language established as not only the language of education and government, but that all Vietnamese would eventually give up their own native language and instead speak the “civilized” language of French (ibid., p. 118). However, as our privileged place in history allows us to observe, such a drastic change would not come to pass, as Vietnamese remains spoken and written by the Vietnamese population today.

The real protagonist that saw a dramatic rise in popularity during this era was that of romanized Vietnamese. Introduced prior to the colonial era, romanized Vietnamese was spread alternatively by Vietnamese nationalist reformists and the French at different points in different areas, as it suited their goals (ibid., p. 79). Over time, the phrase “Quoc Ngu,” literally meaning national language, would come to be used to describe the writing system. The *Gia Dinh Bao*, a government newspaper published in the southern region of Cochinchina, provides the earliest extant record of such appellation from the 15th of April, 1865 (ibid., p. 81). Quoc Ngu was promoted as being the vehicle in which Vietnam could read modernity, knowledge, and success. As the reformist Truong Vinh Ky noted, “thanks to this writing, our poor disinherited country will be able to enter into the community of peoples and the great issues which the West has brought before the world” (ibid., p. 94). To a country, such as Vietnam, that was grappling with the questions of power, identity, and colonial structures, Quoc Ngu was seen as a tool that would allow the repressed people to finally enter the age of modernity. By the end of the colonial period, Quoc Ngu had indeed won out over its competitors, but it still had a long way to go before reaching wide usage, as only about 20% of the population was literate in Quoc Ngu by the end of the colonial era (ibid., p. 219).

3.4. National Independence (1945–Present)

By the end of the colonial period, it was becoming clear that Quoc Ngu was the forerunner to replace Chinese for widespread adoption. However, before Quoc Ngu could see widespread adoption, there were several significant barriers. One of the more fundamental issues was the perception of linguistic inferiority. After decades of French colonialism,

and millennia of Chinese influence and primacy, many were worried that the Vietnamese would have an “inferiority complex” and a “sense of rootlessness” in regards to their own language and national identity (ibid., p. 231). The reformer and political figure Le Kha Ke noted that one of the main struggles facing the Vietnamese people was to “struggle indefatigably” in opposition to this perception of inferiority and that it was essential to “cultivate national pride” and to “re-affirm confidence in the great possibilities of the mother tongue” (cited in DeFrancis (ibid., p. 246)). From Le’s statements, it is clear that there was a conflation between language and national identity. The usage of Vietnamese, in both its written and spoken modes, were seen as essential to crafting a national identity that freed Vietnam from the shackles of colonialism.

Part of the issue of this assumed linguistic inferiority was the question of how to deal with new terms in science and technology that had not yet been represented in Vietnamese. Historically, such borrowings would have come from Chinese, but there was a growing need for the ability to import names and concepts from western civilization (ibid., p. 243). While loanwords and calqueing were a possibility, Le Kha Ke, in his role on the *Section on Scientific Terminology in the Social Science Committee of Viet Nam*, argued for the creation of new terms using Vietnamese language elements such that they retain the highest degree of “national character” (ibid., p. 244).

Finally, the other main barrier facing Vietnamese and Quoc Ngu was the question of education. Such a question would be swiftly answered by Ho Chi Minh, the leader of Vietnam post-colonial period, launched an extensive literacy campaign that would see much of the population gain literacy with Quoc Ngu (ibid., p. 239). Importantly, the promotion of Quoc Ngu for many was the first writing system that they acquired—it was not so much a language shift, but instead a fight against illiteracy that allowed such rapid expansion of Quoc Ngu during this time. During one year of intensive promotion, the newly established Vietnamese government was able to achieve more than what the French colonial government had in sixty years (Buttinger, 1967, p. 349, cited in DeFrancis, 1977, p. 240).

In all, Vietnamese, and especially Quoc Ngu, was a significant tool for the reformers both in the late colonial period and in the early nation-building era of Vietnam. Ho Chin Minh and other activists saw the value of Quoc Ngu as a tool to instill national pride, promote the national language, and to create a post-colonial Vietnamese identity (ibid., p. 259). With this abbreviated background, our attention will now return to Taigi, as we compare the situations that have led to different outcomes.

4. Taigi Revisited—Positioning the Localist Camp

The case of Taiwan surprisingly has a lot of common ground with the history of Quoc Ngu and Vietnamese. Like Quoc Ngu, Pê-ōe-jī was adapted from a missionary script. In both cases, the usage of this missionary script extended past the domain of the Christian church as it was adapted and promoted by revolutionaries, such as the Tonkin Free School in Vietnam and Chhoà Pêe-hóe in Taiwan, who were struggling for a distinct national identity against their respective colonial governments.

In fact, upon closer examination, many of the arguments made by both the Vietnamese revolutionaries and those promoting Pê-ōe-jī in Taiwan would use similar arguments. We shall briefly address three of such arguments here. One such argument is that the romanized system would allow the population to interact with more of the, presumably western, world. During the colonial era, French government officials wrote how the promotion of Quoc Ngu would offer “great convenience” in switching the population from Vietnamese to French (DeFrancis, 1977, p. 129). Similarly, Taigi language activist Aiong Taigi (2020) argues that Pê-ōe-jī is the more intuitive choice for representing Taigi as the majority of the world’s languages are phonographic, so such a choice is more rational for representing Taigi. Similarly, the YouTube channel Tâi-lâm muē-á kàu lí kóng tâigí 台南妹仔教你講台語 [Tainan Little Sister Teaches You To Speak Taigi] host Ayo also states that learning POJ would be helpful for learning other languages, such as English, stating that “*òb lô-má-jī tui òb kî-thann phing-im bē thóng ê gí-giân koh ù tsiok tuā ê pang-tso̍*” 學羅馬字對學其他拼音系統的語言閣有足大的幫助 [Studying romanization has a lot of benefits when it comes to studying other languages that make use of a phonetic character system] (Tâi-lâm muē-á kàu lí kóng tâigí [台南妹仔教你講台語], 2020).

Similarly, both languages are having to face issues of perceived linguistic inferiority. Ayo, in the same video, talks about how when the Nationalist Kuomintang (KMT) came to Taiwan, their main purposes was to “brainwash” everyone into believing that they were also part of this Chinese identity. As such, part of the brainwashing effort was to make everyone believe that Taigi was inferior and did not possess prestige (ibid.). Below is the original Taigi as well as a Mandarin translation, both provided by the video creator, and English translation by this author follows:

國民黨來台灣共咱殖民統治的時陣為著欲共逐家洗腦，一直欲予逐家感覺講
「喔～咱逐家攏是中國人」咱「兩岸一家親」按呢。咱若欲做中國人著愛講北京話啊閣用
罰錢的這個步數來打壓咱的母語予咱感覺「喔～～～咱講家己的母語足無水準」

國民黨來台灣把我們殖民統治的時候為了要洗腦大家，一直要讓大家覺得
「喔～我們大家都是中國人」我們『兩岸一家親』」這樣。我們如果要當中國人就要講北

京話。還用罰錢的這招來打壓我們的母語，讓我們覺得「喔～～
～～我們講自己的母語很沒水準」 (5:52)²

For both situations, promotion of the language in all contexts, included academic, was seen as important aspect of promoting a national identity. For Taigi, its exclusion in these realms contributed to its decline in social status.

Finally, in both contexts, there was an attempt to escape the influence of the colonizer. As addressed in the section detailing Vietnamese history, the promotion of Quoc Ngu was seen as a tool to create a national identity that was entirely focused on the Vietnamese identity. It was seen to throw off the legacy of French colonialism. When discussing the Taigi case, Localist Camp activist A-hoa 阿華 make a very similar argument, as seen in the quote below (Tsiok ing tâi sann siann tō pōng bí phang [足英台三聲道磅米芳], 2021; translation and emphasis mine):

咱知影「Tâi-gí是毋是閩南語」chit題tiō是愛hō所有講Tâi-gí人同齊來決定
nā毋是講Tâi-gí ê人袂用得參加chit題ê討論³

In A-hoa's statement, we can see that there is a distinct desire that Taiwanese themselves have the first say in the identity labels that are used to discuss them. More importantly, as also described by Ayo in her video, there is a rejection of the Southern Min label. Both videos claim that this label of Southern Min was an invention of the Kuomintang brought over in the 1950s in their efforts to subdue the Taiwanese and bring them into a pan-Chinese identity. As such, their rejection of this term is not only a rejection of the label, but also a rejection of the colonial identity. For these speakers, the colonial structure suppressing Taiwanese never actually changed with the end of martial law, it just took a new form in the current government. As pointed out by Klöter (2005, p. 195), this link between ideology and orthography has not gone entirely unnoticed.

Given this comparison between Vietnamese and Taigi, what can we conclude about why Vietnamese shifted to a Latin alphabet while Taigi remained in an unstable state of polyorthographia (ibid., p. 249)? While the colonial periods showed many similarities in situation between the two languages and their speakers, it is what has happened post-colonialization that perhaps has had the biggest impact in the different

2. When the Nationalist Party (KMT) came to Taiwan to colonize us, in order to brainwash everyone, they would continually force everyone to think "oh, we are all Chinese," we are "two straits, one family" and stuff like that. If we want to be Chinese people, we must speak the speech of Beijing. They also used fines and penalties to suppress our mother tongue, and make us think "oh, we are really unrefined when we speak our mother tongue."

3. We know the question of "is Taigi actually Southern Min?" is only for those who speak Taiwanese to decide together. **Those who don't speak Taigi do not have the place** to join in the conversation about this question. (7:57)

outcomes. For the case of Vietnamese, there was a wide social upheaval that allowed for radical departures in policy and for revolutionary concepts. Meanwhile, in Taiwan, one round of colonialism was followed by a second. The second round was not a radical upheaval, but instead a changing of policy while maintaining the same government structures that enforced colonial policies in the first place. For that reason, one could argue that Taiwan has never left the state of being colonized at all—and indeed local language activists do take such a position as illustrated above. The fact that Taiwan has continued to become more dominant in Mandarin has made it more difficult for the political ideals espoused by the Localist Camp to materialize.

In summary, while there are many points of comparison to be made between the Vietnamese and the Taigi situations, the period after colonization changed the trajectory of promotion of the indigenous language. While Vietnam was able to usher in a radical revolution for the vastly monolingual population, Taiwan was grappling with the identity politics and power struggle between the *benshengren* 本省人 and *waishengren* 外省人, fundamentally unable to agree on if they were Chinese or Taiwanese to begin with. While Vietnamese may be able to serve as a model for the Localist Camp language activists wishing to switch entirely to Pê-ōe-jī, they are forced to reckon with the aftereffects of a fragmented identity due to their perceived kinship with China.

5. Conclusion

The story of Taigi is not yet fully written. The past two decades have shown important milestones in a shift towards the revitalization of Taigi in modern society. However, there remain many questions about what that Taiwanese society looks like and how should Taigi be written to begin with. From the perspective of Chinese history, the issues surrounding Taigi at present are not new. There has been a fundamental connection between the written language and identity. Indeed, such a connection, amongst other factors, has allowed for the existence of such diverse varieties of Chinese that, due to the perception that they share a written form, are only dialects of a larger language Chinese. The issue that Taigi should identify its status so strongly as it relates to its written form is merely the modern continuation of what could be seen as an over 2000-year-old tradition.

It is precisely this association with Chinese tradition that the Localist camp wishes to sever. One of the original questions posed at the outset of this essay is why does the colonial mentality seemingly serve as a fundamental concern for the Localist Camp, while it is hardly, if at all, addressed in the other camps? Even more specifically, why does there seem to be so much more resentment towards specifically the colonial ef-

fects of the Kuomintang rather than the Japanese? The comparison with Vietnamese should offer some insights. While colonized by France and Japan, both Vietnam and Taiwan respectively were in the throes of an identity crisis—attempting to determine what it meant to hold their national identity. Vietnam exited this period of colonization with a complete overhaul of society that instilled pride in their national identity. On the other hand, Taiwan went directly into a second period of colonization, one that can be argued to still be ongoing today. In this round, the effects of colonization were much more intense and reached broader success than that of either the French or Japanese governments. As the vast majority of Taiwan is dominant in Mandarin, the question of what it means to be Taiwanese and to speak Taigi has, to some degree, slipped away. Those remaining and fighting for the local identity have to fight against this assimilationist ideology. For them, Taigi refers only to what it was prior to this colonization. The Mandarin influence of the KMT has only rendered the language “impure” or “weak.”

In summary, the Localist Camp focus on fighting against the concepts of colonization so strongly because it is precisely the issue that they see as most important facing the vitality of Taigi. They do not wish to identify with their colonizer, and they do not believe that colonization ever really ended. For the Modernist Camp, there is a degree of acceptance of this colonial identity, although they believe such an era to be in the past. They can safely accept the modern situation as simply the most pragmatic option and aim to create a language that reflects all shared experiences. On the other hand, the Etymologist Camp deepens this colonial association, as they wish to use classical Chinese etymology to determine what modern Taigi should look like. For the Localist Camp, Vietnam can serve as an exemplar of what it truly means to reach a post-colonial state. For the Localist Camp, if Vietnam was able to shed Chinese characters, and therefore their association with China, why should Taiwan not be able to do the same?

The case of the Localist Camp highlights the importance of viewing the history and present situation of Taigi through the lens of post-colonialism. The arguments for the linguistic movement, just as Chhòa Pôe-hôe argued back in the 1930s, are inexorably intertwined with the political. An analysis that does not understand the political views of each camp would fail to understand their rationale for their proposals.

More broadly speaking, the case of Taigi provides a detailed example for the world on the intricate issues of language, society, and nationalism. While Anderson's (1983) “imagined communities” may have existed in the imagination, writing is encountered daily in a very real way. Given such a political nature in the mundane, it is no surprise that the question of how to write Taigi becomes such a heated issue. In Einar Haugen's original formulation on the process for standardization language, he placed equal emphasis on the acceptance of the selected and codified

variety by the community. When the very nature of the community is cause for debate—as well as grappling with a post-colonial identity, the contemporary contested status of Taigi becomes less surprising. Individuals are not just arguing for orthography, but they are also arguing for identity.

References

- Anderson, Benedict (1983). *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. New York: Verso.
- Boltz, William G. (1994). *The Origin and Early Development of the Chinese Writing System*. New Haven, CN: American Oriental Society.
- Buttinger, Joseph (1967). *Vietnam, a Dragon Embattled*. New York: Praeger.
- Cao Feng [曹峰] (2016). “A New Examination of Confucius’ Rectification of Names”. In: *Journal of Chinese Humanities* 2, pp. 147–171.
- Chen, Ping (1999). *Modern Chinese: History and Sociolinguistics*. Cambridge, UK: Cambridge University Press.
- Chung, Wi-vun Taiffalo (2003). “Learning Efficiencies for Different Orthographies: A Comparative Study of Han Characters and Vietnamese Romanization”. PhD thesis. Arlington, TX: The University of Texas at Arlington.
- (2007). “Language, Literacy, and Nationalism: Taiwan’s Orthographic Transition from the Perspective of Han Sphere”. In: *Journal of Multilingual and Multicultural Development* 28.2, pp. 102–116.
- Cockrum, Paul (2022). “Taiwanese Southern Min: Identity and Written Sociolinguistic Variation”. MA thesis. Columbus, OH: The Ohio State University.
- (2023). “Reanalyzing Variation in Written Taiwanese Southern Min: Proposing a Three Camp Framework”. In: *Buckeye East Asian Linguistics*. Ed. by Mineharu Nakayama, Marjorie K. M. Chan, and Zhiguo Xie. Vol. 6. Columbus, OH: Knowledge Bank, OSU Libraries, pp. 15–33.
- DeFrancis, John (1977). *Colonialism and Language Policy in Viet Nam*. The Hague: Mouton.
- (1984). *The Chinese Language: Fact and Fantasy*. Honolulu: University of Hawai’i Press.
- Fishman, Joshua F. (2002). “‘Holy Languages’ in the Context of Social Bilingualism”. In: *Opportunities and Challenges of Bilingualism*. Ed. by Li Wei, Jean-Marc Dewaele, and Alex Housen. Berlin/New York: Mouton de Gruyter, pp. 15–24.
- Hannas, William C. (1997). *Asia’s Orthographic Dilemma*. Honolulu: University of Hawai’i Press.
- Haugen, Einar (1966). “Dialect, Language, Nation”. In: *American Anthropologist* 68.4, pp. 922–935.

- Heylen, Ann (2014). *Japanese Models, Chinese Culture and the Dilemma of Taiwanese Language Reform*. Wiesbaden: Harrassowitz Verlag.
- Huang, Chu-ren et al. (n.d.). "Chinese Language Arts: The Role of Language and Linguistic Devices in Literary and Artistic Expressions". In: *The Routledge Handbook of Chinese Applied Linguistics*. Ed. by Chu-ren Huang, Zhuo Jing-Schmidt, and Barbara Meisterernst. New York: Routledge, pp. 237–255.
- Khoo, Hui-lu (2021). "Emerging Taiwanese Identity, Endangered Taiwanese Language: The Never-Matched National Identity and Language in Taiwan". In: *Taiwan: Manipulation of Ideology and Struggle for Identity*. Ed. by Chris Shei. New York: Routledge, pp. 55–74.
- Klötter, Henning (2005). *Written Taiwanese*. Wiesbaden: Harrassowitz Verlag.
- Liu, Jin (2011). "Deviant Writing and Youth Identity: Representation of Dialects with Chinese Characters on the Internet". In: *Chinese Language and Discourse 2.1*, pp. 58–79.
- Lo Bianco, Joseph (2001). "Viet Nam: Quoc Ngu, Colonialism, and Language Policy". In: *Language Planning and Policy: East Asian Perspectives*. Ed. by Nanette Gottlieb and Ping Chen. Richmond, Surrey: Curzon Press, pp. 159–206.
- Nguyen, Van Huyen (1944). *La Civilisation annamite*. Hanoi: École d'Extrême-Orient.
- Nylan, Michael (1994). "The *chin wen/ku wen* Controversy in Han Times". In: *T'oung Pao* 80.1, pp. 83–145.
- Phan, John (2013). "Chữ Nôm and the Taming of the South: A Bilingual Defense for Vernacular Writing in the *Chi Nam Ngọc Âm Giải Nghĩa*". In: *Journal of Vietnamese Studies* 8.1, pp. 1–33.
- Schieffelin, Bambi B. and Rachele Charlier Doucet (1994). "The "Real" Haitian Creole: Ideology, Metalinguistics, and Orthographic Choice". In: *American Ethnologist* 21.1, pp. 176–200.
- Sebba, Mark (2007). *Spelling and Society*. Cambridge, UK: Cambridge University Press.
- Shih, Fang-long (2021). "Taiwan's Culture Wars from "Re-China-ization" to "Taiwan-ization" and Beyond: President Tsai Ing-wen's Cultural Policy in Long-term Perspective". In: *Taiwan in the Era of Tsai Ing-wen: Changes and Challenges*. Ed. by June Teufel Dreyer and Jacques deLisle. New York: Routledge, pp. 284–311.
- Su, Peicheng (2001). "Digraphia: A Strategy for Chinese Characters for the Twenty-First Century". In: *International Journal of Society and Language* 150, pp. 109–124.
- Sui, Cindy (2011). *Taiwan Deletes Simplified Chinese from Official Sites*. BBC News. URL: <https://www.bbc.com/news/world-asia-pacific-13795301>.
- Sullivan, Michael (1999). *The Three Perfections: Chinese Painting, Poetry, and Calligraphy*. New York: George Braziller.

- Tâi-lâm muē-á kàu lí kóng tâigí [台南妹仔教你講台語] (2020). 【台語的迷思】台語為什麼不叫閩南語？學台語的重要性是啥？ | 台南妹仔教你講台語 [EPO Taiwanese Myths. Why is Taiwanese not called Southern Min? What are the important parts of studying Taiwanese? | Tainan Little Sister Teaches You to Speak Taiwanese]. YouTube. URL: <https://www.youtube.com/watch?v=vFjSqu8HLpI>.
- Taigi, Aiong [阿勇台語] (2020). 阿勇，汝是安盞無塊用漢字？ [Aiong, why do you not use Chinese characters?] YouTube. URL: <https://www.youtube.com/watch?v=MU8jtiiJ4QA>.
- Tam, Gina Anne (2020). *Dialect and Nationalism in China, 1860–1960*. Cambridge, UK: Cambridge University Press.
- Taylor, Insup and M. Martin Taylor (2014). *Writing and Literacy in Chinese, Korean, and Japanese: Revised Edition*. Amsterdam: John Benjamins Publishing Company.
- Tsien, Tsuen-Hsuei (1962). *Written on Bamboo & Silk: The Beginning of Chinese Books and Inscriptions*. Chicago: University of Chicago Press.
- Tsiok ing tâi sann siann tō pōng bí phang [足英台三聲道磅米芳] (2021). 我按怎看「Tâi-gí是毋是閩南語」 [How I see “is Taiwanese Southern Min?”] YouTube. URL: <https://www.youtube.com/watch?v=XgnUCI6k0SA>.
- Weng, Jeffrey (2018). “What is Mandarin? The Social Project of Language Standardization in Early Republican China”. In: *The Journal of Asian Studies* 77.3, pp. 611–633.
- Zhang, Qing (2013). “Language Policy and Ideology”. In: *The Oxford Handbook of Sociolinguistics*. Ed. by Robert Bayley, Richard Cameron, and Ceil Lucas. Oxford, UK: Oxford University Press, pp. 563–586.
- Zhao, Shouhui and Richard B. Baldauf Jr. (2008). *Planning Chinese Characters: Reaction, Evolution or Revolution?* Dordrecht: Springer.

Towards Reading in Four Dimensions

Helen Magowan

Abstract. Writing is implicitly four-dimensional, the outcome of an act that takes place in time and space. However, in East Asian brush writing, time and space are not only explicit but meaning-bearing. The clear expression of four-dimensionality made brush writing a medium which communicated not only language, but also the embodied writer. This paper proposes that in the premodern Japanese context, writing was a powerful mode for communicating social meanings associated with the body, meanings which contemporary reading practices overlook.

1. Introduction

As Amalia Gnanadesikan (2008, p. 3) has pointed out, speech unfolds in time, while writing arranges language in space, “each word following the previous one in a line. Writing is therefore a process of translating time into space”. We may of think this spatial transformation as rendering a 2-dimensional artifact: there is ink, or there is not. At the same time, in (non-automated) writing production, the writing instrument moves in three dimensions: the pen nib or pencil tip rises upwards at the end of a line or graphic element, and moves down into contact with the paper at the beginning of the next. The spatial arrangement of (hand)writing, with its beginnings and ends, thus notionally indicates the third dimension of space and the fourth dimension of time.

In East Asia, however, the traditional instrument of writing is the brush, and control in all four dimensions is needed to achieve competence (Ishikawa, 1994, p. 36; Kaya, 2002, p. 45). The four-dimensionality of writing production is therefore not only explicit, but meaning-bearing in the resulting text. Indeed, this paper proposes that four-dimensionality was an integral aspect of the signifying power of brush

This work was supported by the Arts and Humanities Research Council through the Open-Oxford-Cambridge DTP [ref. AH/R012709/1].

Helen Magowan  0000-0002-9571-6225
E-mail: hlm65@cam.ac.uk

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 489–506. <https://doi.org/10.36824/2024-graf-mago>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

writing. This paper focuses on the writing culture of 18th century Japan to show premodern Japanese brush writing to have been a powerful medium for communicating not only language, but embodiment and associated social meanings, and asks whether such meanings can be accessed by contemporary readers, unaccustomed to the tactics of reading in four dimensions.

2. Writing in Print

As the 19th century turned into the 20th, Japan saw huge socio-cultural and technological changes, which had implications for the writing system. One of these was the introduction of pencils and pens; the more culturally visible change was the transition to moveable type for commercial publishing. Japan's well-established publishing industry had been thriving for some three hundred years, using woodblock print technology.

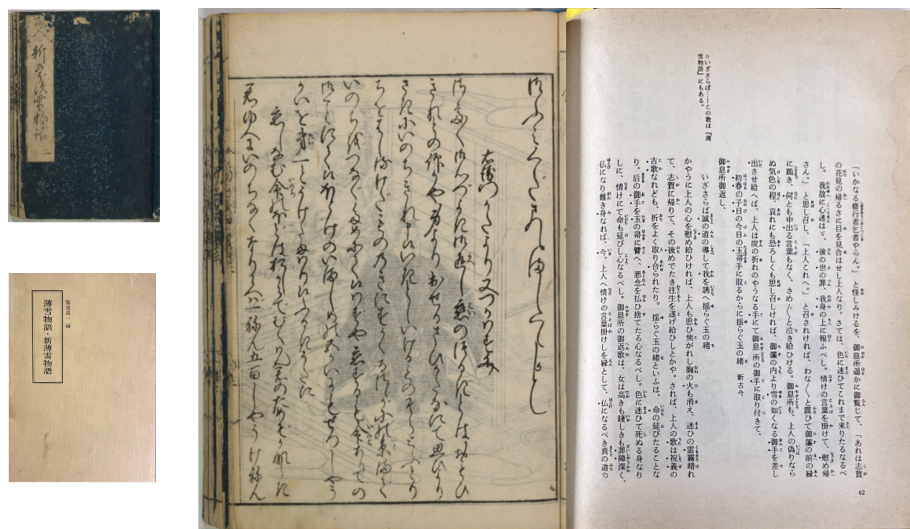


FIG. 1. Woodblock print and typography compared. Left, top, Rankeishi, *Shin Usuyuki monogatari* ('New Tale of Usuyuki'), Osaka, Japan: Kawachiya Tōbei, 1716. Right, bottom, Kikuchi Shin'ichi, ed., *Usuyuki monogatari. Shin Usuyuki monogatari*, Osaka, Japan: Izumi Shoin, 1983

Japanese printers had in fact briefly explored moveable type at the end of the 16th century, and the experiment itself is telling. Figure 2 shows one of the most celebrated of the early moveable type books

known as Saga editions.¹ It is not immediately apparent, perhaps, that this book was typographically produced, as it maintains all the characteristics of handwriting.² Indeed it was the product of collaboration with one of the most extraordinary calligraphers of the day.³

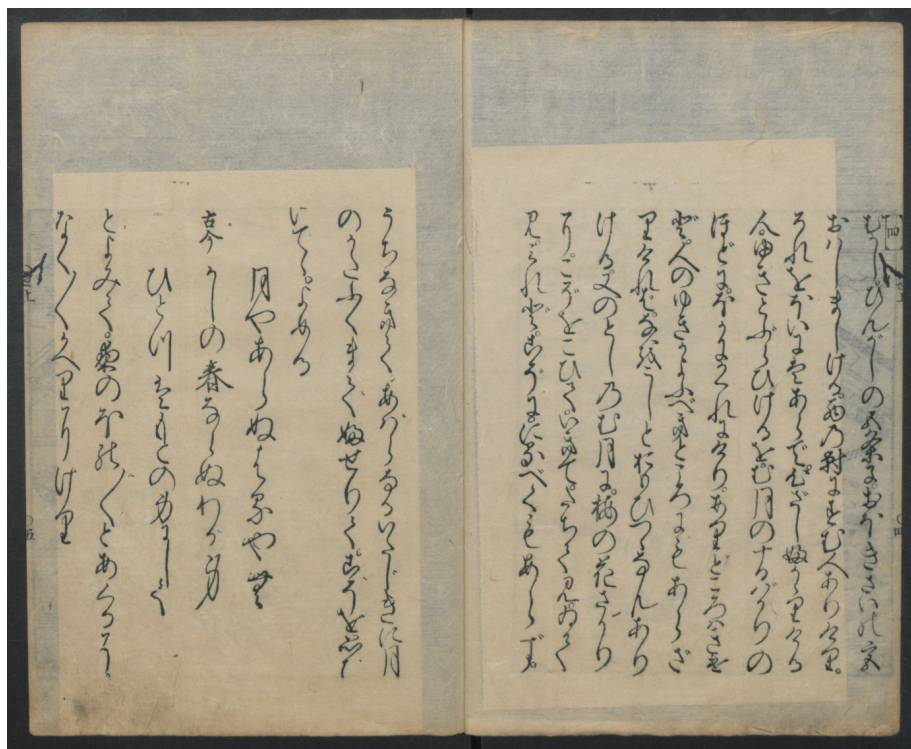


FIG. 2. Saga Edition of *The Tales of Ise*, c. 1608, The Metropolitan Museum of Art, New York

Each piece of type is irregularly sized, accommodating vertically extended, encroaching, and connecting graphemes, with ligatures of up to four graphemes.

1. Also Sagabon 嵯峨本, lit. Saga books, a generic term for a series of books published 1599–c. 1610 by Suminokura Soan 角倉素庵 (1571–1632) in Saga, near Kyoto.

2. The size and page design of these books was also in imitation of manuscripts (Sasaki, 2023, p. 195). Movable type in the West also initially used fonts cast imitating cursive handwriting (Sasaki and Burtscher, 2022, p. 61).

3. Hon'ami Kōetsu 本阿弥光悦 (1558–1637).

This flies in the face of the modular efficiency that moveable type should enable, but in contrast to the regularity and consistency preferred by western scribal and calligraphic practices, premodern Japanese privileged variation.⁴ It was a highly flexible writing system that avoided visual repetition through orthographic choices including allographs and varied cursivity. Typography was evidently a poor fit for Japanese writing. This incompatibility was not merely a matter of aesthetics, but as we shall see, the brush was a conduit for the expressivity of writing, which could not be recapitulated through modular type. A high-fidelity relationship to the manuscript original was required.⁵

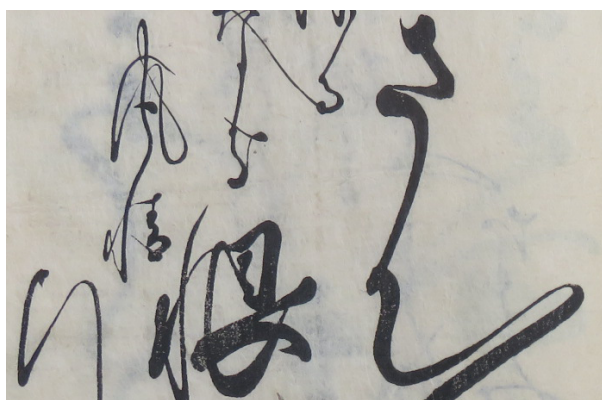


FIG. 3. Detail from Hasegawa Myōtei, *Sazareishi*, vol. 1 f. 9r, 1713

Woodblock print produces a facsimile of a full original page by carving a negative relief. This offers total flexibility in terms of layout, illustrations and textual forms, including degrees of cursivity; crucially, the marks of the brush were remediated with an extraordinary degree of detail (Figure 3). The choice of woodblock technology maintained the brush as integral to the written word.

This paper will first discuss the mechanics of brush writing, and then consider the contribution of the brush to the construction of meaning in writing.

4. Sagabon even show intentional differentiation between printed copies, with several types changed after each sheet was printed so that no two sheets were identical. (Sasaki, 2023, p. 204)

5. While in English there is an ontological difference between ‘manuscript’ and ‘print’, this does not obtain in a premodern Japanese context. See Chance and Davis (2016, pp. 92–94, 106).

3. Brush Writing in Four Dimensions

3.1. The Third Dimension



FIG. 4. Numeral 'one'. By kind permission of Yuasa Keisuke 湯浅圭祐 of Matsumoto Shōeidō 松本松栄堂 calligraphy school.

The beginner calligrapher's first word is likely to be the simplest of Sinitic graphemes, the numeral one, produced by inscribing a horizontal line. However, not all single horizontal lines are this numeral; although apparently simple, the stroke is somewhat involved, and difficult to execute well, as Figure 4, from a modern calligrapher, shows.

There are three highly specific instructions towards correctly forming the character. What is unstated, perhaps because it is aimed at those who are already brush users, is that the beginnings and ends of the grapheme are formed by pressing into the paper, while during the movement from left to right the brush is lifted slightly.⁶ Figure 5 shows the extreme flexibility of the calligraphy brush, and since it is highly sensitive to pressure, the 'depth' of the brush at different points is fundamental to the formation of the strokes and graphemes of Sinitic and Japanese scripts (here the stroke being formed is 'barai').

The third dimension also extends into space perpendicularly above the paper. In Japanese calligraphy the term *kyokaku* (虚画 'empty' stroke) is used for the line travelled by the brush through the air (Figure 6). This is not a ritual formalism: although the page only holds 2-dimensional marks, the connecting 'empty' stroke is visible to those trained in the brush.

6. In pen writing, width has traditionally been controlled through the angle of a flat-ended nib, not vertical pressure. Certain calligraphy styles today control line width through the application of pressure using a flexible nib, the result of a mid-19th century innovation to achieve results that had previously been produced by the flat nib. (Gilderdale, 1999)



FIG. 5. The qualities of the calligraphy brush are integral to the shape of strokes. Here the stroke called *barai* is being formed.



FIG. 6. 'Eternity', showing *kyokaku*, the 'empty' line. Image by kind permission of the Bimoji Blog 美文字ブログ

3.2. The Fourth Dimension

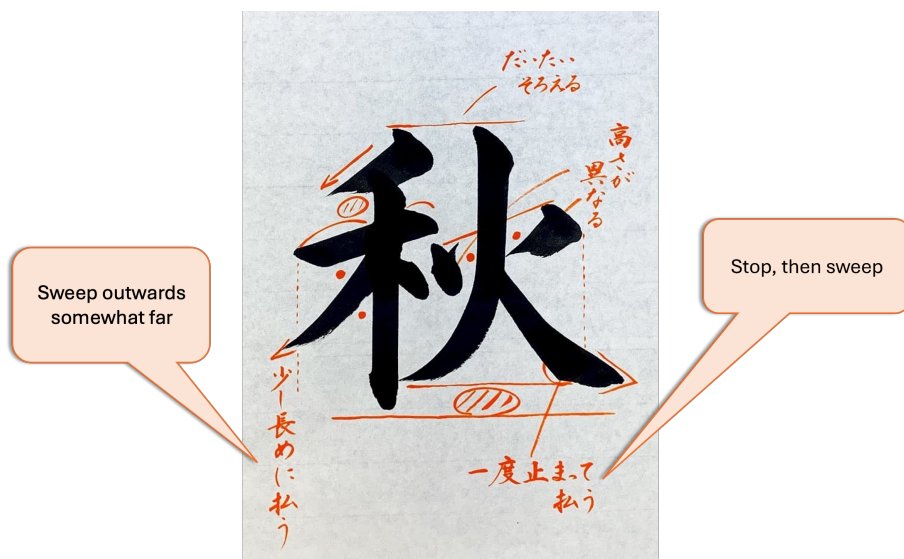


FIG. 7. 'Autumn', Image by kind permission of Yuasa Keisuke, Matsumoto Shōeidō Calligraphy School

While time is implicit in handwriting, it is explicit in brush calligraphy. Figure 7 shows the grapheme for 'autumn', and the calligraphy teacher's instructions include not only the verb of motion *harau* (払う 'to sweep', 'to brush') but a further instruction on pausing before the sweep-

ing motion. The line of ink indicates the speed of the brush's motion as it passes, a factor which is even more prominent in cursive styles.⁷ The variable rhythmicity of brush calligraphy no doubt contributes to its modern status as a performance art.

An intrinsic four-dimensionality of script is particularly clear in media other than paper and ink. Highly valued ancient calligraphy has been preserved through stone carvings, and words carved into stone or wood express the four dimensions of the notional brush: where the brush would press into the paper, the letterform is carved deeper, and where the brush would skim quickly, the carved line is shallower. Whatever the medium, the brush was implicit in the written form (Ishikawa 1994, p. 37).⁸

4. Writing in Four Dimensions

Figure 8 shows a writing lesson in the 18th century, giving us a rounded picture of the practice of (cursive) writing.⁹ The image shows two girl students. The writing girl holds her brush very near the top of the handle, a position which is not common today, but predominates in early modern imagery, particularly when depicting women. The modern lower brush hold may be partly influenced by modern writing tools such as pens and pencils.

The second girl is actively participating in the lesson through observation. As Japanese writing is explicit in that its production takes place in time and space, real-time observation is extremely valuable for learning.

There is a calligraphy model book on the desk, but the girl's copy paper is covered with black scribbles, a sign of repeated overwriting. While there is an economy of paper involved in this practice, what this also indicates is that the intention is not, as we might assume, to make the correct shape on the page. The 2-dimensional line on paper is not the object of the lesson: rather, she is learning to make the correct movement with her body, and the correct movement will produce good lines. Unlike manipulation of the pencil, dominated by the fingers, brushed Japanese

7. Figures shown thus far are of the non-cursive style called *kaisbo* 楷書 (*kāisbū* in Chinese). This is typically called 'standard' or 'regular' script, a somewhat misleading term since in Japan this was used in limited contexts. Today *kaisbo* is taught before cursive, and the images here are beginner-oriented materials.

8. Ishikawa considers there to be a distinct difference between carved and brushed character forms in early Chinese contexts, but I set this aside for the present paper.

9. In early modern Japan, cursive styles were preferred for most contexts. While there are two named cursive styles, *gyōsho* 行書 (*xíngshū*) and *sōsho* 草書 (*cǎoshū*), in Japanese practice they were not strictly differentiated.



FIG. 8. *Wisdom* (Chi), Suzuki Harunobu, 1767, The Museum of Fine Arts, Boston

graphemes are gestures of the body, including the hand, wrist, arm, indeed the whole body—note that the only part of the girl's body in contact with the desk is her non-writing hand. Writing on the page will show if the brush is gripped tightly, or the elbow is held too close to the torso. Controlled but free movement is made possible by an upright posture, appropriately supported from the core. Execution of good writing even depends on the writer's breath.

That writing is a skill of the body is reemphasised by the teacher's holding the student's writing hand (and perhaps her waist). The teacher, like her modern counterparts, does this in order to transmit all four dimensions of writing through the embodied experience of writing, teacher to student, body to body.

5. Writing and Reading and the Body

While the early modern period saw literacy forcefully advocated for all classes of people, the discourse is on writing, not reading. While in English, we speak of children learning to read and write, visitors to early modern Japan observed the reverse: in Japan, *writing preceded reading*.¹⁰ A 17th century book concerning women's education says,

From a tender age, girls must be forced to write. First, if they are not able to write letters, they will miss out on all sorts of things. Moreover, the inability to write means that one is stupid and unable to distinguish the west from the east. **For a woman who cannot write, turning to books is like a blind person turning to a wall** [my emphasis].¹¹

Being unable to write renders one unable to read. Similarly a 17th century male diarist wrote,

Writing should be the first accomplishment for a man. Even good-looking men will be looked down upon if they have no writing [*mubitsu* 'without the brush'] or bad writing [*akubitsu* 'bad brush'] skills. **Those who cannot write are not able to send and receive letters** and are barred from keeping diaries or account books [my emphasis].¹²

The term for illiteracy here refers to the very instrument of writing; furthermore writing skill was necessary to be able to merely receive letters. This was a culture in which reading literacy originated in writing. Reading was not disconnected from brush competence, but on the contrary, was intimately entangled.¹³

Learning to write involved copying graphemes, and then longer texts, and it was widely recommended that even very young children should

10. In 1585 the Portuguese Jesuit Luís Fróis (1532–1597) “observed a pattern of instruction that set Japanese education apart from practices in the West—that is, Japanese children learned to write before reading, whereas Western children practiced the reverse.” (Moretti, 2020, 307 n. 14)

11. *Onna kagami bidensho* (Secret book on ideals for women, 1650), quoted in Moretti (ibid., pp. 29–30).

12. *Kawachiya Yoshimasa kyūki* (Old records of Kawachiya Yoshimasa, c 1693–1706), quoted in Moretti (ibid., p. 32).

13. It is instructive also that copying—which is, in effect, writing—was an accepted method of consuming text in the early modern period, and remains in some contexts even today. The early modern publishing genre *ōraimono narabi ni tehon* (textbooks and copybooks) signals the widespread duality of reading and copying. Kaibara Ekiken's *Wazoku dōjikin* (1710), a guide for parents on the education of children, was given to unmarried women as a copybook, and copying was the route by which children were educated in moral and practical matters. (Koizumi, 2007, p. 42; Dore, 1965, p. 275) Today, publishing series such as *Enpitsu de tanoshimu koten* (Enjoying the Classics via Pencil) offer the opportunity to consume classical texts in an act which is both reading and copying, whilst improving one's handwriting. See for example Ōsako (2012).

be taught from good models from the very beginning. In copying a calligraphic model, one is learning to write words well through tracing the four-dimensional gestures of writing. Much like dance, or martial arts, one must learn to move one's body in the appropriate manner.

Indeed, educators explicitly recommended the simultaneous development of literacy and bodily deportment. Kaibara Ekiken, perhaps the most well-known educationalist of the period, itinerises children's training by age, with calligraphic training outlined contiguously with movement of the body and morality.¹⁴ Starting at the age of six or seven they should learn kana, respect and differences of social status, and they should copy kana texts. From eight, [male] children should learn both 'standard' (*kaisbo*) and cursive (*sōsho*) scripts, starting with large letter-forms so that the hand learns to move easily. This is also the moment to introduce the practice of reading words [*moji wo yomu keiko*], and memorisation of easier passages of Chinese classical texts, alongside etiquette, deportment (立ち居振る舞いの礼 *tachi-i furumai no rei*, 'manners of standing, sitting and actions'), and 'manners of tea' (茶礼 *sarei*). At the age of ten they should read the classical Chinese texts, and learn the literary and military arts (文武の技芸 *bunbu no gigei*), and their minds (*kokoro*) and deportment (*tachi-i furumai*) should be quiet and restrained. At fifteen, they should be fully learning their duty and self-management (*mi wo osameru*, a phrase which uses the word 'body' for the self).¹⁵

Writing is presented as one aspect of a holistic process of enculturing the body, a process discussed by sociologist Pierre Bourdieu in terms of *hexis*. He says,

The child imitates not "models" but other people's actions. Body *hexis* speaks directly to the motor function, in the form of a pattern of postures that is both individual and systematic, because linked to a whole system of techniques involving the body and tools, and charged with a host of social meanings and values: in all societies, children are particularly attentive to the gestures and postures which, in their eyes, express everything that goes to make an accomplished adult—a way of walking, a tilt of the head, facial expressions, ways of sitting and of using implements, always associated with a tone of voice, a style of speech, and (how could it be otherwise?) a certain subjective experience. (Bourdieu, 1977, p. 87)

The development of writing skills can be seen to contribute to the enculturation of appropriate *hexis*, and furthermore, writing may in itself express *hexis*.

English has a relative paucity of words for 'writing', and although the range of terms used in Japanese is illuminating, here I draw attention

14. In *Wazoku dōjikin* (Teaching on Children's Education Traditions in Japan, 1710).

15. Ekiken (1979, pp. 244–247). For comparisons between Ekiken and other educationalists of the period, see Koizumi (2007).

to one in particular: *bisseki* 筆跡. This is usually adequately translated as ‘handwriting’ or ‘calligraphy specimen’: the word is a compound of *bitsu* ‘brush’, and *seki*, which refers to that which is left behind, like footprints, a path, a remnant or residue. A given piece of writing is understood to be the ‘trace of the brush’, the mark left behind by the hand of a writer, the vestige of something that occurred before.¹⁶ While pen writing may be suggestive of the person who held the writing instrument, Japanese calligraphy is a record of a performance of a text by a writer, made possible by the brush acting as an extremely sensitive seismograph of the body.¹⁷

6. Reading in Four Dimensions

Since all readers were also writers, readers were literate not only in written language, but in the embodied idiom of the brush. The brush-literate reader recognises the movement of the brush through an understanding constituted by their experience of the brush. In cognitive science, theories of embodiment fuse “action production” and “action understanding” into a single system, wherein sensory input induces “simulation of the observed actions in the motor system of the observer” (Caramazza, Anzellotti, Strnad, and Lingnau, 2014, p. 7); in observing an action, “the relevant action is effectively reenacted within the observer’s premotor cortex” (Rizzolatti and Sinigaglia, 2010, p. 7).

It has been mentioned that the brushed line can indicate whether a writer’s brush hold is tight or their gestures are awkward, their brush fast or slow. These are qualities that can signify more than mere movement. The brushed line may index physical sickness or old age, hesitation or uncertainty, and even affective states. One calligraphy manual advises beginners to “take up your brush straight of body and upright of mind”.¹⁸ Discourses of affect being transmitted by the brush can be traced as far back as the 11th century classic, *The Tale of Genji*, which situates (kana) brush writing as communicating emotion through the somatic manifestation of the writer’s emotional state. An example is in the character Kashiwagi’s increasing distress of mind being legible to his friends, when his writing began to appear “like the tracks of strange birds”.¹⁹

16. It has been pointed out that “the literate Heian elite [8th–12th centuries] conceptualized the process of writing as an exercise in leaving physical traces”. (Blair, 2017, p. 284)

17. Calligraphy “becomes a record of a performance of a text by the skilful movement of the hand”. (Carpenter, 2019, p. 157)

18. *Hitsudō bidenshō* (筆道秘伝抄 Excerpted Secret Teachings of the Way of the Brush, Oshio Yūshō 小塩幽昭 1692; Oshio, 1914, p. 168).

19. Kashiwagi was writing a letter, “but his hand was trembling badly, and he gave up trying to say all he wished”, and shortly thereafter, “he wrote his reply lying down,

The somatic and even emotional expressiveness of brush writing remains available to readers with expertise in the brush. Modern calligraphy teachers continue to speak of perceiving a student's emotional state at the moment of inscription in their output, but this is a type of reading that is not easily accessible to others.²⁰ However, the embodied expressiveness of brush writing can in some cases be recognised even by 21st century viewers of writing. The early 12th century scroll of *The Tale of Genji* uses tangled and disordered writing for the death scene of the protagonist's deeply beloved wife, a depiction of anguish in writing that remains powerful, even while the text itself is as good as illegible even to highly competent palaeographers.²¹ This is a trope which survived at least into the 18th century, as shown in Figure 9. Here, a distraught fictional heroine writes to her beloved from her deathbed, and the page expresses her disordered mind and body in a way which contrasts to her earlier letters, one of which you can see on the right.



FIG. 9. Rankeishi, *Shin Usuyuki monogatari*, 1716. Left, vol. 5 f. 9v-10r. Right, vol. 1 f. 20r

between bouts of weeping. The words made no sense and resembled the tracks of strange birds" (Tyler, 2003, pp. 676, 677). Further examples include Oborozukiyo's grief-stricken poem to Genji as he departs for Suma, and Genji's melancholy poem to Utsusemi, both "written in a disarrayed manner" (*midare kaki* 乱れ書き) reflective of their emotions. *Genji monogatari* chapters *Suma* and *Yūgao*. (Carpenter, 2019, p. 33)

20. Among the calligraphers who have affirmed this to me I thank Mami Matsuzawa and Yukiko Ayres (Eāzu Shōkaku 恵杏壽昌鶴).

21. As a National Treasure, images are not widely available, but the section in question can be seen at Carpenter et al. (2019, p. 26).

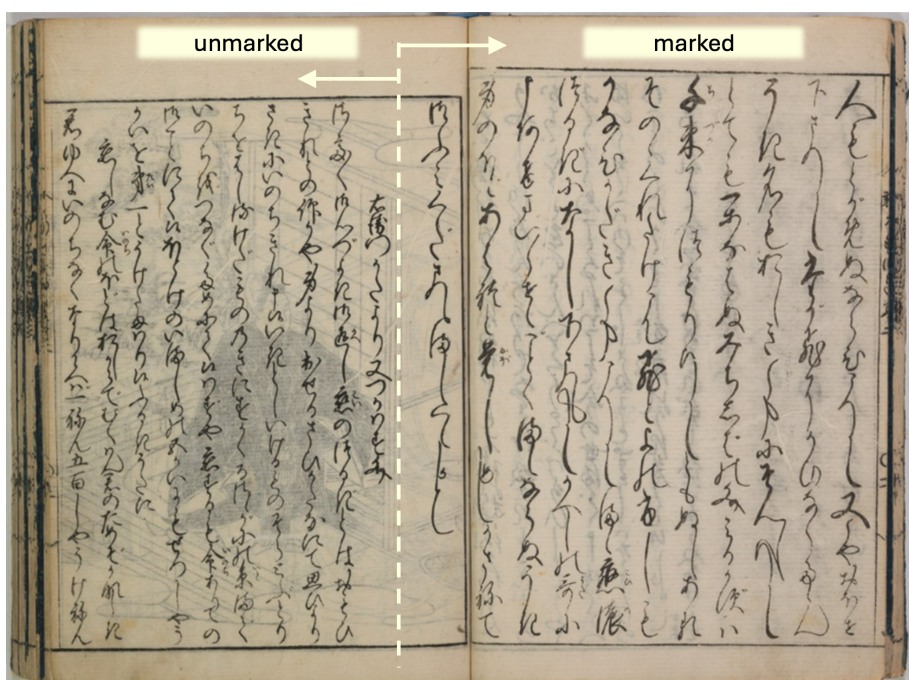


FIG. 10. Usuyuki's writing vs everything else. Rankeishi, *Shin Usuyuki monogatari*, 1716, vol. 2 f. 2v-3r

An attentive reading of brush writing can thus be highly informative, even in the absence of brush skills of premodern readers are absent. The brush is remarkable in its power to communicate all kinds of indexical meanings which relate to, draw on, or are clarified when considered in four dimensions and with attention to the encultured body. The 18th century book shown above is an epistolary romance, in which the heroine Usuyuki's letters are presented differently from the rest of the text: they use the fictional character's fictional handwriting to construct her character and affective state for readers. Her script, and only her script, (Figure 10) is vertically extended in a manner which indexes a particular kind of social relationship, and thus already carries para-linguistic meanings. More vertical extension means longer lines, which are not only more technically challenging, but seismographically expose more of the writing body, making the writing body more legible, both in its physical and social aspects. The circuit of understanding of this text is both constructed and interpreted in four dimensions.

Figure 11 shows a selection of letters from Usuyuki to her love interest, and each has a very different texture. They construct her affective



FIG. 11. Usuyuki's affective variation in script. Rankeishi, *Shin Usuyuki monogatari*, 1716. L-R: vol. 2 f. 7r; vol. 3 f. 3r; vol. 1 f. 20r; vol. 5 f. 9v-10r

stance in the moment of correspondence, arranged here from left to right in terms of intensity of affect. These meanings are partly constructed in the way we normally understand text to operate, through language in all its complex aspects. However, meaning is also partly constructed through her writing production in time and space. The seismograph of the brush and the extended line exposes Usuyuki's writing body to her lover in a way that also increases from left to right.

The more vertically extended writing of the second letter is more intimate than the first, because it allows him to 'read' her writing body through her brush. We see her affective stance changing, gradually un-cloaking herself in her writing from a kind of self-concealing reserve on the far left. The exposure of the body here is an exposure of affects and other meanings associated with the body. If we look at the right-hand side, letterforms are positioned in spatial relations with each other in a way that does not correspond to the linguistic structure of the text. This is a codified *mise-en-page* which indexes sincerity, but it also performs sincerity with exposed and extended brushstrokes which give the writer nowhere to hide.

7. Conclusion

Premodern Japanese writing is challenging to read; for contemporary Japanese readers without palaeographic training, it is impenetrable. For

these kinds of texts to be accessible to modern readers, they have to be transformed into the kind of writing in which we are literate (Figure 12). While the four dimensions of the brush are integral to the historical development of the Japanese writing system, technological changes accompanying dramatic modernisation since the turn of the 19th century have separated the brush from the written word.

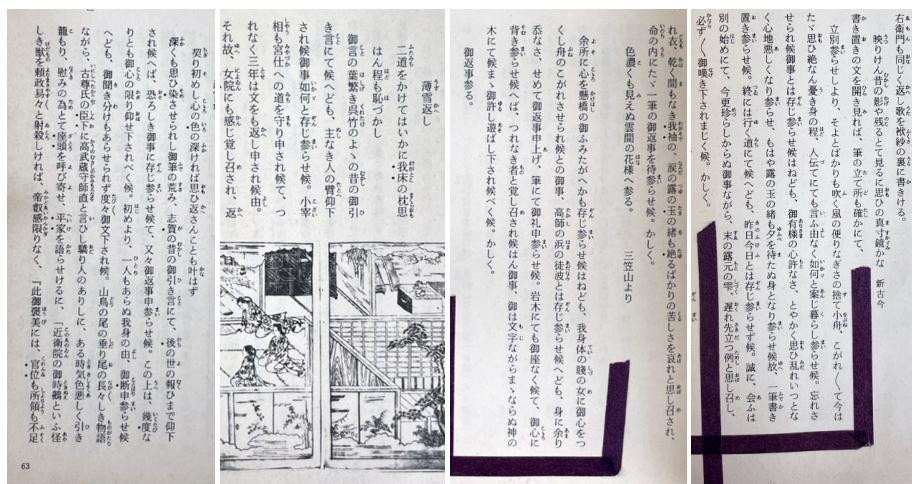


FIG. 12. Usuyuki transcribed—the same letters as Figure 11. Kikuchi Shin'ichi, ed., *Usuyuki monogatari*. *Shin Usuyuki monogatari*, Osaka, Japan: Izumi Shoin, 1983. L-R: Pp. 63, 74, 57, 108

We have come to depend on writing that has been regularised and abstracted away from the human originator. For us, the human hand is at best an inconvenience, a materiality that hampers access to the apparent principal matter: the semantic, immaterial content of text. We live in a world structured by a typographic paradigm, where even in a post-typographic, digital age, typography regulates the regime of knowledge. The text you are reading here could not have been submitted in handwriting, however beautiful and legible that handwriting might be. Early modern Japanese books exist to a modern readership only once they have been transcribed—a process which extracts textual 'content' to fit the automated text of the typographic paradigm, based on a 2-dimensional understanding of what writing does.

Premodern writing, organised by embodied experiences of four-dimensional worlds, was far richer than 2 dimensions allow, and the transcribed page in isolation engages only with the aspects of writing that we are comfortable with; the rest is discarded. Indeed, a 2-dimensional transcription effectively *conceals* a crucial layer of social meaning, and

thereby solidifies a particular understanding of the meaning of writing, which is then applied ahistorically.

The TEI East Asian/Japanese SIG has, in less than ten years, made enormous progress in advancing models appropriate to East Asian writing systems in historical context, from the initial implicitly Eurocentric approach of the TEI project.²² It remains to be seen whether the features of brush-written writing highlighted here could be marked up, particularly in the case of affective and uncoded dimensions of meaning.

Scriptural materiality *is* an inconvenience for the typographic regime: it is a materiality which insists on the unique case over the general, and it disrupts our systems of knowledge. The typographic paradigm has transformed animate ‘writing’—a verbal noun—into disembodied and inanimate ‘text’. This is, I argue, a profound loss which not only diminishes the object of enquiry, but diminishes our own capacity to engage with that enquiry. Nevertheless, the four-dimensionality of the brush-written remains available for as long as the ink persists on the paper. While we may lack the capacity to read such writing fully, the four-dimensional world of the embodied human in which it was produced is the same world that we inhabit, and still structures our perception and experience. The brush’s resistance to the typographic regime can be understood, I suggest, as an invitation to reclaim our embodied experience in an increasingly digital world.

References

- Blair, Heather (2017). “Mothers of the Buddhas: The Sutra on Transforming Women into Buddhas (*Bussetsu Tennyō Jōbutsu Kyō*)”. In: *Monumenta Nipponica* 71.2, pp. 263–293. DOI: 10.1353/mni.2016.0036.
- Bourdieu, Pierre (1977). *Outline of a Theory of Practice*. Trans. by Richard Nice. Cambridge University Press. DOI: 10.1017/CB09780511812507.
- Caramazza, Alfonso et al. (2014). “Embodied Cognition and Mirror Neurons: A Critical Assessment”. In: *Annual Review of Neuroscience* 37.1, pp. 1–15. DOI: 10.1146/annurev-neuro-071013-013950.
- Carpenter, John T. (2008). “Chinese Calligraphic Models in Heian Japan: Copying Practices and Stylistic Transmission”. In: *The Culture of Copying in Japan: Critical and Historical Perspectives*. Ed. by Rupert A. Cox. Japan Anthropology Workshop Series. London: Routledge.
- (2019). “Learning the Women’s Hand in Heian Japan: Kana Calligraphy and the Tale of Genji”. In: *The Tale of Genji: A Japanese Classic Illuminated*. New York: The Metropolitan Museum of Art.

22. Text Encoding Initiative – East Asian/Japanese Special Interest Group. See for example <https://tei-c.org/activities/sig/eastasian/> and <https://tei.dhi.jp/>.

- Carpenter, John T. et al. (2019). *The Tale of Genji: A Japanese Classic Illuminated*. New York: Metropolitan Museum of Art.
- Chance, Linda H. and Julie Nelson Davis (2016). “The Handwritten and the Printed: Issues of Format and Medium in Japanese Premodern Books”. In: *Manuscript Studies: A Journal of the Schoenberg Institute for Manuscript Studies* 1.1, pp. 90–114. DOI: 10.1353/mns.2016.0010.
- Dore, Ronald (1965). *Education in Tokugawa Japan*. London: Routledge & K. Paul.
- Ekiken, Kaibara (1979). “Wazoku dōjikin”. In: *Yamato zokkun/Wazoku dōjikin*. Ed. by Matsuda Michio. Tokyo: Chūkō Bunko.
- Gilderdale, Peter (1999). “The Great Copperplate Myth”. In: *Letter Arts Review* 15.1, pp. 38–47.
- Gnanadesikan, Amalia E. (2008). *The Writing Revolution: Cuneiform to the Internet*. Newark, UK: John Wiley & Sons. URL: <http://ebookcentral.proquest.com/lib/cam/detail.action?docID=428169>.
- Ishikawa, Kyūyō [石川九楊] (1994). 書とはどういう芸術か: 筆蝕の美学 [*What Kind of Art Is Calligraphy?: An Aesthetics of Brush Traces*]. 1st ed. 中公新書 [Chūkō shinsho] 1220. Tokyo: 中央公論社 [Chūō Kōronsha].
- Kaya, Noriko [萱のり子] (2002). “Changes in “Modern” Japanese Calligraphy”. In: 美術科研究 [*Study of Art*] 19, pp. 41–46.
- Koizumi, Yoshinaga [小泉吉永] (2007). 江戸の子育て十カ条—善悪は四歳から教えなさい [*The Ten Principles of Child-Rearing in Edo: Teach Right and Wrong from the Age of Four*]. Tokyo: 柏書房 [Kashiwa Shobō].
- Moretti, Laura (2020). *Pleasure in Profit: Popular Prose in Seventeenth-Century Japan*. Columbia University Press.
- Ōsako, Kanpo [大迫閑歩] (2012). えんぴつで方丈記 [*Hōjōki by Pencil*]. Ed. by Kawaragi Yūji [河原木有二]. えんぴつで楽しむ古典 [Enjoying the Classics by Pencil]. Tokyo: ポプラ社 [Poplar].
- Oshio, Yūshō [小塩幽昭] (1914). “筆道秘伝抄 [Secret Transmission on the Way of the Brush]”. In: 日本書画苑 [*Nihon Shogaen*]. Vol. 1. info:ndljp/pid/945820. Tokyo: 国書刊行会 [Kokushokankōkai].
- Rizzolatti, Giacomo and Corrado Sinigaglia (2010). “The Functional Role of the Parieto-Frontal Mirror Circuit: Interpretations and Misinterpretations”. In: *Nature Reviews Neuroscience* 11.4, pp. 264–274. DOI: 10.1038/nrn2805.
- Sasaki, Takahiro (2023). “Manuscript Features of Early Japanese Movable Type Books: On the Intersection of Eastern and Western Typesetting Techniques”. In: *Between Manuscript and Print: Transcultural Perspectives, ca. 1400–1800*. De Gruyter, pp. 187–208. DOI: 10.1515/9783111242699-008.
- Sasaki, Takahiro and Michael Burtscher (2022). “Jesuit Printing and Hiragana Books”. In: *Monumenta Nipponica* 77.1, pp. 27–75.
- Tyler, Royall (2003). *The Tale of Genji*. New York: Penguin Books.

Synchronic and Diachronic Ordering in Chinese Character Form Patterns

James Myers

Abstract. This study demonstrates that interactions among patterns in modern Chinese character form cannot be ascribed to the diachronic order in which the patterns arose. In particular, lexically idiosyncratic patterns and articulatorily or perceptually motivated patterns interact in the modern system as if ordered early and late, respectively, regardless of when they arose historically. The results help confirm that, just as with spoken and signed languages, historical change in writing systems involves a sequence of synchronic grammars, each restructured from the previous one in accordance with universal synchronic principles.

1. Introduction

As we all know, ontogeny recapitulates phylogeny. Ernst Haeckel's aphorism makes biological sense because evolutionary changes that target earlier stages in embryonic development risk mucking up the whole developmental process; tacking something on at the end is much safer. Humans don't need gills, but trying to grow lungs without starting with gills is likely to leave you without working lungs at all. Similarly, historical sound change tends to leave sequential traces in synchronic systems, with older changes preserved as "earlier" phonological rules (King, 1973). Again this makes sense: adding a new phonetic flourish to your accent is likely to leave your speech more intelligible than distorting it morphophonologically.

Do writing systems conform to the same principle? Before attempting to answer this, we must first confront the fact that Haeckel's principle leaks, even in biology; evolution can tweak embryonic development in a

Thanks to Taiwan's National Science and Technology Council (Taiwan) grant 112-2410-H-194-030-MY3, Yangru Chen, Jane Tsay, the conference audience, and of course Yannis Haralambous for making it all possible.

James Myers  0000-0002-3866-1969
Graduate Institute of Linguistics, National Chung Cheng University, 168 University Road, Min-Hsiung, Chia-Yi 62102, Taiwan
E-mail: Lngmyers@ccu.edu.tw

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 507–531. <https://doi.org/10.36824/2024-graf-myer>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

wide variety of ways unattested in the fossil record, as long as it all works out in the end, an insight that is part of what has become known as *evo-devo* (Love, 2024). Phonological rules need not exactly match the course of sound change either, as we'll see shortly. Thus we should not be surprised if writing systems also show misalignments between diachronic and synchronic order. After all, diachrony also has to make synchronic sense, whether in embryos, speech, or writing, and ultimately we would like to develop phonological and orthographic versions of *evo-devo* that explain why and where history and grammar do and do not match. Pushing linguistic theory in this direction, however, would require us to be relatively concrete in our examples and a bit more sophisticated in our analyses.

To this end, this paper focuses on the history and modern form of Chinese characters, a system that I have been exploring for several years now from a grammar-oriented perspective (Myers, 2016, 2019, 2021a, 2021b, 2022, 2024a, 2024b, 2025). In the rest of this paper, I first review the nature of ordering in phonology and its relation to sound change (Section 2), then discuss a selection of form patterns in Chinese characters and argue for their synchronic ordering (Section 3), and finally explore the relationship between this ordering and the historical evolution of these patterns (Section 4). Section 5 offers some brief conclusions.

2. Ordering in Phonology and Sound Change

Sound changes happen in real time, the same sort of time that historians and biologists and physicists talk about, whereas synchronic rule ordering is an abstract and controversial concept that only a subset of linguists has ever believed in. This might lead one to think that we, as putative scientists, should aim at explaining apparent synchronic ordering (the mysterious) in terms of diachronically ordered sound changes (the well-understood). However, as I hope to make seem plausible in this section, not only is historical sound change intrinsically insufficient to explain interactions within phonological systems, but phonological history itself is better understood in phonological terms, that is, in terms of grammar. These are not new ideas, but they underlie what we'll do when we come back to Chinese characters later in the paper.

We can start with King (1973), who argued for what remains the conventional view: synchronic rule ordering, by and large, follows the order of historical sound change. However, a lot depends on what we mean by "rule ordering," not to mention "by and large." King himself made the conventional caveat that phonology is universally ordered before phonetics, which allows new rules to be inserted between the two modules, including before old phonetics. Since then, of course, phonological theory (at least one of its major dialects) has abandoned the notions of rules

and rule ordering in favor of the simultaneously applied constraints of Optimality Theory (OT; Prince & Smolensky, 2004). The inability of OT to handle certain types of constraint interactions, however, eventually forced its adherents to admit a certain amount of ordering back into the theory (see review in Pruitt, 2023). In this paper I will adopt the ordering approach known as Stratal OT (Kiparsky, 2015), rather than its major rival, harmonic serialism (McCarthy, 2007; Hauser & Hughto, 2020), for two reasons. First, Stratal OT was developed with both diachronic and synchronic phonology in mind, and second, its notion of universally ordered strata explicitly implements King's conventional caveat: phonology (what Stratal OT calls stem and word phonology) applies before phonetics (phrasal phonology).

To explain why the caveat is necessary, I will unpack a notorious case originally based on observations by Joos (1942) and first analyzed in terms of rule ordering by Halle (1962): diphthong raising and flapping in Canadian English. Similar phenomena exist in other English varieties, including my own Midwest American accent, so I can personally vouch for the examples below. Diphthong raising applies before voiceless consonants, as shown in (1a), and flapping, which applies before unstressed syllables, voices coronal consonants, as shown in (1b). This means that flapping could potentially “bleed” raising (in the terminology pioneered by Kiparsky, 1968), that is, remove its conditioning environment, by voicing the voiceless coronal that would otherwise trigger it. What actually happens, however, is that raising “counterbleeds” flapping, thereby “overlapping” (in the terminology of McCarthy, 1999), as in (1c): the diphthong is raised before what would otherwise be voiceless if it weren't for the effects of flapping. In other words, the interaction here is “opaque”: the effects of raising are obscured by the effects of flapping.

- (1) a. write [ɹaɪt] ride [ɹaɪd]
 b. late [leɪt] later [leɪrə]
 c. writer [ɹaɪrə] rider [ɹaɪrə]

As Halle (1962) pointed out, this interaction is just what we would expect if raising applies synchronically before flapping, as demonstrated in (2).

- (2)
- | | <u>writer</u> | <u>rider</u> |
|------------|---------------|--------------|
| Underlying | ɹaɪtə | ɹaɪdə |
| Raising | ɹaɪtə | – |
| Flapping | ɹaɪrə | ɹaɪrə |
| Surface | ɹaɪrə | ɹaɪrə |

If this rule ordering simply fossilizes the effects of diachronic sound change, raising must have emerged at an earlier date than flapping. This seems plausible at first, since Scottish English has a phonological pattern

quite similar to Canadian raising (Aitken, 1981) but does not flap coronal obstruents, and immigrants from Scotland played an outsized role in Canadian history (the first prime minister was named Macdonald after all). The history of Canadian English would then be similar to what is happening now in New Zealand, another former outpost of the British Empire with a heavy Scottish influence, where flapping has only recently begun to emerge (Silby, 2008).

Unfortunately for this simple story, we are not justified in ascribing Canadian raising to Scottish English, since diphthong raising has emerged independently across a variety of geographically dispersed English dialects (Moreton, 2021). Even worse, in some areas flapping is demonstrably older than raising, despite the fact that synchronically it is still ordered later (Fruehwald, 2016). More generally, it seems unwise to lay the burden of explaining the present on the past when only the present is directly observable (explaining the mysterious through the even more mysterious). Even something as apparently well-established as the diachronic ordering of Grimm's law before Verner's law actually remains somewhat controversial (Noske, 2012). Such epistemological confusions should not be surprising, given that the reconstruction of dead languages depends on theoretical assumptions about what makes a plausible human language, assumptions that are derived from the study of living languages. The idea that historical linguistics should be grounded in theoretical linguistics rather than the other way around is an old one that continues to be rediscovered (e.g., Kiparsky, 2014), but it is essential to understanding the relationship between diachronic and synchronic ordering. If the latter is more fundamental, regardless of how it should be formalized or understood in psychological terms, we must recognize that every historical stage of the language has something like it, and this means that what we must actually explain is how each synchronic order morphs into the diachronically next one.

In the case of Canadian English, as with the patterns in Chinese character form that we will look at later, explaining the synchronic ordering is relatively simple: the later pattern is of a type that is universally expected to apply later. In the terms of King (1973), we might say that diphthong raising is (morpho)phonology while flapping is phonetics; in Stratal OT we would say that raising applies in the word-level stratum while flapping is phrasal. The non-phonetic status of raising is shown by lexical anomalies like those in (3), where it "overapplies" in certain cases when the diphthong is not followed by an underlyingly voiceless consonant.

- (3) a. tiger [tʰaɪgə] (Vance, 1987, p. 201)
 b. didactically [dɪdæktikli] (Hall, 2005, p. 194)

The phrasal status of flapping is mostly uncontroversial, since it clearly applies across words, as in (4).

- (4) get it [gɛɾ it]

The tinge of controversy comes from the observations in (5), which show the “underapplication” of flapping before an unstressed syllable in the word in (5b), presumably because this syllable is stressed in the word in (5a) that it is morphologically derived from (Withgott, 1982; Steriade, 2000). Flapping thus seems to undergo morphophonological cyclicity in a shockingly unphonetic way, or, less dramatically, perhaps there is simply enough residual stress on the relevant syllable in the derived word to block flapping as usual. An intermediate position is also possible, namely that flapping is indeed phonetic but that phonetics is sensitive to the abstract prosodic structure built on morphological structure, even when the phonetic correlates of stress are not realized. That is, we might be able to maintain a strict division between phonology and phonetics if we explode one or both into smaller parts that interact in different ways. I will apply this sort of divide-and-conquer approach a few more times before the end of this paper.

- (5) a. mili[t^h]àry
b. mili[t^h]àrism

In any case, the synchronic ordering of raising before flapping seems to be the inevitable consequence of the different natures of these two processes, the earlier more phonological and the latter more phonetic, making irrelevant the order with which the processes emerged historically. It also does not seem arbitrary that one process behaves in a more phoneticky way than the other in all English varieties in which both appear. Flapping is a straightforward effect of underarticulating stop closure in intervocalic position. By contrast, it is still not entirely clear what motivates diphthong raising. It had long been thought (e.g., Chambers, 1973) that the ultimate cause was the shortening of vowels before voiceless codas, which presumably compensates for the greater duration of voiceless consonants relative to voiced ones (voicing requires airflow and thus somewhere for the air to flow to, and space is limited in the restricted or even closed oral cavity created by an obstruent), and the less time there is to articulate a diphthong, the more the nucleus will be raised to shorten the articulatory distance from it to the high offglide. However, Moreton and Thomas (2007) argue for a totally different and even more complex explanation, involving not vowel shortening but instead the distinct effects of voicing and devoicing on the nucleus and offglide of diphthongs. Arguably, then, the productivity of flapping is continually renewed by its transparent articulatory support in the mouths of contemporary speakers, whereas raising took such a convoluted route from phonetics to phonology that its mental reality today is essentially cut off from its phonetic origins.

It turns out to be convenient that raising and flapping differ in their natures, since otherwise OT would not be able to handle their interaction. As OT experts can easily see, (6) confirms that there is no way to rank constraints associated with each relative to constraints that preserve features of the input form (faithfulness constraints, in OT parlance) and still yield an output that conforms to the facts. For all other readers, let me explain that the input form is in the upper left, and the forms below it represent alternative output candidates. Constraints are ranked from left to right, with the stars representing constraint violations. The winning candidate is determined by eliminating all but the most obedient candidates relative to the top-ranked constraint, then continuing to winnow the candidates down through all the other constraints, until we end up with the single winner. With the constraint ranking shown here, the winner is the candidate indicated with an arrow, but this is not the output that we want. Regardless of how the four constraint columns are scrambled, the correct form [ɹaɪɹə] in the last row can never win, because the raised diphthong before the voiced flap violates the raising constraint and both faithfulness constraints.

(6) writer (standard OT)

ɹaitə	FLAPPING	RAISING	FAITH(LOW)	FAITH(VOICE)
ɹaitə	*	*		
ɹaɪtə	*		*	
→ ɹaɪrə				*
ɹaɪrə		*	*	*

Stratal OT deals with opacity via the same sort of ordering proposed by Halle (1962), except that it is restricted to the ordering of those universal strata of stems, words, and phrases. Each stratum itself is a mini-grammar with simultaneously evaluated OT constraints, perhaps with different rankings, where the winning output of each becomes the input to the next. As applied to raising and flapping, this theory gives us an analysis like that in (7), where raising is ranked high in the word stratum but low in the phrasal stratum (note that the pattern of stars differs between strata for the faithfulness constraint for vowel lowness due to the different inputs).

(7) writer (Stratal OT)

Word stratum

ɿaitə̃	RAISING	FAITH(VOICE)	FAITH(LOW)	FLAPPING
ɿaitə̃	*			*
→ɿaitə̃			*	*
ɿairə̃		*		
ɿairə̃	*	*	*	

Phrasal stratum

ɿaitə̯	FLAPPING	FAITH(LOW)	FAITH(VOICE)	RAISING
ɿaitə̯	*	*		*
ɿaitə̯	*			
ɿairə̯		*	*	
→ ɿairə̯			*	*

3. Synchronic Ordering in Chinese Character Form Patterns

Stratal OT formalism turns out to work for Chinese characters as well. I demonstrate this in excruciating detail in Myers (2024a), so here I will restrict myself to the interaction among just three formal patterns that I call (following Myers, 2019) reduplicative identity, idiosyncratic allomorphy, and regular reduction.

As in spoken and signed languages, the reduplication of components within Chinese characters expresses iconic meanings like abundance, as illustrated in (8) (throughout this paper I focus on the traditional characters used in Taiwan, though I will briefly allude to simplified characters in the next section). It is thus analogous to morphology, not phonology (as usual when I write about character phonology, I’m thinking of the silent visual sort like that in sign language). Nevertheless reduplication also reflects purely form-based generalizations, which I have argued are indeed analogous to phonology. One is the restriction of reduplication to a very small number of arrangements, again as illustrated in (8): horizontal doubling, vertical doubling, and doubling along both axes (the triangular grouping being far more common than the square one). This is reminiscent of prosodic constraints on the typically binary shape of reduplicative templates in spoken and signed languages, templates that encode the structure of reduplicants but not their content.

- (8) a. 木 *mù* ‘tree’ 林 *lín* ‘forest’
b. 火 *huǒ* ‘fire’ 炎 *yán* ‘blazing’
c. 日 *rì* ‘sun’ 晶 *jīng* ‘glittering’
d. 又 *yòu* ‘again’ 爰 *zhuó* ‘connect’

The other phonology-like aspect of character reduplication is what fills in the content, namely the copying itself. In OT this sort of thing is not handled by a copying rule, but rather by a species of faithfulness constraint that requires one part of a form to be identical to another (McCarthy & Prince, 1995), which here I call reduplicative identity. Thus each of the reduplicated forms in (8) is the morphological combination

of a base morpheme (a simple component) with a prosodic template (a morpheme meaning ‘abundance’), which then triggers the application of reduplicative identity constraints to yield the full phonological form.

So much for reduplication. The second of the three phonological patterns that I want to discuss is idiosyncratic allomorphy. This pattern is illustrated by the alternations in component form shown at the start of each row in (9), followed by full characters exemplifying these alternations. Myers (2019) calls such alternations idiosyncratic because they involve changes unique to a relatively small subset of character components (around thirty out of several hundred); for example, the deletion of the top stroke in (9b) and the dot in (9d) only happen in these specific components. The idiosyncratic nature of this allomorphy is reflected in Unicode, which has distinct code points for each variant.

- (9) a. 水 → ㄣ *shuǐ* ‘water’ 海 *hǎi* ‘sea’ (cf. 汞 *gǒng* ‘mercury’, 冰 *bīng* ‘ice’)
 b. 手 → 扌 *shǒu* ‘hand’ 拾 *shí* ‘pick up’ (cf. 掌 *zhǎng* ‘palm of hand’)
 c. 糸 → 纟 *mì* ‘silk’ 給 *gěi* ‘give’ (cf. 緊 *jǐn* ‘taut’)
 d. 玉 → 王 *yù* ‘jade’ 球 *qiú* ‘ball’ (cf. 瑩 *yíng* ‘lustrous’)
 e. 艸 → 艹 *cǎo* ‘grass’ 花 *huā* ‘flower’ (cf. 薊 *bù* ‘plants’)
 f. 火 → 灬 *huǒ* ‘fire’ 照 *zhào* ‘view’ (cf. 燈 *dēng* ‘lamp’)
 g. 刀 → 刂 *dāo* ‘knife’ 到 *dào* ‘to’ (cf. 剪 *jiǎn* ‘scissors’)

Being idiosyncratic, the allomorphs must be lexically stored. Nevertheless, as with reduplication, the character analog of prosody is also relevant. Not only is the idiosyncratic allomorph always “lighter” relative to its full-character counterpart, with fewer and/or simpler strokes, but it is also restricted in its position. Namely, the reduced allomorph virtually always appears at the left or top, where even non-idiosyncratic components are usually shrunk in size, while the unreduced allomorph appears at the bottom or right, where components are usually enlarged. Since Myers (2019) argues that shrinking and enlargement are analogous to unstressed and stressed positions respectively, these observations mean that idiosyncratically reduced allomorphs can only appear in unstressed positions, just as one would expect of prosodically light elements, by analogy with spoken phonology. This general pattern can be seen in (9a-e), with (9f-g) showing unusual cases of reduction in stressed positions.

Integrating the idiosyncratic and the regular requires yet another act of divide-and-conquer: the lexicon supplies the allomorphs, while grammar supplies the regularity. Phonologically conditioned allomorph selection is pretty common across the world’s languages (Nevins, 2011), and in OT it can be captured as illustrated in (10), where both heavy and light lexical allomorphs are offered as input, and the chosen one is whichever suits the prosodic constraints (*HEAVY/UNSTRESSED penalizes unstressing a component with relatively more or more complex

strokes, and *LIGHT/STRESSED penalizes the complementary situation; the dashed lines indicate that constraint ranking doesn't matter here).

(10) a. 海

{水, 彡} + 每	*HEAVY/UNSTRESSED	*LIGHT/STRESSED
水每	*	
→彡 每		

b. 冰

彡 + {水, 彡}	*HEAVY/UNSTRESSED	*LIGHT/STRESSED
→彡 水		
彡 彡		*

The third and final phonological pattern that I want to discuss is regular reduction, which, as its name is intended to suggest, is not restricted to a small subset of components. Two major types are what I call diagonalization, which, as shown in (11), converts the lowest horizontal stroke to a rising diagonal stroke, and dotting, which, as shown in (12), converts a falling diagonal stroke into a dot (i.e., very short falling diagonal); the examples shown here could be supplemented with many more. Unlike the case with idiosyncratic allomorphy, Unicode does not have distinct code points for the default and reduced allomorphs associated with regular reduction.

(11) 一 → 乚

- a. 土 *tǔ* 'earth' 地 *dì* 'earth' (cf. 型 *xíng* 'model')
- b. 金 *jīn* 'gold' 鉛 *qiān* 'lead' (cf. 鑒 *jiàn* 'mirror')
- c. 立 *lì* 'stand' 站 *zhàn* 'stand' (cf. 童 *tóng* 'child')

(12) 丿 → 丶

- a. 木 *mù* 'tree' 根 *gēn* 'root' (cf. 宋 *sòng* 'Song' [dynasty])
- b. 夫 *fū* 'husband' 規 *guī* 'rule' (cf. 扶 *fú* 'help')
- c. 火 *huǒ* 'fire' 燈 *dēng* 'lamp' (cf. 燙 *tàng* 'scald')

The influence of prosody is similar to that seen in idiosyncratic reduction, with regular reduction restricted to the unstressed left position, but its regularity points to another motivational factor at play: phonetics. This is because writers prefer to pull the writing instrument towards the writing hand, which means that they prefer to move the writing instrument downward, while right-handers also prefer to move the writing instrument rightward. This is why handwriting typically orders character components from left to right and top to bottom when composing a full character, and within each component, strokes conform to these directions as well, as do the individual strokes themselves. The result

is that changing stroke type in the specific ways seen in both diagonalization and dotting shortens the distance between the end of the last stroke in the first-written component to the start of the first stroke in the next-written component. As with flapping, then, every time a writer applies regular reduction, its articulatory naturalness is reinforced in their mind, something that cannot be the case with idiosyncratic allomorphy.

There are potentially six ways these three patterns could be ordered synchronically, but it turns out that only one ordering correctly captures the facts: first idiosyncratic allomorphy, then reduplicative identity, and finally regular reduction. The ordering of idiosyncratic allomorphy before reduplicative identity is demonstrated by two related observations. Most of the time, for components that have idiosyncratically reduced allomorphs, what is reduplicated is the full allomorph, as shown in (13). That is, idiosyncratic allomorphy is generally not allowed to apply in this context.

- (13) a. 水 𠂇 *shuǐ* ‘water’ 林 *zhuǐ* ‘merged sandbars’
 b. 火 𠂇 *huǒ* ‘fire’ 炎 *yán* ‘blazing’
 c. 手 扌 *shǒu* ‘hand’ 𢵇 *nuò* ‘restrain’

This makes sense if idiosyncratic allomorphy has already had its chance to apply before reduplicative identity comes into effect, and either failed or was undone by the later process. In an OT framework, both scenarios would be formalized the same way. As illustrated in (14), reduplication as a morphological operation is already indicated in the input (by the empty morpheme RED), but in the competition between idiosyncratic allomorphy (a side-effect of *HEAVY/UNSTRESSED) and reduplicative identity, the latter constraint wins out through its higher ranking (REDUPIDENT only applies to the morpheme RED). As shown by the fact that ordinary OT can handle this interaction, it is transparent: reduplicative identity “bleeds” idiosyncratic allomorphy, and nothing over- or underapplies. By the way, this analysis also avoids an apparent ordering paradox highlighted in a classic paper by Anderson (1971), which noted many cases across the world’s languages where phonology appears to apply before reduplication, which, as morphology, should be universally ordered earlier. By exploding reduplication into its morphological and phonological aspects, we can say that its morphological aspect does indeed apply first (in the input), and it is only its phonological aspect, reduplicative identity, that applies later (in the constraint evaluation).

- (14) a. 林

{水, 𠂇} + RED	REDUPIDENT	*HEAVY/UNSTRESSED
→水水		*
𠂇 水	*	

b. 海

{水, 氵} + 每	REDUPIDENT	*HEAVY/UNSTRESSED
水每		*
→ 氵 每		

However, there is a very small number of components that reduplicate the idiosyncratically reduced allomorph rather than the full one, as shown in (15) and (16). It is presumably not coincidental that one of these components also supplies the only exception, in (15b), to the blocking of idiosyncractic allomorphy in reduplication. The reduced allomorph in (16a) also happens to be identical to the otherwise distinct component in (16b).

(15) a. 糸→𣎵 變 *biàn* ‘change’

b. 糸→𣎵 絲 *sī* ‘silk’

(16) a. 玉→玨 珎 *jué* ‘joined jade’

b. 王 *wáng* ‘king’

Together the examples in (15) and (16) provide another argument for the ordering of idiosyncratic allomorphy before reduplicative identity. The exception to reduplicative identity in (15b) not only reconfirms that the reduced allomorph is stored in the lexicon, but also that it can combine independently, rather than having to be derived; Myers (2019) suggests that this example may actually reflect compounding rather than true reduplication. The neutralization of the reduced allomorph with another component, as seen in (16), may similarly give this allomorph an additional puff of life. Thus even though all idiosyncratic allomorphs must be stored in the lexicon, these two may be particularly predisposed to act like ordinary underived forms that can themselves obey reduplicative identity.

The technical name for reduplication that copies reduplicant form onto base form instead of the other way around is backcopy, which is yet another phenomenon in Chinese characters that is also found across the world’s languages (Inkelas and Zoll 2005). A possible OT analysis of the particular situation here is shown in (17), where the choice of reduced allomorph is stipulated in the input by leaving out the full allomorph entirely. This analysis is again transparent, since idiosyncratic allomorphy per se doesn’t come into play at all.

(17) 變

𣎵 + RED + ...	REDUPIDENT	*HEAVY/UNSTRESSED	*LIGHT/STRESSED
→ 𣎵 𣎵			*
𣎵 𣎵	*		

Establishing the order of regular reduction is more straightforward. Evidence that it is ordered after idiosyncratic allomorphy comes from examples like those in (18). The key observation is that the idiosyncratically reduced forms also undergo regular diagonalization in (18a-b) and regular dotting in (18c).

- (18) a. 手→扌 *shǒu* 'hand' 拾 *shí* 'pick up'
 b. 足→𧇖 *zú* 'foot' 路 *lù* 'road'
 c. 衣→衤 *yī* 'clothing' 被 *bèi* 'quilt'

Since idiosyncratic allomorphy involves the selection of an entire allomorph, with all of its strokes, it must apply before regular reduction, or else there would be no strokes to diagonalize or turn into dots. This is particularly clear in (18b), which entirely lacks a horizontal stroke target for diagonalization in the full form, but gains one in the reduced form that incorporates the cognate character in (19).

- (19) 止 *zhǐ* 'stop'

The example in (18c) makes the same point in a subtler way, since the stroke configuration at the bottom of this component can also show the totally different idiosyncratic allomorphy shown in (20), with the full form in (20a) reduced as in (20b), but the falling diagonal stroke is replaced by a dot.

- (20) a. 艮 *gèn* (one of the Eight Trigrams)
 b. 既 *jì* 'since'

In short, idiosyncratic allomorphy “feeds” regular reduction, that is, it creates the conditions for it to apply, putting the two patterns into a transparent relation. This means that their interaction can be handled by ordinary OT, as shown in (21). Note that only the first and last candidate outputs use the standard Unicode symbols for this component. The monstrosities shown in the middle two rows are intended to represent variants of 手 that either lack the topmost stroke (idiosyncratic reduction only) or diagonalize the bottommost stroke (regular reduction only).

- (21) 拾

{手, 扌}+合	REGREDUCT	*HEAVY/UNSTRESSED
手合	*	*
扌合	*	
𠂇合		*
→扌合		

Finally, evidence that regular reduction also follows reduplicative identity comes from examples like those in (22), which show that neither diagonalization (22a) nor dotting (22b-c), nor size reduction for that matter, counts as violating identity. That is, the copies are considered “the same” despite their superficial differences.

- (22) a. 甓 *shēng* ‘broom’
 b. 林 *lín* ‘forest’
 c. 𣏟 *zhǔi* ‘merged sandbars’

This is the reverse of what we saw with idiosyncratic reduction, where reduplication either disallows reduction or else, in rare cases, backcopies the reduced form. Since that was a feeding order, here reduplicative identity “counterfeeds” regular reduction, as illustrated in the derivational analysis in (23).

- | | | | |
|------|------------------------|-------|-------|
| (23) | | 甓 | 林 |
| | Underlying | 生+RED | 木+RED |
| | Reduplicative identity | 生生 | 木木 |
| | Regular reduction | 甓 | 林 |
| | Surface | 林 | 林 |

Counterfeeding is an opaque interaction, so if we want to do this in OT, we need to go beyond its usual formalism. If we use Stratal OT, we must accept that reduplicative identity applies in an earlier stratum than regular reduction. Myers (2024a) gives a number of arguments that the strata associated with reduplicative identity and regular reduction must be the stem-level and word-level strata, respectively. The simplest argument is that the only other universal stratum available in the theory is the phrasal stratum, but this is inapplicable to Chinese characters because characters are stored in the lexicon and so their grammar has analogs to morphology and phonology, but not to syntax. The analysis would thus be as in (24), where reduplicative identity is maximally general and thus strict, so it does not allow any deviation from identity, no matter how small. This prevents the surface form from being chosen in the first stratum where identity is high-ranked, but instead the winner waits until the next stratum for regular reduction to enforce the tiny tweaks in stroke form that we see on the surface.

- (24) 林

Stem stratum

木+RED	REDUPIDENT	REGREDUCT
→木木		*
林	*	

Word stratum

木木	REGREDUCT	REDUPIDENT
木木	*	
→林		*

Putting all of this together, a derivational analysis of all three patterns would be as in (25). A Stratal OT analysis would work basically the same way, except that both idiosyncratic allomorphy and reduplicative identity apply within single OT mini-grammar in the stem stratum, while regular reduction applies in the word stratum.

(25)		地	根	拾	林	林	變
Underlying		土+也	木+艮	手/扌+合	木+RED	水/氵+RED	糸+RED+...
Idiosyncratic allomorphy		—	—	扌合	—	氵水	—
Reduplicative identity		—	—	—	木木	水水	糸糸
Regular reduction		地	根	扌合	林	林	—
Surface		地	根	拾	林	林	變

As with the ordering of Canadian raising and flapping, the ordering here makes sense. Regular reduction comes last because it is the most clearly motivated in terms of manual phonetics. Idiosyncratic allomorphy comes first because it is anything but clearly motivated; readers and writers must simply memorize the alternating forms, even if they can predict in which prosodic context they can appear. The status of reduplicative identity lies somewhere in the middle, since despite being tied to a synchronically quite unproductive morphological process, it remains visually highly salient, and Myers (2016) showed that readers have clear intuitions on what well-formed reduplication should look like even in made-up characters. The synchronic ordering of these three processes thus follows from their relative productivity.

4. The history of Chinese character form patterns

The history of Chinese characters has attracted attention from curious linguists since ancient times (see Qiu, 2000, for a comprehensive overview). This is thanks in part to the fact that unlike speech or signing, writing leaves physical traces that go back thousands of years. This fact raises the possibility that the synchronic ordering in Chinese character form that we have just examined might indeed reflect nothing more than the order with which these three processes arose; perhaps here the past really is less mysterious than the present. This proves to be only partially

correct, and arguably entirely wrong, in the sense that it is relative productivity that actually drives synchronic ordering, even diachronically.

Given the great length and geographical diversity of Chinese character history, I will restrict myself here to an incomplete and misleadingly linearized timeline based on the historical character images available in the online database of Juang (2017). We can get some sense of what this timeline looks like from the examples in (26) (the gaps here reflect gaps in this database). All of these examples have already been discussed except for the one in the first column (魚 *yú* ‘fish’). This set of characters does not illustrate any of the processes discussed in this paper, but I include it to highlight what is by far the most common approach to “explaining” Chinese character development, namely increasing abstraction (for a recent criticism of this approach, see Han, Kelly, Winters, & Kemp, 2022). We can even see how abstraction has continued beyond the traditional characters shown in the previous section, into the modern system of simplified characters (I phrase it this way because many of these simplified forms are ancient, but were not incorporated into a standardized system until the twentieth century).

(26)	Oracle bone script (ca. 1200 BCE)					
	Bronze inscriptions (ca. 1050 BCE)					
	Small seal script (ca. 200 BCE)					
	Early clerical script (ca. 50 BCE)					
	Late clerical script (ca. 100 CE)					
	Traditional regular script (ca. 1200 CE)					
	Simplified regular script (ca. 1950 CE)					

The dates here are very approximate, and are merely meant to indicate the temporal ordering. Oracle bone script is the oldest known, and as the name suggests, it was carved into flat animal bones, including oxen shoulder blades and turtle shells, as part of divination rituals. Incompletely written exemplars demonstrate that carvers sometimes scraped a bunch of lines in the same direction across multiple characters before rotating the bone to add lines in a different direction (Ven-

ture, 2001). Bronze inscriptions were also carved, this time with a stylus in the clay mold used for casting. Small seal script was the first to be officially standardized, since it was used to distribute official business across long distances, which meant that bones and bronze were out and bamboo strips were in, with the writing now done with ink brush pens. This change in physical medium may help explain the predilection in this script for curved strokes, which are difficult to carve. However, the physical medium cannot explain why clerical script, which was also written with a brush pen, nevertheless returned to the straighter strokes of earlier scripts. This peculiarity makes sense once one remembers that the temporal linearization here is misleading; the earlier straight-stroke styles had not disappeared during the small seal script era, and remained a source of influence on later styles. In fact, what I label here as early and late clerical script refer to the Western and Eastern Han dynasties, respectively, and thus reflect differences in space as well as time. It is an interesting coincidence that the gradual change from clerical script to traditional regular script, the modern version of which remains standard in Taiwan and Hong Kong, only began after paper came into widespread use in the first century CE, though it took another millennium before regular script became standard, starting in the Song dynasty, and in any case it is not obvious why a writing surface of greater versatility than bamboo strips would encourage strokes to become even straighter than they had already been in clerical script. Finally, the cobbling together of modern simplified script from bits of traditional regular script and alternate character forms, sometimes from stroke-deprived calligraphic styles, led to no change whatsoever in any of the patterns discussed in this paper (see Myers, 2019, for evidence that the grammars of traditional and simplified characters are virtually identical), and so it will not be discussed further. Note that neither this simplification, nor the many other small changes that occurred in Chinese script between the Song and Mao, and which for some reason elicit virtually no attention in the scholarly literature, involved any change in the physical medium.

Yes, increasing abstraction and changes in the tools of writing have both affected the evolution of Chinese characters, but that is hardly all there is to say about it. In particular, the above array of historical forms should not merely be scanned vertically, but also horizontally: each script has its own internally consistent synchronic system, or in other words, its own grammar. A complete analysis of all these synchronic grammars and all of their diachronic changes would go far beyond what I am capable of doing in this paper (though see Myers, 2019, for some first attempts at analyzing the synchronic grammars of the small seal script and the modern simplified system), but I can at least say something meaningful just about our three modern character form regularities: idiosyncratic allomorphy, reduplicative identity, and regular reduction. Namely, when did each of these patterns first emerge, and

was their real-world temporal ordering consistent with what we deduced in the previous section about their apparent ordering in the synchronic grammar of modern characters?

The answers are clear: like the synchronic ordering, regular reduction appears late in the historical record, but unlike the synchronic ordering, reduplicative identity arose long before idiosyncratic allomorphy. Reduplication as a morphological process is already attested in oracle bone script, and by definition the phonological phenomenon of reduplicative identity is attested then too; see (27), which shows oracle bone examples above the modern characters with which the corresponding Chinese morphemes are written today. However, as can be seen in (27b), the prosodic restriction on the arrangements of the copied elements did not yet exist in oracle bone script; the modern arrangements only emerged as many others were gradually lost over the course of the bronze and small seal script eras (see Behr, 2006, and Liu, 2008, for details).

(27) a.



林 *lín* 'forest'



炎 *yán* 'blazing'



晶 *jīng* 'glittering'

b.



疆 *jiāng* 'border'



少 *shǎo* 'few'



羶 *shān* 'rank odor'

Idiosyncratic allomorphy only appeared much later, during the development of clerical script, though the precise timing depends on the specific component, as shown in (28), where the horizontal lines indicate the division between scripts before and after the change. This apparent variation in timing may partially reflect incomplete records (note the gaps, including a lack of evidence for these specific characters in oracle bone script), but perhaps also lexical diffusion, where patterns spread from one word (or word class) to another by analogy, a diachronic course the is typical for lexicalized phonological patterns (Chen & Wang, 1975; Labov, 1981).

Regular reduction also emerged late, but dotting first appeared around the same time as the earliest idiosyncratic allomorphs, in early clerical script, whereas diagonalization did not appear until regular script. As shown in (29), dotting also showed apparent variation across characters containing the same component, as can be seen by comparing the first and second columns of characters.

(28)	Allomorphy	水 → 氵	手 → 扌	糸 → 纟	火 → 灬
	Bronze inscriptions				
	Small seal				
	Early clerical				
	Late clerical				
	Traditional regular				
		<i>hǎi</i> 'sea'	<i>tí</i> 'lift'	<i>gěi</i> 'give'	<i>zhào</i> 'shine'
(29)	Component	木	木	土	
	Oracle bones				
	Bronze inscriptions				
	Small seal				
	Early clerical				
	Late clerical				
	Traditional regular				
	Traditional regular	<i>gēn</i> 'root'	<i>xiāng</i> 'view'	<i>dì</i> 'earth'	

Variation in the development of regular reduction may again indicate lexical diffusion, but given that it is difficult to tell precisely when a stroke becomes short enough to consider a dot, or whether the deviation of a stroke from the strict horizontal is intentional, these variations could instead reflect phonetics. In favor of the lexical diffusion interpretation is the fact that dotting first appears around the same time that idiosyncratic allomorphy is also replacing full strokes with dots, as seen in the previous set of examples. It may also matter that the example of early dotting in the first

column above happens to be in a phono-semantic character, which is of a much more productive morphological type than the semantic compound showing late dotting in the second column. These subtleties make a difference to the analysis because, as we saw in the previous section, regular reduction has stronger phonetic motivations than idiosyncratic allomorphy, which would lead us to expect it to appear in the historical record in the classic all-at-once Neogrammarian fashion, rather than word by word as with more lexicalized patterns. I will need to take a closer look at the data in future research, but at least we can be sure that the final position of regular reduction in the modern synchronic ordering is only partially consistent with the historical chronology, given that it and idiosyncratic allomorphy began to emerge around the same time.

Setting all the inconvenient complexities aside, we can summarize the historical development of our three patterns with the misleadingly clean timeline in (30), where the examples are ordered chronologically from top to bottom but the rows do not necessarily represent historical simultaneity. Not only does this diachronic order deviate a bit from the synchronic ordering argued for in the previous section, but it also reveals that grammar played an active role in history, rather than merely being a fossilized remnant of it. In particular, note the interaction between reduplicative identity and idiosyncratic allomorphy in the rightmost two columns, in one of which these processes appeared simultaneously (with backcopy) and in the other of which reduplicative identity applied first, then was undone by idiosyncratic allomorphy, and finally reduplicative identity prevailed after all. The persistence of reduplicative identity across multiple scripts shows that it retained some degree of synchronic productivity even many centuries after its first appearance, whereas idiosyncratic allomorphy essentially lost whatever psychological backing it had had soon after its first appearance. The distinct ways in which these processes behave is more consistent with general psychological (or grammatical) principles choosing which pattern lives or dies, rather than the fickle vagaries of history.

Among the many ways in which this timeline is misleading is that it ignores the synchronic coherence within each of the historical scripts. Indeed, if something like traditional rule-ordering theories or Stratal OT have any psychological reality, each of these scripts itself had its own grammar with its own synchronic ordering. In particular, it would be interesting to see if the interaction between reduplicative identity and regular reduction has always been as opaque as it is in the modern grammar, which in Stratal OT terms would mean that they apply in universally distinct strata. That is what we expect to see if regular reduction has always been a phonetically motivated process (argued in the previous section to apply in the word stratum), in contrast to morphologically driven reduplication (in the stem stratum). As noted earlier, however, figuring this out would take more careful analysis of a richer database,

not to mention establishing grammars for each of the individual scribes in this database, in order to distinguish random phonetic variation from systematic character-by-character lexical diffusion. Readers who have glanced down to the end of this paper already know that I am not going to do any of this here.

(30)						
	Earliest forms	(bronze)	(seal)	(seal)	(bronze)	(oracle)
	Reduplicative identity: pre-seal					
					(seal)	(seal)
	Idiosyncratic allomorphy: clerical					
	Regular reduction: (post)clerical					
		(modern)	(clerical)	(modern)		
	Modern forms					

5. Conclusions

Just as in biology, the synchrony of Chinese character structure does not recapitulate its diachrony, but instead, at least as far as we can tell given the limited data discussed here, each synchronic stage has its own internal and apparently natural (rather than ad hoc) ordering of processes. This makes the evolution of this writing system similar to what has been observed for human language more generally, and presumably also for other writing systems. Concepts like phonological rules and prosodic OT constraints have been shown to be applicable to a wide variety of writing system patterns (see, e.g., Evertz, 2018, for German and English scripts, and Gnanadesikan, 2023, for Korean and Maldivian scripts), but I would be curious to know about synchronic patterns in other writing systems that only make sense if analyzed in terms of synchronic ordering mechanisms, whether or not the ordering matches history. A crude example would be the historical evolution of lowercase Roman letters from the much older uppercase, even though in the modern system the lowercase acts as the default, with capitalization restricted to special contexts (Primus, 2004).

Bausman and Weber (2025) argue that the biologist's evo-devo framework finds genuine analogs in the cultural evolution of human language, with the evo part relating to change over historical time and the devo part reflecting the cognitive constraints that shape the learning and use of the individual languages at specific historical stages. Based on the results in this paper, it seems that the same analogs can be extended to writing systems as well.

References

- Aitken, Adam J. (1981). "The Scottish Vowel-length Rule". In: *So many people longages and tonges: Philological essays in Scots and Mediaeval English presented to Angus McIntosh*. Ed. by Michael Benskin and M. L. Samuels. Edinburgh: The Middle English Dialect Project, pp. 131–157.
- Anderson, Stephen R. (1975). "On the interaction of phonological rules of various types". In: *Journal of Linguistics* 11, pp. 39–62.
- Bausman, William C. and Marcel Weber (2025). "What you can do for evolutionary developmental linguistics". In: *European Journal for Philosophy of Science* 15.1, pp. 1–18.
- Behr, Wolfgang (2006). "Homosomatic juxtaposition and the problem of 'syssymantic' (huiyi) characters". In: *Écriture chinoise: données, usages et représentations*. Ed. by Françoise Bottéro and Redouane Djamouri. École des hautes études en sciences sociales, Centre de recherches linguistiques sur l'Asie orientale, pp. 75–114.
- Chambers, Jack K. (1973). "Canadian Raising". In: *Canadian Journal of Linguistics* 18, pp. 113–135.
- Chen, Matthew Y. and William S.-Y. Wang (1975). "Sound change: Actuation and implementation". In: *Language* 51, pp. 255–281.
- Evertz, Martin (2018). *Visual prosody: The graphematic foot in English and German*. Berlin: Walter de Gruyter.
- Fruehwald, Josef (2016). "The early influence of phonology on a phonetic change". In: *Language* 92.2, pp. 376–410.
- Gnanadesikan, Amalia E. (2023). "Segments and syllables in Hangeul and Thaana: A comparison and optimality theoretic analysis". In: *Written Language & Literacy* 26.2, pp. 239–266.
- Hall, Kathleen Currie (2005). "Defining phonological rules over lexical neighbourhoods: Evidence from Canadian raising". In: *Proceedings of the 24th West Coast Conference on Formal Linguistics*. Ed. by John Alderete, Chung-hye Han, and Alexei Kochetov. Vol. 24. Somerville, Mass: Cascadia Proceedings Project, pp. 191–199.
- Halle, Morris (1962). "Phonology in generative grammar". In: *Word* 18, pp. 54–72.
- Han, Simon J. et al. (2022). "Simplification is not dominant in the evolution of Chinese characters". In: *Open Mind* 6, pp. 264–279.

- Hauser, Ivy and Coral Hughto (2020). "Analyzing opacity with contextual faithfulness constraints". In: *Glossa* 5.1, pp. 82.1–33.
- Inkelas, Sharon and Cheryl Zoll (2005). *Reduplication: doubling in morphology*. Cambridge: Cambridge University Press.
- Joos, Martin (1942). "A phonological dilemma in Canadian English". In: *Language* 18, pp. 141–144.
- Juang, Der-Ming [莊德明] (2017). 小學堂文字學資料庫的研發與應用 [*The development and application of the Xiaoxuetang Wenzixue Database*]. Taipei: Academia Sinica Center for Digital Cultures. URL: <https://xiaoxue.iis.sinica.edu.tw/>.
- King, Robert D. (1973). "Rule insertion". In: *Language* 49.3, pp. 551–578.
- Kiparsky, Paul (1968). "Language universals and linguistic change". In: *Universals in linguistic theory*. Ed. by Emmon Bach and Robert Harms. New York: Holt, Rinehart & Winston, pp. 170–202.
- (2014). "New perspectives in historical linguistics". In: *The Routledge handbook of historical linguistics*. Ed. by Claire Bower and Bethwyn Evans. Abingdon: Routledge, pp. 64–102.
- (2015). "Stratal OT: A synopsis and FAQs". In: *Capturing phonological shades within and across languages*. Ed. by Yuchau E. Hsiao and Lian-Hee Wee. Newcastle upon Tyne: Cambridge Scholars Publishing, pp. 1–44.
- Labov, William (1981). "Resolving the Neogrammarian controversy". In: *Language* 57.2, pp. 267–308.
- Liu, Man [刘曼] (2008). "叠体字的历时考察与认知比较研究 [The diachronic study and cognitive comparison of stacked characters]". PhD thesis. Beijing: Tsinghua University.
- Love, Alan C. (2024). *Evolution and development*. Cambridge, UK: Cambridge University Press.
- McCarthy, John (1999). "Sympathy and phonological opacity". In: *Phonology* 16.3, pp. 331–399.
- (2007). *Hidden generalizations: Phonological opacity in Optimality Theory*. London: Equinox Publishing.
- McCarthy, John and Alan Prince (1995). "Faithfulness and reduplicative identity". In: *University of Massachusetts Occasional Papers in Linguistics* 18. Ed. by Jill Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk. Amherst, MA: GLSA, pp. 249–384.
- Moreton, Elliott (2021). "Phonological abstractness in English diphthong raising". In: *American Speech* 106.1, pp. 13–44.
- Moreton, Elliott and Erik R. Thomas (2007). "Origins of Canadian Raising in voiceless-coda effects: A case study in phonologization". In: *Laboratory Phonology*. Ed. by Jennifer S. Cole and José Ignacio Hualde. Vol. 9. Berlin: Mouton, pp. 37–64.
- Myers, James (2016). "Knowing Chinese character grammar". In: *Cognition* 147, pp. 127–132.

- Myers, James (2019). *The grammar of Chinese characters: Productive knowledge of formal patterns in an orthographic system*. Abingdon: Routledge.
- (2021a). “Areal script form patterns with Chinese characteristics”. In: *Written Language & Literacy* 24.2, pp. 259–283.
- (2021b). “Levels of structure within Chinese character constituents”. In: *Proceedings of Grapholinguistics in the 21st Century, 2020*. Ed. by Yannis Haralambous. Vol. 5. Grapholinguistics and Its Applications. Brest: Fluxus Editions, pp. 645–681.
- (2022). “Teaching Chinese character grammar”. In: *Chinese Language Learning and Technology* 2.2, pp. 1–37.
- (2024a). “Interactions among patterns in Chinese character form”. In: *Looking at language from all sides*. Ed. by James Myers and James H-Y. Tai. Taipei: Crane Publishing, pp. 129–152.
- (2024b). “Perception and production of a feature correlation in Chinese characters”. In: *Written Language and Literacy* 27, pp. 153–177.
- (2025). “Prosody-like asymmetries in handwritten Chinese characters”. In: *Proceedings of the 2024 Annual Meeting of the Canadian Linguistic Association*. Ed. by Gavin Bembridge. Ottawa: Canadian Linguistic Association, pp. 1–14.
- Nevins, Andrew (2011). “Phonologically-conditioned allomorph selection”. In: *The Blackwell companion to phonology, Volume IV: Phonological interfaces*. Ed. by Marc van Oostendorp et al. Malden, MA: Wiley-Blackwell, pp. 2357–2382.
- Noske, Roland (2012). “The Grimm-Verner push chain and Contrast Preservation Theory”. In: *Phonological explorations: Empirical, theoretical and diachronic issues*. Ed. by Bert Botma and Roland Noske. Berlin: De Gruyter, pp. 63–86.
- Primus, Beatrice (2004). “A featural analysis of the Modern Roman Alphabet”. In: *Written Language & Literacy* 7.2, pp. 235–274.
- Prince, Alan and Paul Smolensky (2004). *Optimality Theory: Constraint interaction in generative grammar*. Malden, MA, and Oxford, UK: Blackwell.
- Pruitt, Kathryn (2023). “Serialism and opacity in phonological theory”. In: *Annual Review of Linguistics* 9, pp. 497–517.
- Qiu, Xigui (2000). *Chinese writing*. Compiled and translated from Chinese by G. L. Mattos and J. Norman. Berkeley: The Society for the Study of Early China and The Institute of East Asian Studies, University of California.
- Silby, Winston (2008). “t-flapping in New Zealand English: A change over time”. In: *New Zealand English Journal* 22, pp. 24–35.
- Steriade, Donca (2000). “Paradigm uniformity and the phonetics-phonology boundary”. In: *Papers in Laboratory Phonology*. Ed. by Michael Broe and Janet Pierrehumbert. Vol. 5. Cambridge, UK: Cambridge University Press, pp. 313–335.
- Vance, Timothy J. (1987). “‘Canadian Raising’ in some dialects of the northern United States”. In: *American Speech* 62, pp. 195–210.

- Venture, Olivier (2001). "Quelques observations au sujet de la mise en page des textes de divination sur plastron". In: *Actes du colloque international commémorant le centenaire de la découverte des inscriptions sur les carapaces*. Ed. by Shun-chiu Yau and Chrystelle Maréchal. Paris: Éditions Langages Croisés, pp. 71–90.
- Withgott, M. Margaret (1982). "Segmental evidence for phonological constituents". PhD thesis. University of Texas at Austin.

Beyond the Alphabet, Beyond the Binary, Maybe Beyond ‘Chinese’?

Digital Input Constraints on Gender-Inclusive Chinese Pronouns

Janet Ganon-Davey

Abstract. The emergence of gender-inclusive pronouns in Chinese reveals how globalised technological infrastructure for writing can create institutional barriers to orthographic innovation. Written Chinese has only distinguished gender in third-person pronouns for about a century, with 他 ‘he’, 她 ‘she’ and 它 ‘it’ all pronounced as *tā* in Mandarin. Recently, several new Chinese gender-inclusive pronouns have emerged. The emerging pronouns include a romanised form based on pinyin (‘TA’), as well as Chinese character forms (Sinographs) encoding nonbinary gender (e.g., 「无也」). In this study, I analyse data from two large Chinese-language corpora to investigate the frequency and use of these emerging gender-inclusive pronouns alongside binary pronouns 他 ‘he’ and 她 ‘she’. Results of the corpus analysis highlight how institutional technical requirements—particularly Unicode encoding standards and input method compatibility—shape which linguistic innovations can succeed. Proposed Sinograph pronouns remain virtually absent from mainstream discourse, as they cannot be typed using standard input systems. Meanwhile, ‘TA’ is increasingly accepted in mainstream discourse, with its utility as a gender-neutral pronoun facilitating its emergence as a gender-inclusive form. These findings reveal how the parameters of digital writing can constrain language change through requirements for global standardisation that neither local solutions nor social acceptance alone can overcome. While the introduction of the feminine pronoun 她 ‘she’ in the 1920s required navigation of social and practical linguistic constraints in China, contemporary Chinese pronoun innovation must also work within the parameters of global technological infrastructure governing Sinograph creation. This study thus illuminates broader questions about how globalised contemporary writing technologies shape the possibilities for script reform and innovation.

1. Introduction

In recent years, growing recognition of gender diversity has prompted greater attention to using gender-inclusive language, and in particular,

Janet Ganon-Davey  0000-0001-6607-393X

The Australian Centre on China in the World, China in the World Building #188, Fellows Lane, The Australian National University, Canberra 2601, Australia
E-mail: janet.davey@anu.edu.au

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 533–550. <https://doi.org/10.36824/2024-graf-dave>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

gender-neutral or gender-inclusive pronouns (Bradley, 2020; Robertson and Thompson, 2022; Troncoso, Schudson, and Gelman, 2023).¹ While much attention has focused on English singular ‘they’ and novel pronouns (‘neopronouns’) like ‘ze/zir’ (Arnold, Mayo, and Dong, 2021; Bjorkman, 2017; Sheydaei, 2021), the development of gender-inclusive pronouns in Chinese illuminates a distinct challenge: the relationship between linguistic innovation and digital writing infrastructure. In Chinese, the creation of new Sinographs now requires multiple layers of centralised institutional approval and technical implementation before widespread use becomes possible. This globally standardised constraint has major implications for how gender-inclusive language evolves in Chinese.

The Chinese third-person pronoun system has only distinguished gender in writing for about a century, with 他 ‘he’, 她 ‘she’, and 它 ‘it’ all pronounced *tā* in Mandarin (Ling, 1989).² In the past decade, several new gender-inclusive pronouns have emerged to cater to nonbinary and other gender-diverse Chinese language users. These innovative pronouns take various forms: some are standalone Sinographs (e.g., 「𠂇无也」), some combine Sinographic components with letters (e.g., 她), while others like ‘TA’ draw on the existing *tā* pronunciation (Lu, 2021). However, the practical constraints of digital Chinese writing significantly impact which of these new pronouns can achieve widespread use.

In this paper, I analyse how emerging gender-inclusive pronouns are used in contemporary Chinese texts compared to established binary pronouns 他 ‘he’ and 她 ‘she’. Through corpus analysis of pronoun frequency and usage patterns, I demonstrate that practical considerations—particularly those driven by technological constraints—are shaping which emerging gender-inclusive pronouns can succeed. While Sinograph neopronouns remain virtually absent, the pinyin-inspired pronoun ‘TA’ is becoming established in mainstream discourse. The technical requirements of typing and displaying new Sinographs thus appear to be creating significant barriers to Chinese pronoun innovation. These findings, reinforced by a recent survey of pronoun use among queer Chinese speakers (Davey, 2024), suggest that technological

1. Throughout the paper, I use ‘gender-neutral’ to refer to pronouns or other words that do not differentiate binary gender and/or are used for both men and women; ‘gender-inclusive’ to refer to words that either explicitly denote or implicitly encompass nonbinary genders; and ‘ungendered’ for words that do not contain or imply gender information. In some cases, the same pronoun can be gender-neutral or gender-inclusive. For example, English singular *they* can be used to refer to someone who is nonbinary, or someone whose gender is unknown (but is assumed to be a man or a woman).

2. Two additional third-person pronouns are used in Taiwan, *tā* 牠 for animals and *tā* 祂 for gods and deities (Cheng, 2016).

constraints may be steering Chinese gender-inclusive pronoun development toward solutions that work within existing digital parameters.

2. Background

Chinese characters, or Sinographs, are composed of distinct components that combine in rule-governed ways to convey both semantic and phonetic information (Myers, 2019; Wu, 2022). These semantic components play a crucial role in encoding meaning distinctions in writing that may not be reflected in speech. For instance, in modern Chinese pronouns, while all third-person singular forms are pronounced as *tā* in Mandarin, their written forms use different semantic components to distinguish gender. The masculine pronoun 他 ‘he’ features the component 亻 ‘human’ on the left side, reflecting its historical use as an ungendered pronoun. The feminine pronoun 她 ‘she’ instead uses 女 ‘woman’ on the left side to explicitly mark feminine gender (Liu, 1995). Both pronouns have 也 on the right side, which indicates the *tā* pronunciation in Mandarin.

This gender-distinguished pronoun system is relatively new—written Chinese has only marked gender in pronouns for a hundred years (Hong, 2020). However, the introduction of 她 ‘she’ in the 1920s has created an asymmetric system where the ‘human’ component of 他 permits its continued use as a default or generic pronoun, while 她 is exclusively used for women. Many scholars (e.g., Cheng, 2016; Farris, 1988; Hodge and Louie, 1998; Jung-Palandri, 1991; Moser, 1997) argue the specificity of 她 perpetuates default male subjectivity in written Chinese. This argument is supported by psycholinguistic research showing that the semantic components of Sinographs play a crucial role in gender processing during pronoun resolution, with 他 functioning as a default form that can apply to all genders while 她 is processed as specifically feminine (Su et al., 2012). This asymmetric gender marking in written but not spoken Chinese pronouns has sparked efforts to develop more inclusive alternatives for contemporary language users (Koon, 2022).

Several solutions have emerged to create more inclusive pronouns in contemporary Chinese. One approach advocates returning to the historical usage of 他 as a truly ungendered pronoun, arguing that its ‘human’ component better reflects this purpose (Cheng, 2016). Others suggest adopting pronouns from Chinese languages that lack written gender distinction, such as 佢 from Cantonese or 伊 from Wu, Southern Min and Taiwanese (Lu, 2021). More recently, two innovative proposed Sinographs have emerged specifically to represent nonbinary gender identity. The Sinograph neopronoun 𠄎, created in 2015 by intersex community group ‘雙性人 The Missing Gender 0.972’, preserves the *tā* pronunciation through 也 and uses 乂 as its left semantic component to reflect growing use of ‘X’ as a gender or sex maker (Quinan and Hunt, 2023;

Tang, Yi, and Bedin, 2022).³ 她 was formally encoded in Unicode 17.0 in September 2025 at codepoint U+323BF in the CJK Unified Ideographs Extension J block. Likewise preserving the *tā* pronunciation, another Sinograph neopronoun 「𠂔无也」, which was proposed by Ziping Zhu in 2021, features *wú* 无 ‘none’ as its left-side semantic component, explicitly rejecting binary gender categorisation (Papadopoulos and Zhu, 2022). Alongside these Sinograph neopronouns, the pinyin-inspired form ‘TA’ has gained traction in digital spaces (Ferrari, 2022). ‘TA’ follows a precedent of romanised loanwords being adopted in modern Chinese (e.g., PK ‘player kill—to take on, go head to head, showdown’; APP ‘smartphone app’; COS ‘cosplay’; Q ‘cute; pleasantly chewy’) while avoiding gender specification entirely.

However, these proposals face major technological hurdles. While the introduction of 她 ‘she’ in the early twentieth century met significant social resistance and required technical effort to implement through printed works, these challenges could at least be addressed through local solutions in individual print shops and publishing houses (Brokaw and Reed, 2010; Huang, 2009). The shift to digital writing has fundamentally altered how new Sinographs can be introduced. Unlike many alphabetic writing systems where pressing a sequence of keys on a keyboard immediately produces those exact symbols on screen—what Mullaney (2017, p. 317) calls a ‘what-you-type-is-what-you-get’ system—Chinese input requires converting user actions to encoded graphs in computer memory. This process relies on Input Method Editors (IMEs), “middleware” programs that mediate between user input and graph output (Mullaney, 2024, p. 5). To type in Chinese, users either enter phonetic ‘spelling’ using systems like Sogou pinyin, or build Sinographs by selecting character components or drawing strokes on a screen. The IME intercepts these inputs and continuously searches its database, presenting users with candidate graphs that match their keystrokes or gestures in a manner akin to predictive text (for a detailed discussion, see Mullaney, 2024). However, this means users can only type graphs that are already encoded in the system’s database—a constraint that has transformed localised technical barriers into requirements for global institutional approval.

Chinese input databases operate within the encoding frameworks of Unicode and ISO/IEC 10646. The Ideographic Research Group (IRG) reviews and coordinates the inclusion of proposed new graphs into the CJK (Chinese, Japanese, Korean) Unified Ideographs set and the Uni-

3. In Chinese, the term *xìngbié* 性别 encompasses both ‘sex’ and ‘gender’ as understood in English. While the United Nations gender-inclusive language guidelines promote *shèhuì xìngbié* 社会性别 ‘social gender’ and *shēnglǐ xìngbié* 生理性别 ‘sex’ to distinguish these concepts (United Nations, 2012), these terms are not widely used in everyday discourse.

versal Multiple-Octet Coded Character Set (USC, ISO/IEC 10646; Tsu, 2022). These centralised technological requirements create fundamental constraints on Chinese orthographic innovation. Since 「𠂇无也」 has no Unicode encoding, it cannot be rendered as a unified graph, and must be represented here via its component parts, with 𠂇 indicating the left-right arrangement. By contrast, 𠂇 has now completed this stage. Following an IRG submission from the UK in 2021 (UK-20538; UK, 2021), 𠂇 was formally encoded in Unicode 17.0 in September 2025 as U+323BF. As Figure 1 shows, 𠂇 is now able to be rendered as a single graph with the same visual unity as established Sinographs like 她.



FIG. 1. The Sinograph 𠂇 neopronoun, encoded as U+323BF in Unicode 17.0

Yet Unicode encoding alone does not guarantee adoption. Before a newly encoded Sinograph can be typed or displayed, it must be incorporated into IMEs, predictive input algorithms, and handwriting recognition systems, each of which requires independent institutional action at a global scale (Mullaney, 2024). As of mid-2026, 𠂇 remains absent from mainstream IMEs and the font sets bundled with major operating systems, meaning it still cannot be typed or reliably displayed by most users. These technological hurdles fundamentally shape how gender-inclusive language can develop in contemporary Chinese.

3. Methodology

To examine how emerging gender-inclusive pronouns are used in contemporary Chinese, I analysed data from two large-scale Chinese language corpora: Sketch Engine’s Chinese Web Corpus 2017 (zhTenTen17; Sketch Engine, 2020) and WuDaoCorpora (Yuan et al., 2021). zhTenTen17 provided the primary dataset, containing 16.6 billion tokens (13.5 billion words) of internet texts collected in 2016. To verify these findings against more recent language use, I also examined a 15 GB subset (91+ million tokens) of WuDaoCorpora, which consists of internet texts collected in 2022 by the Beijing Academy of Artificial Intelligence for AI model training.

My analysis proceeded in two stages. First, I examined Key Word In Context (KWIC) results to determine how frequently each pronoun appeared in the corpora. KWIC analysis displays the target word with its surrounding context, allowing examination of how words are used in

natural language data. Using Sketch Engine's online interface, I conducted case-insensitive searches for each pronoun (including variants like 'ta' and 'Ta' for 'TA'). For comparative analysis of each pronoun, I extracted randomly-sampled datasets of 10,000 concordance lines each for 他 'he' and 她 'she', and all 9,366 concordance lines for 'TA'. Since the frequency results showed no instances of 「无也」 or 她 functioning as pronouns, I excluded these from further analysis.

Second, I conducted collocation analysis to understand how 'TA' is being used in online discourse relative to binary pronouns 他 'he' and 她 'she'. Collocation analysis reveals which words ('collocates') frequently appear near a target word (the 'node'). However, simple frequency counts can be misleading since some words are inherently more common in a language. I therefore used two complementary statistical measures to identify meaningful collocates within three words of each pronoun:

- Log-likelihood scores: identify typical collocates by measuring how significant the co-occurrence is, accounting for overall word frequencies in the corpus
- Mutual information (MI) scores: measure strength of association by calculating how much more likely words are to appear together than separately

Using both measures allowed me to consider not just which words typically appear near pronouns, but also which word combinations were distinctive (Desagulier, 2017). Since both statistical measures are affected by corpus size, using equivalent-sized concordance datasets was crucial for valid comparison (Pojanapunya and Todd, 2016). For this analysis, I used AntConc (Anthony, 2022a) and RStudio (Posit Team, 2023) with R v.4.2.1 (R Core Team, 2022). Because Chinese text lacks marked word boundaries, all data was first processed using TagAnt (Anthony, 2022b) for word segmentation, allowing me to identify meaningful word collocates rather than just adjacent Sinographs or punctuation marks. The processed data was then analysed in two complementary stages: I first examined overall frequency patterns to identify which pronouns appear in contemporary online discourse, then conducted a detailed collocation analysis to understand how technological constraints can influence Chinese language users' pronoun choices.

4. Corpus Results

The corpus analysis revealed three key patterns that illuminate how digital writing infrastructure shapes contemporary Chinese pronoun use. First, stark frequency differences between established and emerging pronouns highlight immediate barriers to adopting Chinese gender-inclusive pronouns. Second, collocation patterns reveal both similarities

and differences between ‘TA’ and binary pronouns—while shared patterns demonstrate ‘TA’ functioning as a standard pronoun, distinct patterns show its broader utility beyond binary alternatives. Third, specific discourse contexts favouring ‘TA’ over binary pronouns suggest practical considerations can outweigh concerns about maintaining traditional orthographic standards—a tension that echoes centuries of debate about Chinese language reforms (Tsu, 2022; Zhou, 2003).

4.1. Pronoun Frequency

The KWIC analysis revealed pronounced differences in the frequency of third-person pronouns in zhTenTen17. As shown in Table 1, 他 ‘he’ occurred over 34 million times (0.21% of corpus), more than twice as frequently as 她 ‘she’ (15+ million hits, 0.093%). The disparity between the corpus frequency of 他 compared to 她 reflects several factors: 他 appears in compound words (e.g., *qítā* 其他 ‘other’), transliterations (e.g., *jítā* 吉他 ‘guitar’), and crucially, in the default plural pronoun *tāmen* 他们 ‘they’. The higher frequency of 他 in news content, particularly in coverage of political figures, also contributes to this disparity.

TABLE 1. KWIC results for Chinese pronouns in Chinese Web Corpus 2017 (zh-TenTen17)

Pronoun	Total hits	Clean hits	Hits per million tokens	Percentage of corpus
他	34,456,382	–	2,076.54	0.21%
她	15,355,986	–	925.44	0.093%
TA	17,071	15,969	1.03	0.000093%
它	9,558,920	–	576.08	0.058%
祂	16,918	–	1.02	0.00010%
牠	4,832	–	0.29	–
牠	35	0	–	–
「无也」	54	0	–	–

The romanised form ‘TA’ appeared much less frequently than 他 ‘he’ and 她 ‘she’, with 17,071 total occurrences in zhTenTen17. After removing false hits (such as abbreviations for ‘teaching assistant’ or airline flight numbers), 15,969 instances remained where ‘TA’ functioned as a pronoun. Most notably for this investigation of technological constraints, the Sinograph neopronouns 「无也」 and 牠 were entirely absent as pronouns; while these graphs appeared 54 and 35 times respectively, manual examination revealed these were all false hits in mathematical or programming contexts. The WuDaoCorpora dataset showed similar

patterns, suggesting these frequency differences persist in more recent online Chinese discourse. More broadly, these frequency patterns provide initial evidence of how technological constraints—namely the ability to type and display characters—shape which pronouns can achieve widespread use in contemporary Chinese discourse.

4.2. Collocation Patterns

Having established pronounced differences in pronoun frequency, I next examined how the pronouns function in context through collocation analysis. Analysing the collocation patterns revealed that the use of ‘TA’ shows both similarities and differences with binary pronouns 他 ‘he’ and 她 ‘she’. The possessive marker *de* 的 appeared as the most frequent immediate right collocate for all pronouns (‘TA’: 28%, 她: 27%, 他: 25%; i.e., TA的 ‘TA’s’, 她的 ‘her’, 他的 ‘his’). This suggests that ‘TA’ serves a standard pronominal function in contemporary Chinese discourse. However, the three pronouns showed distinct patterns in their other common collocates. While 他 ‘he’ was associated strongly with verbs of speech and authority (e.g., *shuō* 说 ‘speak’, *biǎoshì* 表示 ‘express’, *zhīchū* 指出 ‘point out’), and 她 ‘she’ frequently appeared in passive constructions with *ràng* 让 and *gěi* 给, ‘TA’ demonstrated more versatile positioning. As shown in Figure 2, the top collocates of ‘TA’ by log-likelihood included both active and passive markers (*gěi* 给 #3, *ràng* 让 #4, *duì* 对 #8, *gàosù* 告诉 #9), suggesting ‘TA’ functions flexibly in various syntactic positions and discourse roles.

Two collocation patterns proved particularly revealing about how ‘TA’ functions in contemporary Chinese discourse, patterns that partially explain why this pinyin form has achieved greater success than Sinograph alternatives. First, the plural marker *mén* 们 ranked notably higher for ‘TA’ (#2 in both log-likelihood and MI rankings) compared to binary pronouns (*tāmen* 他们 #19, *tāmen* 她们 #124 for 他 and 她 respectively). This suggests ‘TA’ frequently serves to de-gender plural references, offering an alternative to *tāmen* 他们 ‘they’ for referring to mixed-gender groups. Second, a cluster of ‘love’ and ‘relationship’ related collocates appeared among the top MI-ranked collocates for ‘TA’. As shown in Figure 3, this cluster includes *xīnài* 心爱 ‘beloved’ (#4), *xīnyí* 心仪 ‘admire’ (#6), and *ài* 爱 ‘love’ (#17), along with *xiàngmào* 相貌 ‘appearance’ (#1), *yuǎnlí* 远离 ‘be far away from’ (#3) and *ānwèi* 安慰 ‘comfort’ (#5).

To investigate whether this apparent clustering of ‘love’ and ‘relationship’ collocates was distinctive to ‘TA’, I conducted a keyword analysis comparing the ‘TA’ concordance data against reference corpora of 他 ‘he’ and 她 ‘she’. A keyword is a word that appears with a statistically significant higher frequency in the target corpus compared to the reference corpus (Anthony, 2023; Pojanapunya and Todd, 2016). The key-

TABLE 2 (continued)

Rank	TA vs. 他	TA vs. 她
16	让 'let/make'	可能 'possible'
17	浪漫 'romantic'	最 'most'
18	朋友 'friend'	款 'sum; section'
19	想 'think/want'	有 'have'
20	是 'is/are'	们 (plural suffix)
21	那么 'so/then'	分手 'break up'
22	有 'have'	喜欢 'like'
23	孩子 'child'	软件 'software'
24	你们 'you (plural)'	的 'of'
25	分手 'break up'	伴侣 'partner'

Relationship-related words with high keyness scores for 'TA' included *bǎobǎo* 宝宝 'baby' (#5/7), *duìfāng* 对方 'other party; significant other' (#8/10), *àiqíng* 爱情 'romantic love' (#11/10) and *làngmàn* 浪漫 'romance' (#13/17). These words all had a normed frequency in the 'TA' corpus that was significantly greater than their normed frequency in the binary pronoun reference corpora, providing evidence to suggest that this cluster of 'love'/'relationship' collocates distinctly appear with 'TA'.

4.3. Discourse Contexts For 'TA'

To better understand the contexts in which 'TA' appears in contemporary Chinese discourse, I conducted detailed analysis of the concordance data. This examination revealed two main contexts where 'TA' is frequently chosen over binary pronouns 他 'he', 她 'she' or the construction 他/她 'he/she' in contemporary online discourse. First, 'TA' is used as a convenient gender-neutral way for social media and e-commerce platforms to communicate with or represent their users. For example, the social media platform Renren could generate this message to users: "TA们还在人人网等着你" ("**they** [TA] are waiting for you on Renren.com").

Second, 'TA' often appears in online discussions of love or relationships where the referent's gender is deliberately unspecified. In many cases, this appears to facilitate more open discussion of romantic sentiments towards another person by representing them as an abstract, ideal person (e.g., my 'Miss/Mr. Right')

(1) 第二步：选择你喜欢的QQ个性红包吧，有很多个性红包供你选择。第三步：把你满满的祝福和爱意发给心爱的TA吧。

Step two: Choose a QQ personalised red envelope that you like. There are many personalised red envelopes to choose from. Step three: Send your heartfelt wishes and love to your **beloved** [TA].



FIG. 3. Top 20 collocates of each pronoun by mutual information (MI) score

(2) 不管是男人还是女人，爱上一个人时，可以图TA的相貌，图TA的内在，甚至是TA的物质，但千万别掏心掏肺的去爱上TA，得想办法让TA爱上你。

No matter if it's a man or a woman, when you fall in love with someone, you may be attracted to **their** [TA's] appearance, **their** [TA's] inner qualities or even **their** [TA's] material possessions. But never ever pour your whole heart and soul into loving **that person** [TA]. You must find a way to make **them** [TA] fall in love with you.

These usage patterns suggest that, in mainstream contemporary discourse, 'TA' functions primarily as a gender-neutral pronoun—one that avoids specifying gender while still operating within the binary framework—and only infrequently as an explicitly gender-inclusive pronoun. In Example (2), the phrase “不管是男人还是女人” (“no matter if it's a man or woman”) frames 'TA' as operating within, rather than challenging, the gender binary. The broader utility of 'TA' as a gender-neutral pronoun—particularly in relationship discourse and platform user communication—appears to be key to its growing mainstream acceptance. Meanwhile, the technical barriers to typing and displaying Sinograph neopronouns appear to be severely limiting their adoption beyond specialised queer spaces. This contrast highlights how both practical utility and technical accessibility shape which new pronouns can gain widespread use in contemporary Chinese.

5. Discussion

The corpus analysis reveals how globalised technological infrastructure actively shapes, rather than simply enables or constrains, the emergence of gender-inclusive pronouns in contemporary Chinese. The data demonstrates three interconnected patterns: the complete absence of Sinograph neopronouns despite their creation predating many instances of ‘TA’; the emergence of ‘TA’ as a functionally flexible alternative serving both standard pronominal and distinctive discourse roles; and the adoption of ‘TA’ primarily for its practical utility in avoiding gender specification rather than explicitly for gender inclusivity. Together, these patterns illuminate how technical constraints actively shape the possibilities for Chinese pronoun innovation.

First, the absence of Sinograph neopronouns from a 13.5 billion word corpus is striking. This cannot be attributed solely to their recent creation; 他 was created in 2015, predating many instances of ‘TA’ in the data. Rather, the corpus evidence suggests that technical barriers to typing and displaying new Sinographs effectively prevent linguistic innovations from entering general usage, regardless of their potential social acceptance. This mirrors historical tensions in Chinese writing reform, where practical implementation requirements have long shaped which innovations succeed (Huang, 2009; Tsu, 2022).

Second, the collocation patterns provide further evidence of how technological constraints influence contemporary pronoun development. ‘TA’ demonstrates both standard pronominal functions—with high frequencies of possessive and plural constructions and both active and passive markers—and distinctive usage patterns centred around relationship-focused discourse. These patterns suggest that ‘TA’ has achieved wider adoption not just as a substitute for binary pronouns, but as a practical solution to situations where gender specification is unnecessary or undesirable. Like English singular ‘they’, ‘TA’ can thus serve either as a gender-neutral pronoun for unspecified binary gender or as a gender-inclusive pronoun for nonbinary referents (Bjorkman, 2017).

Third, the specific discourse contexts revealed by the corpus data further illuminate how practical utility drives pronoun innovation. ‘TA’ appears frequently in platform communication and relationship discussions, contexts where gender neutrality serves communicative purposes beyond deliberate gender inclusivity. Survey data reinforces this finding, with queer Chinese language users noting that ‘TA’ “suits people’s everyday pronunciation habits” and “doesn’t create issues with having to specify someone’s gender” (Davey, 2024). This parallels the historical introduction of 她 ‘she’ in the 1920s, where successful adoption depended not just on social acceptance but on matching existing language conventions (for a detailed discussion, see Davey, 2024). However, while the technical hurdles for writing 她 could be addressed through local inno-

vation (Huang, 2009), contemporary Chinese pronoun innovation faces globalised technological constraints.

These three interconnected patterns revealed by the corpus analysis together highlight how contemporary Chinese pronoun innovation operates within fundamentally different constraints than both alphabetic systems and historical Chinese writing technologies. New English pronouns like 'ze/zir' can be typed as soon as they are conceived, and other writing technologies at least allowed for local creation and reproduction of new Sinographs through handwriting, or else woodblock or metal type printing (Brokaw and Reed, 2010). Conversely, while contemporary Chinese input systems are highly sophisticated—with typing speeds that can match or exceed those achieved in alphabetic systems (Mullaney, 2024)—new Sinographs require centralised institutional approval and global technical implementation. A newly encoded Sinograph must be incorporated into IMEs before it can be typed, into predictive input algorithms before it surfaces as a candidate, and into font sets before it can be displayed, with each step requiring independent institutional action at a global scale. The trajectory of 他 illustrates this: formally encoded in Unicode 17.0 in September 2025—more than a decade after its creation—it remains absent from mainstream IMEs and inaccessible to most users. Unlike historical writing technologies where local solutions allowed for Sinograph creation and reproduction, none of these steps can be achieved by individual language users or communities acting alone. The result is that orthographic innovation in digital Chinese writing remains effectively beyond the reach of those it is meant to serve.

The corpus results therefore reveal how institutional technological constraints are actively steering the emergence of Chinese gender-inclusive pronouns. While the identical pronunciation of all third-person pronouns as *tā* in Modern Standard Chinese might seem to facilitate gender-inclusive language development, the technical requirements of digital Sinograph creation have pushed development toward solutions that work within existing digital parameters. In particular, the corpus evidence shows that while 'TA' has found viable use cases that facilitate its adoption, Sinograph neopronouns remain effectively excluded from mainstream discourse. This disparity cannot be explained by social factors alone. Rather, the complete absence of Sinograph neopronouns from the corpus data demonstrates how the technical requirements of digital writing—particularly Unicode encoding and input method compatibility—create fundamental limitations on orthographic innovation that differ markedly from both historical Chinese writing technologies and contemporary alphabetic systems. Survey data from queer Chinese speakers reinforces this interpretation (see Davey, 2024). While many survey respondents expressed preference for a 'real' Chinese pronoun, they consistently noted that Sinograph neopronouns were "hard to type" and "cannot be displayed by many computer systems". The emergence

of 'TA' in the corpus data, coupled with the complete absence of Sino-graph neopronouns, reveals how practical technological considerations can outweigh traditional orthographic concerns.

More broadly, these findings underscore how globalised technological infrastructure fundamentally reshapes the possibilities for linguistic innovation in contemporary Chinese. While historical barriers to Sinograph creation could be overcome through technological and social change at a local level, creating new Sinographs in modern digital writing systems requires multiple layers of global institutional approval and technical implementation that remain inaccessible to ordinary language users. The case of gender-inclusive pronouns illustrates this transformation clearly: despite the identical *tā* pronunciation providing a seemingly natural foundation for innovation, the technical parameters of digital writing have actively steered development toward solutions like 'TA' that work within existing systems. This highlights how global technological infrastructure plays a formative role in shaping contemporary language change, moving beyond merely enabling or constraining linguistic innovation to actively steering its development through institutionalised technical requirements.

6. Conclusion

The development of gender-inclusive pronouns in Chinese offers a window into how technological infrastructure shapes linguistic possibilities. While the introduction of gender-distinguished pronouns a century ago also required navigation of social resistance and existing linguistic conventions, these could at least be addressed within China. Contemporary Chinese pronoun innovation faces an additional challenge: the centralised technological parameters and institutional approval processes of digital Chinese writing. The corpus evidence presented in this paper reveals how these constraints manifest in actual language use, with Sino-graph neopronouns remaining absent from mainstream discourse while 'TA' gains acceptance through its broad utility as a dual gender-neutral and gender-inclusive pronoun. These findings have implications beyond the specific case of Chinese gender-inclusive pronouns. As written Chinese continues to evolve in the digital age, the requirements of Unicode encoding and input method compatibility create specific barriers to linguistic innovation even as Chinese digital writing demonstrates remarkable efficiency and adaptability in other respects. Yet the emergence of 'TA' suggests an alternative path—one where practical utility may sometimes outweigh adherence to traditional orthographic conventions. This highlights how the technological infrastructure of modern writing systems does not simply enable or constrain linguistic innovation but actively shapes the direction of language change.

References

- Anthony, Laurence (2022a). *AntConc (version 4.2.0)*. URL: <https://www.laurenceanthony.net/software>.
- (2022b). *TagAnt (version 2.0.5)*. URL: <https://www.laurenceanthony.net/software>.
- (Mar. 17, 2023). "Common statistics used in corpus linguistics". In: URL: https://laurenceanthony.net/resources/statistics/common_statistics_used_in_corpus_linguistics.pdf.
- Arnold, Jennifer E., Heather C. Mayo, and Lisa Dong (2021). "My pronouns are *they/them*: Talking about pronouns changes how pronouns are understood". In: *Psychonomic Bulletin & Review* 28.5, pp. 1688–1697. ISSN: 1069-9384, 1531-5320. DOI: 10.3758/s13423-021-01905-0. (Visited on 12/19/2024).
- Bjorkman, Bronwyn M. (2017). "Singular *they* and the syntactic representation of gender in English". In: *Glossa: A journal of general linguistics* 2.1. ISSN: 2397-1835. DOI: 10.5334/gjgl.374. (Visited on 12/19/2024).
- Bradley, Evan D. (Mar. 2020). "The influence of linguistic and social attitudes on grammaticality judgments of singular 'they'". In: *Language Sciences* 78, p. 101272. ISSN: 03880001. DOI: 10.1016/j.langsci.2020.101272.
- Brokaw, Cynthia Joanne and Christopher A. Reed, eds. (2010). *From woodblocks to the Internet: Chinese publishing and print culture in transition, circa 1800 to 2008*. Sinica Leidensia. Leiden ; Boston: Brill. 440 pp.
- Cheng, Vincent T.-W. (2016). "Radical equity: A case study of the use of Chinese third-person pronouns in Taiwan's third grade social studies textbook". In: *Intercultural Communication Studies* 25.3, pp. 99–111.
- Davey, Janet (2024). "Taking 'TA' beyond the binary: In search of multi-modal gender-inclusive pronouns in Chinese". In: *Image [ε] Narrative* 25.3.
- Desagulier, Guillaume (2017). *Corpus linguistics and statistics with R*. New York, NY: Springer Berlin Heidelberg.
- Farris, Catherine S. (1988). "Gender and grammar in Chinese: With implications for language universals". In: *Modern China* 14.3, pp. 277–308.
- Ferrari, Pisana (Apr. 25, 2022). "The gradual rise of gender-neutral pronouns in Hong Kong and mainland China". In: *cApStAn*. URL: <https://web.archive.org/capstan.be/the-gradual-rise-of-gender-neutral-pronouns-in-hong-kong-and-mainland-china/> (visited on 05/10/2022).
- Hodge, Bob and Kam Louie (1998). *The politics of Chinese language and culture: The art of reading dragons*. Culture and communication in Asia. London, New York: Routledge. 182 pp.
- Hong, Yeonok (2020). "Change in Chinese personal pronouns from a typological perspective". In: *The Linguistics Journal* 14.1, pp. 233–258.
- Huang, Xingtao (2009). "她"字的文化史: 女性新代词的发明与认同研究 [*The cultural history of the Chinese character "她": A study of the creation and acceptance*

- of a new feminine pronoun]. 福建 [Fujian]: 福建教育出版社 [Fujian Education Press].
- Jung-Palandri, Angela (1991). "Gender and sexism in Chinese language and literature". In: *Schriftfestschrift: Essays on writing and language in honor of John DeFrancis on his eightieth birthday, Sino-Platonic Papers*. Ed. by Victor H. Mair. Vol. 27. Sino-Platonic Papers. Philadelphia, PA: Department of Oriental Studies, University of Pennsylvania, pp. 167–170.
- Koon, Wee Kek (Feb. 24, 2022). "How non-binary Chinese people seeking a gender-neutral third-person pronoun for themselves are coming up with solutions, including a new Chinese character". In: *South China Morning Post*. URL: <https://www.scmp.com/magazines/post-magazine/short-reads/article/3168100/how-non-binary-chinese-people-seeking-gender> (visited on 05/10/2022).
- Ling, Yuanzheng (1989). "“她”字的创造历史 [The history of the Chinese character “她”]". In: *语言教学与研究 [Language Teaching and Linguistic Studies]* 4, pp. 139–151.
- Liu, Lydia He (1995). *Translingual practice: Literature, national culture, and translated modernity—China, 1900-1937*. Stanford, CA: Stanford University Press. 474 pp.
- Lu, Zhao (June 26, 2021). "他/TA/X也: What pronouns do Chinese queer people use?" In: *RADII*. URL: <https://radii.co/article/pronouns-chinese-queers> (visited on 05/01/2022).
- Moser, David (1997). "Covert sexism in Mandarin Chinese". In: *Sino-Platonic Papers*. Ed. by Victor H. Mair. Vol. 74. Philadelphia, PA: Department of Asian and Middle Eastern Studies, University of Pennsylvania, pp. 1–23.
- Mullaney, Thomas S. (2017). *The Chinese typewriter: A history*. Cambridge, MA: MIT Press.
- (2024). *The Chinese computer: A global history of the information age*. Studies of the Weatherhead East Asian Institute, Columbia University. Cambridge, MA: MIT Press.
- Myers, James (2019). *The grammar of Chinese characters: Productive knowledge of formal patterns in an orthographic system*. New York ; London: Routledge.
- Papadopoulos, Ben and Zipeng Zhu (Aug. 2, 2022). "A conversation with Zipeng Zhu". In: *Gender in Language Project*. URL: www.genderinlanguage.com/mandarin/zipengzhu (visited on 05/10/2022).
- Pojanapunya, Punjaporn and Richard Todd (2016). "Log-likelihood and odds ratio: Keyness statistics for different purposes of keyword analysis". In: *Corpus Linguistics and Linguistic Theory* 14. DOI: 10.1515/cllt-2015-0030.
- Posit Team (2023). *RStudio: Integrated development environment for R*. Boston, MA. URL: <http://www.posit.co/>.
- Qualtrics (2023). *Qualtrics XM*. Version April 2023. URL: <https://www.qualtrics.com>.

- Quinan, C. L. and Mina Hunt (2023). "Non-binary gender markers: Mobility, migration, and media reception in Europe and beyond". In: *European Journal of Women's Studies* 30.3, pp. 380–390. ISSN: 1350-5068, 1461-7420. DOI: 10.1177/13505068211024891. (Visited on 12/19/2024).
- R Core Team (2022). *R: A language and environment for statistical computing*. Vienna, Austria. URL: <https://www.R-project.org/>.
- Robertson, Meg and Riki Thompson (2022). "Shifting attitudes, shifting styles: Codifying gender-inclusive language use in style manuals". In: *Attitudes towards gender-inclusive language: A multinational perspective*, September 8–9, Queen Mary University of London, London, UK.
- Sheydaei, Iman (2021). "Gender identity and nonbinary pronoun use: Exploring reference strategies for referents of unknown gender". In: *Gender and Language* 15.3. ISSN: 1747-633X, 1747-6321. DOI: 10.1558/genl.18871. (Visited on 12/19/2024).
- Sketch Engine (Sept. 17, 2020). *ZhTenTen – Chinese corpus from the web*. URL: <https://www.sketchengine.eu/zhtenten-chinese-corpus/#toggle-id-1>.
- Su, Jui-Ju et al. (2012). "When 'he' can also be 'she': An ERP study of reflexive pronoun resolution in written Mandarin Chinese". In: *Frontiers in Psychology* 7. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2016.00151. (Visited on 12/19/2024).
- Tang, Chelsea, Irene Yi, and Cooper Bedin (2022). "Mandarin Chinese". In: *Gender in Language Project*. URL: www.genderinlanguage.com/mandarin (visited on 05/06/2022).
- Troncoso, Solangel C., Zach C. Schudson, and Susan A. Gelman (June 2023). "Women versus females: Gender essentialism in everyday language". In: *Journal of Psycholinguistic Research* 52.3, pp. 975–995. ISSN: 0090-6905, 1573-6555. DOI: 10.1007/s10936-022-09917-0. (Visited on 12/19/2024).
- Tsu, Jing (2022). *Kingdom of characters: The language revolution that made China modern*. New York: Riverhead Books.
- UK (May 1, 2021). "IRG N2487: UK Submission for IRG Working Set 2021". In: *IRG Collection 2021, Universal Multiple-Octet Coded Character Set, International Organization for Standardization*. URL: <https://appsrv.cse.cuhk.edu.hk/~irg/irg/irg56/IRGN2487UKData002.pdf> (visited on 05/22/2023).
- United Nations (2012). "中文性别包容性语言指南 [Guidelines for gender-inclusive language in Chinese]". In: URL: <https://www.un.org/zh/gender-inclusive-language/guidelines.shtml> (visited on 05/02/2022).
- Wu, Junru (2022). "Neurocognition in the reading of Chinese characters". In: *Journal of Chinese Writing Systems* 6.3, pp. 167–183. DOI: 10.1177/25138502211061605.
- Xu, Zhe and Patrick Sturt (2023). "The influence of stereotypical information on gender inference in Chinese". In: *SN Social Sciences* 3.2,

- p. 30. ISSN: 2662-9283. DOI: 10.1007/s43545-023-00618-6. (Visited on 12/19/2024).
- Yuan, Sha et al. (2021). “WuDaoCorpora: A super large-scale Chinese corpora for pre-training language models”. In: *AI Open* 2, pp. 65–68. ISSN: 2666-6510. DOI: 10.1016/j.aiopen.2021.06.001.
- Zhou, Youguang (2003). *The historical evolution of Chinese languages and scripts*. Pathways to Advanced Skills Series. Foreign Language Publications.

The Efficiency of Spelling-Sound and Spelling-Meaning Mappings in Two Logographic Writing Systems

Noah Hermalin

Abstract. A line of research in linguistics and cognitive science argues that many properties of language and linguistic structure are shaped, at least in part, by functional pressures to communicate efficiently, with efficiency defined relative to the trade-off between the accuracy and effort of communication. Research in this vein has argued that certain properties in language which seem intuitively inefficient, such as lexical ambiguity, are not only less inefficient than is commonly thought, but may in fact support, rather than contradict, the hypothesis that efficiency pressures shape language. The work presented here applies this line of thinking to two unrelated writing systems, written Sumerian and written Japanese, which both prominently feature properties which might be seen as inefficient, namely ambiguity and logography. Drawing on methods from information theory and past work on communicative efficiency, the efficiency of mappings between written forms and sound and between written forms and meanings is quantified for these two writing systems and compared against a battery of plausible hypothetical competitor systems, including variants which make greater use of phonography. The real systems are found to be more efficient overall than the hypothetical competitors, which is consistent with the efficiency hypothesis. The results are discussed relative to the question of efficiency pressures in writing systems, the inefficient ‘reputation’ of certain writing systems, and the linguistic fit of writing systems.

Introduction

Writing systems invariably have some degree of non-isomorphism between written forms and other linguistic information such as sounds and words. It is common, for example, for a writing system to have written forms that can be read in more than one way, or multiple ways of spelling a given sound or word. Another property found, to varying degrees, in virtually all writing systems is that a given word’s spelling might not be a function only of that word’s pronunciation; this is especially salient

Noah Hermalin  0009-0002-3200-5095

Department of Linguistics, University of California, Berkeley, US

E-mail: nmhermalin@berkeley.edu

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 551–595. <https://doi.org/10.36824/2024-graf-herm>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

in writing systems that often have individual characters encode information at the lexical or morphological level. The former property, the lack of one-to-one mappings, can be termed *ambiguity*, *polyvalence*, or *non-isomorphism*. The latter property falls under the header of *logography*. Both of these properties have been cast by some as being sources of inefficiency in writing systems, and have factored into arguments both for and against the idea that writing systems are shaped by ‘natural’ pressures, such as pressures to be communicatively efficient. The research presented here is concerned with the interaction of these two properties, and how they affect writing system (in)efficiency. How, and why, do certain writing systems make use of polyvalent, logographic characters/spellings, and do these properties manifest in a way that facilitates, rather than impedes, communicative efficiency?

The expectation is that the presence and instantiation of logography and non-isomorphism in writing systems is more beneficial, rather than detrimental, to the efficiency of such writing systems, and thus constitute evidence in favor of the hypothesis that writing systems are shaped by communicative efficiency pressures. In other words, these properties, despite their uneven reputation, are not structural flaws which are merely tolerated for reasons of culture or a general ‘conservatism’ regarding writing systems. This hypothesis fits in not only with functionalist approaches to linguistics and cognitive science generally, particularly with regards to the burgeoning literature on how efficiency shapes language (Gibson et al., 2019), but also with broader question of why writing systems are the way they are (and aren’t the ways they aren’t).

Comments on Terminology

As is often remarked on, writing systems terminology varies by author. Appendix A provides brief definitions for certain terms as they will be used in the current paper.

Efficiency

Language, in all modalities, is used for communication. As such, one might expect, or at least hope, that language is well suited for communication. This expectation can be taken a step further by hypothesizing that language is the way it is (at least in part) *because* it has been shaped by communicative pressures. Adding one more layer of specificity, one can consider whether the pressure to communicate *efficiently*, as defined below, can explain various properties of human language. The hypothesis that efficiency shapes language will be referred to here as the *efficiency hypothesis*.

The last few decades have seen an influx of research that directly considers the efficiency hypothesis (for recent reviews, see Kemp, Xu, and Regier (2018), Gibson et al. (2019), Mahowald, Dautriche, et al. (2022), and Levshina (2022, pp. 3–35))¹. Such research has focused on a range of linguistic topics, both broad and narrow, but much of it is unified by similar methodological approaches which make use of concepts and methods from information theory (Cover and Thomas, 1991; Shannon, 1948).

To begin, there is the basic information theoretic model of what communication is. As summarized by Gibson et al.:

First, an information source selects a message to be transmitted. Next, the message is encoded into a signal, and that signal is sent to a receiver through some medium called a channel. The receiver then decodes the signal to recover the intended message. Successful communication takes place when the message recovered at the destination is [identical or nearly identical] to the message selected at the source. Efficiency in communication means that successful communication can be achieved with minimal effort on average by the sender and receiver. (Gibson et al., 2019, p. 391)

In the context of linguistic communication, both the information source and the encoder are a language user who wishes to linguistically convey some idea, message, knowledge state, etc. Similarly, the receiver and destination are both some other language user, who receives the signal and decodes it in an attempt to reconstruct the target message. The signal itself takes the form of linguistic units, such as words, as realized by a particular modality.

As mentioned above, communicative *efficiency* is based on both how accurate communication is and how effortful it is. Regarding the terminology that will be used in this paper, a system's *informativeness* is a matter of whether it enables communication which is accurate/successful. A system's *complexity* refers to how effortful it is to use that system. Ideally, a communication system is maximally informative and minimally complex: taken to the extreme, a maximally efficient system would be one that is completely effortless to learn and use and enables communication that is one-hundred percent accurate one-hundred percent of the time.

However, such a system does not exist. There is a tension underlying informativeness and complexity, namely that each of these two factors imposes limits on the other which leads to a trade-off relationship between them. In order for a communication system or event to increase

1. It should of course be acknowledged that functionalist, efficiency-based accounts of language are by no means the only accounts of language, nor is the efficiency hypothesis without good-faith critics. Some recent critiques of some efficiency-related arguments include Caplan, Kodner, and Yang (2020), Levshina (2021), and Morin and Koshevoy (2024).

informativeness, it typically needs to be more complex, and vice versa. In light of the push-pull of informativeness and complexity, efficiency becomes a matter of how well a system optimizes the informativeness-complexity trade-off. If a system is as informative as it can possibly be given its level of complexity and is as simple as it can be given how informative it is, it can be viewed as optimally efficient. An important consequence of this approach is that two systems that differ in both informativeness and complexity can still be comparably efficient, provided that the more complex system is more informative than the simpler system.

In order to put this model of efficiency into practice, it is necessary to define informativeness and complexity in ways that can be quantified. Conceptually, any measure which can compare the difference between the intended message of the sender and the reconstructed message of the receiver, or can capture the quality and consistency of using particular signals for communication, would be suitable for informativeness. Concepts from information theory (e.g., surprisal, entropy, mutual information) are often used to quantify informativeness, though there is not a single, unified informativeness metric which is the standard across the literature. Complexity (or effort) encompasses a wide range of factors relevant to language. Measures such as utterance length, rate of communication, motor difficulty, or short-term memory burdens are among the ways to capture aspects of in-the-moment effort. Counting the number of distinct unit types in a language (e.g., distinct morphemes, phonemes, etc.) or the number of grammatical rules that a language's users need to know would help measure effort from the perspective of acquiring and maintaining proficiency. Like with informativeness, there is no single, unified complexity metric, and any given element of complexity may itself be measured in different ways. In addition, some dimensions of complexity may trade-off with other dimensions of complexity.

The question of whether language is shaped by efficiency pressures can be rephrased as: to what extent are various *properties* of language shaped by efficiency pressures? Turning to the literature, one finds evidence that quite a few properties of language seem to be shaped at least in part by efficiency pressures, including (but not limited to): word length (e.g., Mahowald, Fedorenko, Piantadosi, and Gibson, 2013; Piantadosi, Tily, and Gibson, 2011; Pimentel, Meister, et al., 2023; Zipf, 1949); articulation (e.g., Aylett and Turk, 2004; Cohen Priva, 2017; Gahl, Yao, and Johnson, 2012); syntax and word order (e.g., Futrell, Mahowald, and Gibson, 2015; Gildea and Temperley, 2010); morphology (e.g., Dye, Milin, Futrell, and Ramscar (2018) for grammatical gender; Wang and Walther (2023) for classifiers; Fedzechkina, Jaeger, and Newport (2011) and Lee (2009), and Kurumada and Jaeger (2015) for case marking; Mollica, Bacon, Zaslavsky, et al. (2021) for tense); pronouns (Denić, Steinert-Threlkeld, and Szymanik, 2020); information rate (e.g., Coupé,

Oh, Dediu, and Pellegrino, 2019; Jaeger, 2010); and, as will be discussed below, semantic typology, colexification, and ambiguity.

Ambiguity and Efficiency

One prevalent property of language which is often raised as an example of communicative *inefficiency*, is that of ambiguity, which is present at multiple levels of linguistic structure (cf. Wasow, 2015). One of the more salient types of ambiguity is lexical ambiguity, including homophony and polysemy/colexification, and it is lexical ambiguity that will be the main focus of this brief review.

Intuitively, ambiguity is detrimental for communication from the perspective of the decoder who, in the absence of additional information, will have a reduced likelihood of reconstructing the intended message; in terms of a complexity-informativeness trade-off, ambiguity reduces informativeness, and as such reducing ambiguity has the potential to improve efficiency. Indeed, there is evidence that ambiguity avoidance may be an explanatory factor in language change (e.g., Wedel, Kaplan, and Jackson (2013) regarding phonological mergers; Zehentner (2022) on the emergence of syntactic constructions) and acquisition (e.g., Yin and White, 2018). There is also evidence that, at least for high frequency forms, homophones are less common than would be expected by chance (Trott and Bergen, 2020; 2022), while minimal pairs are more common than would be expected (see also Dautriche et al., 2017).

Nonetheless, it has been proposed that some amount of ambiguity is necessary (e.g., Juba, Kalai, Khanna, and Sudan, 2011) and may even be beneficial for language (e.g., Peloquin, Goodman, and Frank, 2020; Piantadosi, Tily, and Gibson, 2012). The necessity of ambiguity is intuitive when one considers how impractical it would be to have a completely unambiguous system where every possible meaning has its own distinct form. The crux of the pro-efficiency argument for ambiguity is that ambiguity has the potential to decrease system complexity, by virtue of decreasing the number of distinct forms needed to communicate, and that in practice, contextual information will serve to disambiguate otherwise ambiguous forms, mitigating losses to informativeness. Note that this line of argument isn't incompatible with the view that shifts away from ambiguity can also contribute to efficiency. Ambiguity isn't always good or always bad, but rather is a property which languages can take advantage of to increase efficiency, but will shy away from if the cost to informativeness is not worth the decrease in complexity. For example, building on their previous finding that phonological mergers are avoided if they would lead to greater homophony in the lexicon, Wedel, Jackson, and Kaplan (2013) temper their earlier results by showing that additional contextual information can influence merger avoidance; for

example, mergers that would result in homophones that share a lexical category (e.g., both nouns) are less common than mergers that would result in cross-category homophones (e.g., a noun and a verb).

The potential efficiency of lexical ambiguity has been approached from various angles. Corpus studies have found that lower effort forms are more likely to have a disproportionately large number of meanings (Piantadosi, Tily, and Gibson, 2012), and a word's predictability in context has a positive correlation with how lexically ambiguous it is (Pimentel, Maudslay, Blasi, and Cotterell, 2020), which suggests that language users may make contexts more informative when using words which are more lexically ambiguous. Evidence from communication simulations also support the efficiency argument, with Peloquin, Goodman, and Frank (2020) finding that the presence of ambiguous forms were more likely in situations with greater context.

Turning to the semantics of ambiguity, there are the questions of whether certain meanings are more likely to colexify, (i.e., share a form), and whether typological trends in how meanings colexify are consistent with the efficiency hypothesis. Studies on semantic typology have yielded evidence that the lexicons of natural languages do indeed seem to 'carve up' the space of possible meanings in ways that facilitate efficient communication (Kemp, Xu, and Regier, 2018). Such results have been found for a range of semantic domains, including color (e.g., Zaslavsky, Kemp, Regier, and Tishby, 2018), kinship (Kemp and Regier, 2012), containers (Xu, Regier, and Malt, 2016), animals (Zaslavsky, Regier, Tishby, and Kemp, 2019), sensory terms (Majid et al., 2018; Winter, Perlman, and Majid, 2018), and terms relating to climate and environment (Regier, Carstensen, and Kemp, 2016). A recurring notion in many of these studies is the idea that languages adapt to be efficient relative to the cultural and environmental context in which they are used. In particular, the degree to which communicating a particular concept will affect the overall efficiency of the language will be based in part on the likelihood with which users of that language actually need to communicate about that concept. Even if communicating about a particular concept is costly, it will have a minimal effect on efficiency overall so long as communicating about that concept is a rare occurrence. If the distinction between two concepts rarely matters, those concepts can more safely be colexified.

Expanding the scope beyond individual semantic domains, Xu, Duong, et al. (2020) consider which general factors influence colexification rates. Their results, based on data from 246 different languages, suggest that both conceptual similarity (e.g., *fire* is similar to *flame* are similar concepts) and conceptual relatedness/associativity (e.g., *scent* is associated with *nose*) are strong predictors of whether two meanings will colexify. Similar conclusions were made by Karjus et al. (2021), who found that semantic similarity predicted colexification in a novel language

learning participant study, but also found that participants were less likely to colexify similar concepts that often needed to be distinguished between during communication. Brochhagen and Boleda (2022) expand on the role of similarity in colexification, arguing that, while meanings are more likely to colexify if they're semantically related, languages may avoid colexifying meanings that are *too* similar. They found that pairs of extremely related concepts were less likely to colexify than pairs of more moderately related concepts, and proposed that, as meanings become too closely related, the risk of confusability increases, and thus colexifying such meanings risks hurting informativeness to an extent that is not worth the modest reduction in complexity.

To summarize, there is mounting evidence that languages, and language users, make use of ambiguity in ways that reduce complexity at little or no cost to informativeness, thereby supporting efficient communication. One might expect that, excluding spoken language-specific topics such as phonology, much of the previous work on lexical ambiguity and efficiency directly translates to written language. However, this rests on the assumption that written language is always a one-to-one mirror of spoken language, which is not the case. Sharing a spoken form is no guarantee of sharing a written form (e.g., English ⟨tea⟩ versus ⟨tee⟩, both /ti/), and vice versa (e.g., English /wind/ and /wāind/, both ⟨wind⟩). Even different senses of a polysemous word may have distinct forms depending on the modality: for instance, (spoken) Japanese /atu/ “hot” is spelled 熱 in reference to hot objects, but as 暑 for hot weather or climate. As such, whether or not writing systems and written language make efficient use of ambiguity is a question that can't be answered without focusing directly on writing systems and written language².

Writing Systems and Efficiency

The idea that writing systems are (or are not) shaped by functional communicative pressures is not new. Many arguments regarding writing system efficiency could be slotted into three loose categories: either functional pressures exert little to no influence over writing systems;

2. It is true that some of the past work on the efficiency of lexical ambiguity has used written data (such as text corpora or language simulations that use written communication, as in Karjus et al. (2021)). In most cases this is done for reasons of data availability/convenience, and the use of written data may be couched as being a proxy of spoken language (and, when possible, written data may be converted to approximate spoken data). Nonetheless, even though such studies typically aren't framed as being about written language per se, they are still relevant to whether written language is efficient (and in fairness, they sometimes are treated as being analyses of written rather than spoken language by virtue of their choice of data, though this may get portrayed as a concession rather than a goal, as in e.g., Pimentel, Nikkarinen, et al., 2021).

or functional pressures act on writing system in such a way that some (types of) writing systems end up more efficient than others; or functional pressures act on writing system in such a way that all writing systems are comparably efficient. What follows is a brief review, with an eye for the main topics of the current study, namely ambiguity and logography.

The Validity of Functionalist Approaches to Writing Systems

To begin, it is worth addressing the possibility that writing systems are not shaped by functional pressures. In short, this view often takes the form of arguing that writing systems are the way they are mostly, if not entirely, because of societal factors (e.g., (Coulmas, 2003; Trigger, 1998; Cooper, 2004, p. 91; Coulmas, 2009, p. 9; de Voogt, 2024, p. 896; see also discussion in Houston, 2012a), and such societal pressures often serve to reduce or inhibit shifts towards writing system utility (e.g., Hannas, 1997). A succinct form of this argument is provided by Coulmas:

It is a mistake to see writing systems as quasi-natural organisms governed in their development by natural laws. Every script is a cultural implement subject to human ingenuity and error, created under certain circumstances for certain purposes and a certain language. To be sure, there are common traits, and economy of effort clearly is one of the guiding principles of human behaviour. Yet there is plenty of room for waste, extravagance and manifestations of the human mind defying bare utility. Cultural inertia and conservatism [...] and normativism [...] are strong forces at work in every literate community. They have little to do with writing systems as such or with their efficiency, yet they exercise a strong influence on their formation. Writing is a cultural product *par excellence*, and its development must be understood as such rather than in quasi-naturalistic terms. (Coulmas, 2003, pp. 200–201)

Written language does indeed seem to be more resistant to diachronic shifts than non-written language, especially if that written language is standardized, or functions as a prestige literary language. Top-down spelling reforms are, of course, a result of social, cultural, and political action, and a lack of spelling reforms (for writing systems that some might feel are in need of some changes) may be attributed to sociocultural factors. To argue that writing systems are completely unaffected by functional pressures, however, would be premature³. The question is: *to*

3. Two points must be made here: first, it is rare to encounter an argument as extreme as “writing systems are completely unaffected by functional pressures”; as evidenced in the above quote from Coulmas, the potential for functional pressures to shape writing systems can be acknowledged even when arguing for the relative strength of social and cultural pressures. Second, arguments that cast doubt on the role of functional pressures are often made in response to proposals that writing systems are *predominantly* shaped by such pressures (such as the ‘evolutionary’ views of writing

what extent do functional pressures shape writing systems? Even if ‘natural’ pressures only had a weak effect on writing systems, such pressures would still very much worth investigating, and any results in such a vein would absolutely be relevant to broader questions of human language, writing systems, and cognition. Or, as neatly summarized by Sampson:

It is understandable that political considerations may sometimes outweigh simple efficiency in deciding what form of writing a society uses. One might suppose, though, that where politics does not impinge, functional considerations would constrain the ways in which a script could evolve. (Sampson, 2015, p. 58)

Criteria of Writing System Effectiveness

There have been a range of proposals over the years regarding what criteria best measure the effectiveness of writing systems (e.g., Baroni (2011), Cahill and Karan (2008), Coulmas (2009), Daniels and Share (2018), Powlison (1968), Rogers (1995), and Venezky (1970); see also Meletis (2019, p. 206)). Such proposals vary as to whether or not these measures of effectiveness *predict* how writing systems develop, or are an ideal (attainable or otherwise) to which writing systems should aspire. Considerations such as regularity of mappings, inventory size, and visual distinctiveness, which are among the more frequently proposed criteria, could be treated as measures of either informativeness or complexity, as per the current study’s treatment of efficiency. Notably, such lists also tend to make mention of ambiguity, specifically as something to be avoided by writing systems, though it is sometimes acknowledged that writing systems may need to balance one source of ambiguity with another (e.g., morphological regularity versus phonetic regularity). Indeed, the theme of trade-offs, in line with the informativeness-complexity trade-off that is at the core of how the current study treats efficiency, is not uncommon in the writing systems literature (e.g., Civil, 1973; Daniels and Share, 2018; Rogers, 1995; Salomon, 2012; Seidenberg, 2012; Share, 2014; Trigger, 1998).

Inventory size and learnability are two factors which have featured prominently in some of the more influential (and critiqued) theories regarding writing system development. While not the first to raise such arguments, Gelb (1963), and contemporaries such as Diringer (1962), helped popularize the idea that writing systems necessarily ‘evolve’ towards greater efficiency, following a monotonic path from logographic

system development reviewed in this section), and in fairness it is indeed unlikely that functional pressures are the only force behind writing system development and structure.

to syllabic to segmental/alphabetic. By Gelb's account, a writing system's efficiency is based on his 'principle of economy,' defined as "the effective expression of the language by means of the smallest possible number of signs." (Gelb, 1963, p. 72). In other words, efficient writing systems are those that prioritize reducing inventory size (complexity), not those that optimize the informativeness-complexity trade-off (cf. the current study's treatment of efficiency).

Such arguments regarding writing system evolution and the comparative utility of different writing system types (in part or in whole) have faced no shortage of critics (e.g., Baroni, 2011; Coulmas, 2003; Daniels, 1990; de Voogt, 2024; Mattingly, 1985), but the general idea that some (types of) writing systems are more functional or practical is still present, in various forms, in research on writing systems.

The Effectiveness of Logography

Among proponents of the view that some types of writing systems are inherently (dis)advantageous, the most common stance (at least in the Anglophone literature) has been that logography is less efficient than phonography. Points raised in support of more logographic writing systems being less practical than more phonographic systems include: logographic systems require larger character inventories (e.g., Gelb, 1963; Pulgram, 1976); logographic systems are inconvenient for lexicography (DeFrancis, 1996); logographic systems don't capitalize on learner's already strong phonological knowledge (DeFrancis, 1996; Hannas, 1997); logographic systems take more time and effort to acquire and master (Hannas, 1997; Powlison, 1968); and logographic characters tend to be visually complex. Such discussions are usually focused on written Chinese (or Sinograms generally, including as used in written Japanese and Korean), though similar ideas can be found (or are at least mentioned) in reference to the writing systems of ancient Egypt (e.g., Baines (2004, p. 181)) and Mesopotamia (e.g., Cooper (2004, p. 92); N. Veldhuis (2011, p. 86)), or early writing systems more generally (Woods, 2010, p. 22).

There is, of course, not unanimous agreement that logography is disadvantageous, and indeed the current study's hypotheses are at odds with the idea that logography is inherently inefficient. This is not because of a lack of evidence for many of the proposed downsides of logographic systems: in more logographic systems, characters do tend to be more visually complex (Chang, Chen, and Perfetti, 2018; Miton and Morin, 2021); character inventories are larger (e.g., Chang, Chen, and Perfetti, 2018); characters are less informative about phonological information (e.g., Marjou, 2019; Sproat and Gutkin, 2021); and total literacy (at least regarding character knowledge and formal schooling) takes longer to acquire. A critical point to make is that none of these points necessarily lead to inefficiency, as defined here. Rather, they suggest

that logographic systems will trend towards increased complexity (regarding visual complexity and memory/acquisition) and decreased informativeness regarding sounds. However, such systems are only inefficient if these downsides aren't accompanied by improvements in other areas. Indeed, certain advantages have been proposed for retaining logography, such as: accommodation of dialectal differences (e.g., Sampson (1985, p. 170); Chen (1999, pp. 140–141)); homophone disambiguation (e.g., Sampson (1985, p. 170)); Taylor and Taylor (1995, p. 323); Chen (1999, pp. 140–141); Handel (2013); Meletis (2019, p. 268)) regularity of spellings with regards to morphological alternations (e.g., Berg and Aronoff, 2017; Chomsky and Halle, 1968; Venezky, 1970); semantic transparency (e.g., Handel, 2013); and ease of scanning texts for specific words or concepts (Cooper, 2004, p. 98); cf. Morita and Tamaoka, 2002).

Linguistic Fit

Another possibility is that certain types of writing systems are better for certain types of spoken languages (e.g., Baroni, 2011; Frost, 2012; Halliday, 2010; Handel, 2019; Joyce and Meletis, 2021; Katz and Frost, 1992; Mattingly, 1985; Meletis, 2019; Seidenberg, 2011; 2012; Voegelin and Voegelin, 1961), a concept known (among other names) as linguistic fit. Most takes on the linguistic fit argument can be divided into two pieces, one analytical and one empirical: the analytical is that certain types of writing system are better suited to certain types of spoken languages, particularly with regards to that spoken language's morphology and phonology (e.g., simpler syllable structure is more compatible with syllabic writing systems). The empirical portion of the linguistic fit argument is whether it is indeed the case that writing systems trend towards, or away from, certain structural properties so as to better fit their respective spoken languages. Proponents of linguistic fit will mostly agree that the empirical question can be answered in the affirmative (though see Meletis (2019, pp. 355–356) for a more nuanced answer), but there is disagreement over whether this fit is *optimized* (see (responses to) Frost, 2012).

Ambiguity

Ambiguity avoidance has factored in to various discussions of writing system development (e.g., Boltz, 2011; Woods, 2010), borrowing (e.g., Handel, 2019), and reform (e.g., Chen, 1999; Handel, 2013). Innovations and developments such as determinatives, using different spellings for homophonous words, and including redundant information in spellings have been touted as evidence that writing systems prefer to avoid ambiguity. However, the inevitability and trade-offs of ambiguity in writing systems have been noted as well (e.g., Fortson, 2023; Salomon, 2012),

and the presence of ambiguity in writing system has also been cited as evidence against such systems being shaped by functional pressures (e.g., de Voogt, 2024). What is missing from many of these claims, however, is quantified empirical evidence: for example, claims about the disambiguating benefits of determinatives tend not to be accompanied by counts of just how many words are disambiguated by the use of determinatives.

Quantitative methods are more common in the robust literature on the ambiguity and consistency of spelling-sound mappings in writing systems, often referred to as *orthographic depth* or *transparency* (e.g., Borleffs, Maassen, Lyytinen, and Zwarts, 2017). While not typically focused on efficiency or functional pressures, the depth/transparency literature overlaps with the current study not only in its focus on ambiguity, but also its use of information theoretic methods (as in e.g., Borgwaldt, Hellwig, and Groot (2004) and Protopapas and Vlahou (2009); and Siegelman, Kearns, and Rueckl, 2020). Such studies have predominantly focused on more phonographic (usually more alphabetic) systems, however, and the emphasis on character-sound mappings has left underexplored the topic of character-morpheme mappings (though see Siegelman, Rueckl, et al., 2022).

Cognitive and Quantitative Approaches to Writing System Efficiency

Finally, it is worth highlighting some recent studies that, like the current study, consider writing systems from a more cognitive, quantitative, and/or efficiency-focused (in the *efficiency hypothesis* sense) perspective. Much of the research in this vein has focused on visual properties, such as visual complexity and redundancy (Changizi and Shimojo, 2005; Han, Kelly, Winters, and Kemp, 2022; Kelly, Winters, Miton, and Morin, 2021; Koshevoy, Miton, and Morin, 2023; Miton and Morin, 2021), representational iconicity (e.g., Kuperman and Bertram (2013) for the spelling of compound words), and congruence with human visual cognition (e.g., Changizi, Zhang, Ye, and Shimojo, 2006; Morin, 2018). Overall, the results of these studies support the idea that functional pressures shape the development of written character forms. Regarding visual simplicity, the available evidence suggests that new written forms simplify rapidly over a few generations (Garrod et al., 2007; Kelly, Winters, Miton, and Morin, 2021), but over longer stretches of time characters don't seem to trend towards greater simplicity (Miton and Morin, 2021), and may even trend towards increased visual complexity, perhaps to support visual distinctiveness (Han, Kelly, Winters, and Kemp, 2022).

Case Studies—Sumerian and Japanese

Both ambiguity and logography have somewhat uneven reputations regarding their contributions towards the utility of writing systems and written language. Logography has traditionally been considered a negative, and while this view is increasingly called into doubt, there remains a demand for more quantitative, empirical investigations of logography's advantages and disadvantages. Such approaches have been used to test the proposed efficiency of ambiguity, but rarely with a focus on writing systems and written language. The current study aims to help fill both of these gaps.

In light of this focus on ambiguity and logography, it makes sense for the initial case studies to be two writing systems which a.) make extensive use of logography (including more morphographic and semantographic spellings) and b.) feature numerous polyvalent characters and spellings: written Sumerian and written Japanese. If it's found that even these highly ambiguous, highly logographic systems are communicatively efficient, it would be strong evidence that these properties are not as inefficient as has previously been assumed, which in turn would support the general hypothesis that writing systems are shaped by efficiency pressures.

What follows is a quick overview of the relevant similarities and differences between (written and spoken) Sumerian (as it was used in the Ur III period, c. 2112–2004 BCE) and Japanese.

Morphology and Phonology

Spoken Sumerian and spoken Japanese can both be generally described as agglutinating: morpheme boundaries are usually fairly transparent, compounds can be formed by concatenating two (or more) roots, and most grammatical information is represented via affixes or clitics.

Syllables in both languages are typically analyzed as minimally V, maximally CVC (depending on the analysis, the Japanese syllable may be maximally CyVC/CyVV or CyVVC)⁴. Sumerian is less restrictive than Japanese regarding which consonants can occur as syllable codas. In addition to having similar syllable structures, the two languages are comparable in the size of their respective phoneme inventories⁵.

4. The palatal glide is rendered in this paper as /y/ rather than IPA /j/.

5. Sumerian phoneme inventory: /p, b, t, d, k, g, s, z, š, h, m, n, ŋ, l, r/; /a, i, e, u/. Among the possible Sumerian phonemes which aren't included here are the glottal stop and controversial /r̥/ phoneme (see also Black, 1990). They are omitted because of their absence (or inconsistent usage) in the text corpus used as data for the current study. It is unclear whether Sumerian had phonemic vowel length (compare e.g., Jagersma (2010) with Michalowski, 2020), but the current study will assume that all

In Sumerian, most non-borrowed morphemes are monosyllabic, and some grammatical morphemes may be analyzed as being shorter than a syllable. Most borrowed morphemes (of Semitic origin) are multisyllabic. Japanese morphemes of Japanese origin (*wago*) tend to be one or two syllables (and one or two morae) in length with (C)V or (C)VCV forms, though many verb stems are underlyingly CVC. Japanese morphemes of Chinese origin (*Sino-Japanese*), which constitute a large percentage of the lexicon, tend to be monosyllabic but bimoraic. More recent (mostly European-origin) borrowings into Japanese (*gairaigo*) span a range of different lengths.

The two example sentences given below illustrate some of the morphological similarities (and differences) between Sumerian 1 and Japanese 2. For clarity, content morphemes are formatted in bold.

- (1) **dub-sar-e** **e-gal** **dumu-ani-ra**
tablet-write-ERG **house-great** **child-3S.A.POSS-DAT**
 mu-na-n-**du**
 VENT-3S.A.DAT-3S.ERG-**build**

“The scribe built a palace for their child.”

- (2) **gaku-sya-ga** **siro-o** **oya-ni** **tate-te-age-ta**
academic-person-NOM **castle-ACC** **parent-DAT** **build-give-PAST**

“The scholar built a castle for their parent(s).”

Writing Systems

To begin, the two writing systems make use of both logographic and phonographic mappings at the character level: a character can map to an entire morpheme (or, more rarely, multimorphemic word), or can be used to encode a stable portion (no smaller than a syllable/mora) of a phonological form. In Sumerian, any given character may be used both logographically and phonographically: for example, 𒀭 can be used logographically to write either a “water” or *duru*₅⁶ “wet,” but 𒀭 can also

Sumerian vowels are short, again for reasons relating to the available data.

Japanese phoneme inventory: /p, b, t, d, k, g, s, z, h, m, n, r, w, y, N/; /a, i, u, e, o/. Two caveats to note: First, vowel length is contrastive in Japanese, so it may be more accurate to list the vowel phoneme inventory as /a, i, u, e, o, a:, i:, u:, e:, o:/ . Second, each consonant phoneme (other than /w, y, N/) has a contrastive palatalized counterpart, though such palatal consonants could be analyzed as Cy sequences rather than individual C^y consonants.

6. Some brief notes on formatting and transliteration practices for Sumerian: Each character has a standardized name, which is always formatted in all caps. To avoid two distinct characters having the same name, a character that would have the same name

TABLE 1. Examples of polyvalent characters in the two target writing systems.

Sumerian			Japanese		
Character	Sound	Meaning	Character	Sound	Meaning
𒀭	a	water	食	ta(be)	to eat
𒀭	duru	wet	食	syoku	meal, eating
𒌶	gidru	scepter	食	ku(w)	to eat
𒌶	pa	stick, branch	生	u(m)	birth/born
𒌶	sag	to strike	生	nama	raw, fresh
𒌶	ugula	overseer	生	sei	life

be used to encode the syllable /a/, showing up in spellings such as 𒀭 -a “-LOC,” 𒀭𒀭 -a-ni “-3s.A.POSS,” and 𒀭𒀭𒀭 a-ga “rear, back”. Written Sumerian does not have a set of characters which are *only* used as phonograms: for any given character, that character will likely have at least one logographic function.

Japanese, by contrast, has two sets of characters which are used exclusively as moraic phonograms: *hiragana* and *katakana*, collectively referred to as *kana*. The two types of kana have different usage patterns (though kana usage as a whole is somewhat flexible). For each hiragana character, there is one katakana character with the exact same phonographic value, and vice versa. The other set of characters traditionally used in Japanese are *kanji*, which are typically used as logograms. Modern written Japanese also makes use of the Roman alphabet *rōmaji*.

Sumerian and Japanese spellings and character can be ambiguous from both the reader’s and writer’s perspective. In both writing systems there are numerous characters which can each map to multiple different morphemes; these morphemes are often, but not always, semantically related. See table 1 for examples. In addition, as already mentioned, a character in Sumerian can have a mix of different logographic and phonographic mappings. Regarding encoding ambiguity, in both writing systems any given sound string and/or morpheme may have multiple valid spellings. For example, Japanese *oka* “hill” can be spelled logographically as 丘 or 岡, and phonographically as おか (using hiragana) or オカ (using katakana). When spelled logographically, spellings are usually unaffected by surface phonological variation, but phonographic spellings may vary depending on surface forms.

as another character has a subscript number appended to its name (so, for example, KA and KA₂ refer to different characters). Unless the reading of a character is unknown, Sumerian words are typically transliterated at the level of the characters’ readings (i.e., approximate pronunciations). In this transliteration, hyphens indicate character boundaries, not morpheme boundaries, and subscript numbers serve as markers which indicate character identity.

One last striking similarity present in the two writing systems relates to the spellings of bound grammatical morphemes. Vowel-initial affixes are present in both spoken Sumerian and spoken Japanese. When these affixes immediately follow a consonant-final morpheme, they may be spelled as if they begin with the preceding morpheme's final consonant. For example, the Sumerian nominalizing suffix */-a/*⁷ has a default spelling of 𒀭 *a*, but is often written as 𒀭 *sa* after */s/* (e.g., 𒀭 *us₂-sa* “follow-NOMINALIZER”), 𒀭 *ra* after */r/* (e.g., 𒀭 *sar-ra* “write-NOMINALIZER”), and so forth. While this spelling strategy is used for both nominal and verbal morphology in Sumerian (albeit inconsistently), it is more or less exclusive to, and mandatory for, verbal suffixes in Japanese. For example, the non-past suffix, which is underlyingly */-u/* (after consonant-final stems), is written as 飲む *mu* in 飲む */nom-u/* “drink,” as 話す *su* in 話す */hanas-u/* “speak,” and so forth.

This spelling strategy has two immediate consequences for ambiguity in the writing system. First, it exacerbates non-isomorphism between characters and grammatical morphemes. For Sumerian, which doesn't have dedicated phonograms in the way Japanese does, this can also serve to inflate the number of morpheme mappings of individual characters. However, the overt, redundant indication of the preceding morpheme's final consonant may serve to disambiguate what would otherwise be an ambiguous written form: for example, Sumerian 𒀭 is, in a vacuum, highly ambiguous, with values including (but far from limited to) *gub* “to stand,” *tum₂* “to carry,” *ĝen* “to go,” and *kur_x* “to enter”. When suffixed, such as with the aforementioned nominalizing */-a/*, this ambiguity can be abated by spelling the suffix as if it were */-Ca/* rather than */-a/*: using 𒀭 *ba* would indicate that the target is b-final (*gub*), using 𒀭 *ma* would indicate that the target is n-final (*ĝen*), etc. The disambiguating potential of this way of spelling affixes has already been noted elsewhere (e.g., Sampson (1985, p. 85); Coulmas (2003, p. 182); Handel, 2019; Honda, 2007; 2008), though the results of Honda (2007) suggest that, at least for Japanese, the overall reduction in ambiguity might be more modest than expected.

In summary, the two writing systems, and their respective spoken languages, have substantial structural overlap and make substantial use of both logography and ambiguity (see also Handel (2019, pp. 281–308) for similar observations on the potential for comparison between Sumerian and Japanese). These similarities can't be attributed to any genealogical or sociocultural relation, since Japanese and Sumerian (written and spoken) are completely unrelated, with their usage separated by thousands of kilometers and thousands of years. In addition, the two writing systems, as analyzed here, have had a comparable amount of ‘development’ time: Ur III Sumerian is roughly 1,000–1,400 years removed

7. Perhaps underlyingly */-ʔa/* (Jagersma, 2010).

from the earliest extant cuneiform texts (Woods, 2006), while modern written Japanese is roughly 1,200 years removed from the earliest clear evidence of vernacular written Japanese (Frellesvig, 2010; Seeley, 2000). As such, any observed similarities between the two system can't be attributed to their simply being related, and any observed differences between the two systems can't be attributed to one system having had less time to be shaped by efficiency pressures.

Data

The Sumerian data were drawn from the Ur III Administrative Corpus (hereafter Ur3Admin), hosted by the electronic Pennsylvania Sumerian Dictionary 2 (ePSD2), a project of the Open Richly Annotated Sumerian Corpus (ORACC; Tinney and Robson, 2014)⁸. As suggested by the name, the Ur3Admin corpus consists solely of administrative documents dated to the Ur III period (c.2112-2004 BCE); these documents are mostly receipts and records of debts, wages, property, taxation, resource allocation, and trade. The Ur3Admin corpus was chosen because it is the largest single-genre, single-time period annotated corpus available for written Sumerian.

The Japanese data were drawn from the Balanced Corpus of Contemporary Written Japanese (BCCWJ; Maekawa et al., 2014). BCCWJ draws on written material published between 1976 and 2006, and includes texts from a variety of sources and genres, such as newspapers, books and textbooks, magazines, online message boards, blogs, and official government minutes.

Both BCCWJ and ORACC are organized primarily at the word level. Because the current study is concerned with morphemes, rather than words, additional processing needed to be done to get morpheme-level information and mappings. In particular, compound words needed to be parsed into their constituent morphemes, and affixes needed to be separated from roots, in such a way that individual morphemes can be aligned with (minimally character-length) portions of written forms. Morphological and character-level parsing and aligning were mostly handled by custom Python scripts written for the task, with additional manual adjustments as needed.

During cleaning, certain word tokens and types needed to be removed. For the Sumerian data, proper nouns, most numerals, words with uncertain pronunciation or meaning, and tokens marked as damaged were all removed. For the Japanese data, recent foreign borrowings,

8. At time of writing, raw downloads for the Ur3Admin corpus can be found here: <https://oracc.museum.upenn.edu/epsd2/JSON/index.html>

TABLE 2. Type and token counts after additional cleaning and processing

	Character Tokens	Morpheme Tokens	Spelling Types	Morpheme Types
Japanese	55.49M	45.65M	4826	2531
Sumerian	2.83M	2.36M	2281	1716

proper nouns, and lower frequency words and forms were all excluded⁹. Even after cleaning, the size of the Japanese data was many times larger than the Sumerian data (see table 2).

The data was organized relative to spelling-sound-morpheme triplets. The set of mappings between spellings and sounds/meanings was determined based solely on these triplets, and was independent of whether that spelling would traditionally be considered to be logographic or phonographic. For example, based on the data snippet given in table 3, the spelling DU (𒅗) has (at least) three spelling-sound mappings (ra, gub, de) and (at least) four spelling-morpheme mappings (/a/ “NOMINALIZER,” /-ak/ “GENITIVE,” /gub/ “to stand,” /de/ “to carry”).

TABLE 3. Snippet of the organized, cleaned Sumerian data

Graphic form	Pronunciation	Morpheme/meaning	Frequency
SI-IGI	silim	/silim/ “healthy”	2
DI	silim	/silim/ “healthy”	13
DU	ra	/-a/ “NOMINALIZER”	902
DU	ra	/-ak/ “GENITIVE”	8
DU	gub	/gub/ “to stand”	7464
DU	de	/de/ “to carry”	1060

9. The decision to remove recent foreign borrowings (*gairaigo*) from the Japanese data was made for a few reasons. First, *gairaigo* words are almost always written phonographically, using katakana, with logographic spellings being exceedingly rare. In addition, the fact that *gairaigo* are *recent* borrowings (mostly from the past century or so) means that they were absent from most of the history of written Japanese, and it's possible that the efficiency of the writing system hasn't 'caught up' to the influx of recent borrowings (though note that past findings such as those of Kelly, Winters, Miton, and Morin (2021) suggest that efficiency pressures could operate on a writing system, or at least on written forms, in time spans as short as a couple centuries). More importantly, the current study is most directly concerned with questions of non-isomorphism and logography, meaning that *gairaigo*, which are almost always written phonographically, are of less relevance. It should nonetheless be stressed that removing *gairaigo* does mean that the Japanese data used here should *not* be treated as representative of modern written Japanese, which makes extensive use of *gairaigo*, but rather as a proxy for written Japanese before the recent influx of borrowing from (mostly) English and other European languages.

Methods

Complexity and Informativeness

For this study, two simple complexity measures were used to quantify system effort: *strokes per morpheme* and *characters per morpheme*. The former measure serves as a direct approximation of motor production effort, while also providing a measure that at least indirectly indicates visual complexity (Chang, Chen, and Perfetti, 2018). Because different characters tend to take up a comparable amount of space within a system, the character-based metric captures the spatial and material cost of a text. For Sumerian, character stroke counts were manually defined for each character based on the exemplar forms given by Steve Tinney's Cuneiform Composite font¹⁰. For Japanese, each character has a canonical stroke count.

Following past work on efficiency pressures in language, (especially Kemp and Regier (2012) and Xu, Regier, and Malt (2016), and Kemp, Xu, and Regier, 2018) the informativeness metric used here is based on the expected amount of information that is lost during communication, here termed *communicative cost* (ComCost, or *C*). Recall that an information theoretic model of communication involves a sender (writer) encoding messages into signals which are decoded by a receiver (reader), who attempts to reconstruct the original message. These messages can be modeled as probability distributions over possible values. In the current study, these values are either phonological forms or morphemes, and each system will thus have two different informativeness scores: the phonological communicative cost captures how informative a system is about sounds, while the semantic communicative cost captures how informative a system is about meanings/morphemes. Each of the informativeness measures will be compared against each of the two complexity measures, resulting in four different efficiency analyses for each system.

The instantiation of communicative cost used here makes the assumption that the writer knows exactly which value they are trying to communicate: effectively, the sender's original message is a probability distribution with all of the mass allocated to the target value. The reader's probability distribution over values given a written form is taken here to be based on how similar possible values are to the values which are empirically spelled using that written form. The assumption is that the reader expects similar values to have similar forms. For example, if a written form is often used to encode the syllable /ta/, the reader's probability distribution for that form will assign much of its probability mass to /ta/, but will also assign some mass to similar syllables (e.g., /da/, /ra/), while assigning very little mass to a highly dis-

10. See <https://oracc.museum.upenn.edu/doc/help/visitingoracc/fonts/>.

similar syllable like /bi/. Similarly, if a written form is often used to encode a morpheme which means “young,” then the reader distribution for that form will assign more probability mass to semantically similar or related morphemes (e.g., “junior” or “child”) than to semantically dissimilar morphemes (e.g., “potash”).

Communicative cost, then, can be measured based on the difference between the writer’s original probability distribution and the reader’s reconstructed probability distribution. Again in line with past work, and in light of the assumption of writer certainty, this can be measured as the reader’s surprisal during communication about a given value. However, while it’s assumed that the reader incorporates semantic/phonological similarity during reading, it is also assumed that the reader has prior experience and knowledge regarding the frequency with which a given value is spelled with a given spelling, and will incorporate that knowledge during reading. As such, the communicative cost measure used here deviates slightly from similar prior work in the literature by further weighting the cost associated with communicating about a given value by the probability of that value being spelled with a given written form.

More precisely: The communicative cost $C(v)$ associated with communicating about a particular value v will be calculated according to (1):

$$(1) \quad C(v) = \sum_{g \in G} p(g|v) * \log_2\left(\frac{1}{R_g(v)}\right),$$

where G is the set of all written forms, and $R_g(v)$ is the similarity-based reader distribution:

$$(2) \quad R_g(v) \propto \sum_{w \in V} \text{sim}(v, w) * p(w|g),$$

where V is the set of all values (sound strings or morphemes, depending on the condition). More details on how similarity was calculated are given in appendix B.

The communicative cost $E[C]$ of the entire system is the expected communicative cost over written forms, as given in (3):

$$(3) \quad E[C] = \sum_v C(v)N(v).$$

The incorporation of need probability $N(v)$ (i.e., the probability that writers will need to communicate about value v) accounts for the aforementioned efficiency consideration that cultural needs will be reflected in that culture’s languages.

Because of how it’s being calculated, the range of possible communicative cost scores is partially a function of how many values there are and what the similarity relations are between those values, and will thus

differ for different languages. To make the communicative cost measure more comparison-friendly, it was normalized:

$$(4) \quad C = \frac{C_{\text{emp}} - C_{\text{min}}}{C_{\text{max}} - C_{\text{min}}},$$

where C_{emp} is the empirical communicative cost score, and C_{max} and C_{min} are respectively the cost of the most uninformative and most informative possible systems for a given language and dataset. In line with the model of communication being used here, the least informative possible system is one which only has one form, which is used for all possible values, while the most informative system is one which assigns every unique value its own unique form. C_{max} and C_{min} can thus be calculated from the given data by either making all written forms identical or by assigning a unique written form to every value. Note that a normalized C score of 0 would mean that a system is optimally informative (relative to a given language and corpus).

Hypothetical Competitors

Recall that a system is efficient to the extent that it's as informative as possible given its complexity, and as simple as possible given its informativeness. As such, looking at a single system's informativeness and complexity in a vacuum doesn't necessarily reveal much about its efficiency; what needs to be shown is that the system is more efficient than other systems, plausible competitors which can, theoretically, convey the same messages. Examples of such plausible competitors include random baselines, variants of the real system that tweak certain parameters, or variants which are theoretically optimized relative to a particular goal. This strategy of hypothetical system generation and comparison is a well-established practice in the efficiency literature, and has been applied to a range of topics including word lengths (e.g., Pimentel, Nikkariinen, et al., 2021), word order (e.g., Futrell, Mahowald, and Gibson, 2015; Gildea and Temperley, 2010), pronouns (Denić, Steinert-Threlkeld, and Szymanik, 2020; Zaslavsky, Maldonado, and Culbertson, 2021), ambiguity (e.g., Trott and Bergen, 2020; 2022), grammatical marking (Mollica, Bacon, Zaslavsky, et al., 2021), quantifiers (Steinert-Threlkeld, 2021), and semantic typology (e.g., Karjus et al., 2021; Kemp and Regier, 2012; Zaslavsky, Kemp, Regier, and Tishby, 2018; Zaslavsky, Regier, Tishby, and Kemp, 2019).

This 'hypothetical competitor' methodology was adopted here as well: hypothetical variants of the target writing systems were created to serve as competitors against which the efficiency of the real systems could be evaluated. For all of these hypothetical systems, the only difference from the real system was the set of graphic forms and their mappings; everything else about the data was identical between systems. For

example, the frequency of a given value is the same for all systems, but the set of spellings used for that value can vary.

Most of the hypothetical systems used here involved randomly generating new graphic forms, relative to certain restrictions. Thousands of such systems were generated and compared against the real systems. For each generated system, a percentage (from 0% to 99%) of pre-existing mappings would be held constant; this was done so that the generated systems would span a range of plausibility, from variants that completely rewrite the existing system to variants which merely tweak a handful of the real system's mappings.

The suite of hypothetical systems is as follows:

Shuffled Systems (ShufS)

The existing mappings between graphic units and values are randomly shuffled. For example, if given the following 'real' system:

Graphic form	Pronunciation	Morpheme/meaning	Frequency
KA	ka	/kag/ "mouth"	1,300
KA	ka	/-ak/ "GENITIVE"	4,500
DU	gub	/gub/ "to carry"	1,000
DU	tum	/tum/ "to bring"	35

The possible shuffled systems would be any that randomly reorder the 'graphic form' column but keep all other columns fixed, such as:

Graphic form	Pronunciation	Morpheme/meaning	Frequency
KA	ka	/kag/ "mouth"	1,300
DU	ka	/-ak/ "GENITIVE"	4,500
DU	gub	/gub/ "to carry"	1,000
KA	tum	/tum/ "to bring"	35

If the real systems distribute their mappings in ways that facilitate communicative efficiency, then the expectation is that shuffling these mappings will disrupt both informativeness (similar values will no longer be more likely to share forms) and complexity (higher frequency values will no longer get assigned to simpler forms).

Graphotactically Generated (GGen)

New spellings are generated one character at a time using a weighted bi-gram language model with a 5 percent chance of ignoring the graphotactics and picking a character purely at random instead (this was done to

allow for the possibility of novel bigrams). While generating a spelling, the probability that the next character chosen x_n will be character $\hat{x}$ is:

$$p(x_n = \hat{x} \mid x_{n-1}) = (.05 * \frac{1}{|X|}) + (0.95 * p(x_{n-1} \mid \hat{x})),$$

where X is the set of all characters (including characters that mark the beginning or end of a spelling).

Phonographically Generated (PGen)

New spellings are generated for each item based on that item's phonological form. This is done by generating a new string of characters which can be read as the target phonological form based on those characters' extant character-sound mappings. The generation process is rerun for each graphic form-morpheme-phonological form triplet, meaning that homophones do not necessarily receive identical spellings. The PGen process also incorporates the empirical frequency of character-sound mappings, and when generating a new 'phonographic' spelling for a given sound string, it is more likely to pick characters that more often map to those sounds. This type of generated system was only run for the Sumerian analysis.

For example, Sumerian 𒌦 has among its possible readings /mu/ (as in mu_2 'to grow') and /kiri/ (as in $kiri_6$ 'orchard'). In a PGen system, any phonological form that contains /mu/ or /kiri/ could be respelled such that the character 𒌦 is part of the new spelling. 𒌦 by itself would thus be a possible generated spelling for words such as mu 'name' or $kiri_3$ 'nose'. 𒌦 could also show up as part of the generated spelling for a word like $dumu$ 'child' or $mušen$ 'bird'.

In addition to the randomly generated systems described above, two 'curated' systems were included as points of comparison. These systems are, by design, highly phonographic, thus fitting a different typological profile than both the more logographic real systems and the generated systems (except for the pseudo-phonographic PGen systems). Because these systems are specifically catered to spelling-sound mappings, the expectation is that they will score better than the real systems for phonographic informativeness, but worse for semantic informativeness.

Syllabary Spellings (SylS)

All written tokens are respelled using a phonographically isomorphic syllabary (i.e., a set of characters and mappings such that each character maps to exactly one extant syllable/mora and each extant syllable/mora maps to exactly one character). This results in all homophonous forms having identical spellings. The only polyvalence that

can remain is if a given morpheme maps to multiple pronunciations, in which case it will receive a different spelling for each of those pronunciations.

For Japanese, the syllabary was the existing katakana sub-system, i.e., the system was ‘created’ by simply using the katakana spelling for all morphemes. For Sumerian, a syllabary was created based on the character-sound mappings already present in the writing system. The process for creating this syllabary is detailed in appendix C.

Alphabetic System (AlphS)

All written tokens are respelled using the Roman alphabet, i.e., the romanization of that token’s spoken form is treated as its spelling.

Results

Figures 1 (Sumerian) and 2 (Japanese) plot the extant writing systems against their respective hypothetical competitors. Table 4 shows the percentage of generated hypothetical systems that performed better than their respective real systems in terms of informativeness, complexity, and/or efficiency. For both Sumerian and Japanese, the real systems outperformed the hypothetical systems for at least one of, and more often both of, informativeness and complexity. A small percentage of hypothetical systems were more efficient than their respective real systems, with this being more common when informativeness was measured relative to spelling-sound mappings.

As expected, the more phonographic competitors were more phonographically informative. For Sumerian, this almost always came at the cost of system complexity: the hypothetical syllabary system, alphabetic system, and over 90% of the generated Sumerian PGen systems would require, on average, more strokes and more characters to write a given text as compared with the extant Sumerian writing system. The picture for Japanese is a bit more nuanced. If complexity is measured in characters, then the syllabary and alphabetic competitor systems follow the same pattern as for Sumerian, with the improved phonological informativeness offset by a substantial increase in complexity. However, if complexity is measured in strokes, then both of these systems are entirely more efficient than the real Japanese writing system. Also as expected, the phonographic variants of Japanese are worse with regards to semantic informativeness; however, it is noteworthy that the more phonographic hypothetical Sumerian systems are comparable to the real system for semantic informativeness.

For Japanese, the randomly shuffled competitors often demonstrated higher informativeness for sounds, but worse informativeness for mean-

TABLE 4. Percentage of generated hypothetical systems that were less complex, more informative, and/or more efficient than their respective real systems

	Sumerian				Japanese		
	ShufS	GGen	PGen	All	ShufS	GGen	All
Info. (Sem.)	65.33	0.00	13.64	27.56	0.24	0.00	0.11
Info. (Phon.)	1.20	0.00	96.73	26.39	85.18	0.00	41.37
Compl. (Stroke)	2.67	18.27	4.36	7.95	3.76	6.11	4.97
Compl. (Char.)	0.27	22.93	9.27	10.98	0.47	12.22	6.51
Effic (Sem. & Stroke)	0.13	0.00	0.73	0.24	0.00	0.00	0.00
Effic (Sem. & Char.)	0.00	0.00	1.64	0.44	0.00	0.00	0.00
Effic (Phon. & Stroke)	0.00	0.00	3.82	1.02	1.29	0.00	0.63
Effic (Phon. & Char.)	0.00	0.00	8.18	2.20	0.24	0.00	0.11

ings. Sumerian showed the opposite pattern, with the real system regularly outperforming the shuffled systems for phonological communicative cost, but performed worse for semantic communicative cost. It may seem surprising that the randomly shuffled systems regularly demonstrate higher informativeness than the real systems for any informativeness metric. One possible explanation is that the randomly shuffled systems result in less polyvalence overall. For example, the number of unique spelling types ($N=2,281$) is greater than the number of morpheme types ($N=1,716$) in Sumerian, with there being many high-effort but low-frequency spelling types. Because frequency doesn't factor in to the shuffling process, this may result in systems wherein high frequency morphemes get assigned unique but high-effort forms, which would account for the higher complexity and higher informativeness of these systems.

Discussion

Overall, the results are consistent with the efficiency hypothesis. With only a few exceptions, the plausible hypothetical competitor systems were less informative and/or more complex than the target systems. Before going in to how these results fit in to the literature more broadly, a few of the results bear some additional discussion.

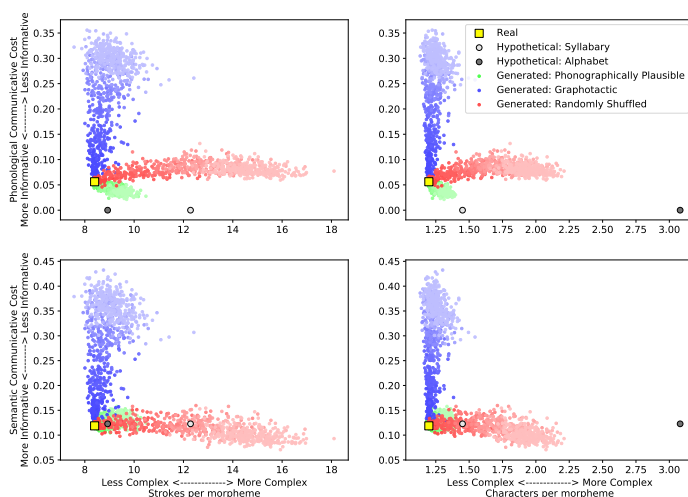


FIG. 1. Plot of Sumerian results. For the generated hypothetical systems, the darkness of the dots indicates the percentage of mappings that were fixed (i.e., identical to the real system): lighter dots represent systems with fewer fixed mappings.

More Efficient Systems

Even though a handful of generated systems did turn out to be more efficient than the real systems, these systems were only more efficient by a small margin. Furthermore, the only generated hypothetical systems which ever boasted better efficiency were those for which a high percentage of mappings were fixed during the generation process, meaning that they were mostly identical to the real systems. Nonetheless, the presence of any more efficient systems means that these results don't support the conclusion that the real systems are completely optimized for communicative efficiency, though the results are still consistent with the target systems being *near-optimized*. As discussed earlier, the argument here isn't that communicative efficiency is the only force shaping writing systems, so it is not a surprise, nor a challenge to the hypothesis, that the real systems are not as optimal as they possibly could be.

The biggest outliers among the hypothetical systems were the phonographic variants of written Japanese, which were the only hypothetical systems which were more efficient than a real system by a substantial margin (albeit only for one of the four informativeness-complexity pairings). It comes as no surprise that a variant of Japanese that abandons the use of logographic kanji and instead uses only katakana or rōmaji would

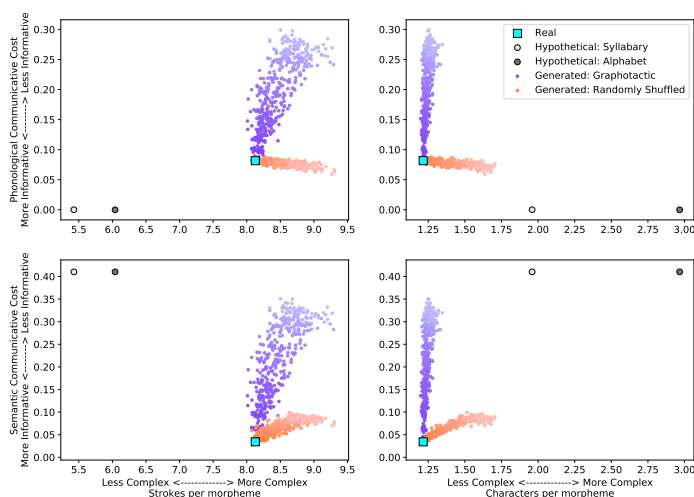


FIG. 2. Plot of Japanese results. For the generated hypothetical systems, the darkness of the dots indicates the percentage of mappings that were fixed (i.e., identical to the real system): lighter dots represent systems with fewer fixed mappings.

require fewer strokes and be more informative about sounds, and thus be more efficient relative to the goal of conveying phonological information. What is more surprising is just how much worse these systems would be regarding semantic informativeness, with the phonographic Japanese variants boasting worse semantic informativeness than even the randomly generated spellings. Furthermore, while katakana- and rōmaji-only systems would, by virtue of a reduced stroke count, require less motor effort (and likely be less visually complex), they would also require an increase in character tokens per text.

Logography, Phonography, and Linguistic Fit

Definitive conclusions about writing system typology and linguistic fit cannot be drawn based on a sample of only two languages/writing systems. What follows is a brief discussion of how the current results *could* be viewed as being consistent with the idea that spoken language morphology and phonology may influence what kinds of writing systems best enable efficient communication.

Starting with Japanese, it is often argued/assumed that Japanese has too many homophones for a strictly sound-based writing system

to be effective, and that the retention of kanji is beneficial, if not necessary, for the purpose of homophone disambiguation (e.g., Backhouse (1984), Sampson (1985), and Smith (1996); Taylor and Taylor (1995, p. 323):323). The current results may support this view, to some extent: the phonographic Japanese variants were substantially less semantically informative than even the randomly generated, but still arguably logographic, competitors.

This pattern wasn't observed for Sumerian: the phonographic competitors and the real system had comparable semantic informativeness. Sumerian has fewer homophonous morphemes than Japanese¹¹, but the results suggest that Sumerian's logographic writing system was efficient. This in turn suggests that a high number of homophones is not the only factor that would push a writing system towards greater logography.

More broadly, the results for the phonographic competitors paint an interesting picture relative to the presumed merits of phonography over logography. The expectation that the phonographic variants would be more phonographically informative is indeed borne out. However, in many cases this came at the cost of both complexity *and* semantic informativeness: one step forward, but two steps back. One interpretation of this result is that, at least for Sumerian and Japanese, a shift towards phonography may well result in the systems actually being less efficient overall. (Of course, a shift towards phonography may yield benefits for factors not considered in the current analysis, such as rate of acquisition.) If nothing else, the phonographic competitors do not seem to be *more* efficient than the original logographic systems, which runs counter to argument that logography is inherently disadvantageous.

Modality and Efficiency

As mentioned earlier, while the body of evidence in favor of the efficiency hypothesis continues to grow, much of this evidence is either based on spoken language or is modality-agnostic. The current study, by contrast, very directly focuses in on writing systems, specifically two writing systems which are not direct 'mirrors' of their respective spoken languages, especially with regards to the instantiation of ambiguity. In other words, the observed efficiency of these systems, ambiguity and all, is not merely 'inherited' from their spoken languages.

The results not only support the hypothesis that writing systems are shaped by functional communicative pressures, but by extension, and in conjunction with the existing efficiency literature, further support the

11. In the current datasets roughly 90% of underlying phonological forms mapped to two or more morphemes for Japanese, but only around 50% of URs were homophonous for Sumerian (at least based on modern understanding of Sumerian phonology).

view that human linguistic communication in general, independent of modality, is shaped by such pressures. However, the question of whether modality affects the realization of efficiency remains open.

Future Considerations

The study presented here only addresses a small piece of the broader question of whether efficiency pressures shape writing systems and written language. To close, it may be worth briefly discussing some of the ways in which this kind of study can be improved in future research.

Optimization and the Space of Possible Systems

One consequence of considering an entire writing system/written language is that the space of all *possible* hypothetical variants is intractably large (and, depending on limitations, theoretically infinite). In comparison with some past efficiency studies which narrowed in on specific semantic domains, this means that it's not easy to tell how a given writing systems stacks up complexity-wise in the space of all possible systems. As such, future work may benefit from establishing plausible optimized competitor systems (in a similar vein as the syllabary/alphabetic systems used here) which can serve as benchmarks of comparison. The possibility space being language-specific also means that, again unlike other work in the efficiency literature, the two target writing systems couldn't be directly compared against each other in the same space. Establishing a language-neutral space is a challenge, since phonology and lexicons are so language-dependent, but doing so would allow for more direct comparisons of writing systems.

Complexity

While the two types of complexity used here are certainly relevant for writing systems and constitute a strong starting point, an analysis of writing system efficiency would benefit from considering a wider array of possible types of complexity and effort, such as inventory size, learnability, and visual complexity. Perhaps chief among these is the size of the inventory of characters (or other graphic units), and by extension the costs associated with learning and retaining a system. For example, while the hypothetical syllabary-only systems considered in the current study tended towards greater motor effort and/or material costs, they also presumably resulted in systems which would require learning a much smaller number of distinct characters.

Informativeness

Given the significant role that context has been argued to play in the efficiency of ambiguity (Piantadosi, Tily, and Gibson, 2012), informativeness measures may benefit from incorporating contextual information, which wasn't done in the current study. Previous work (Hermalin and Regier, 2019) has already found evidence that Sumerian character ambiguity is greatly reduced by even a small amount of additional context, but the overall in-context efficiency of written Sumerian, as well as written Japanese, remains to be tested.

Another potential issue with the current implementation of informativeness is that the similarity-based reader distribution always prefers that more similar referents have the same form. However, as argued in Brochhagen and Boleda (2022), it may be more advantageous for two meanings to use different forms if those two meanings are *too* similar. As such, similarity-based informativeness measures used in future work may benefit from assuming a less monotonic relationship between similarity and informativeness. The task of quantifying semantics, especially for ancient or low-resource languages, is itself another challenge for research in this vein (see appendix B for details, and critiques, of how the current study handled this issue).

Conclusion

The results reported here provide evidence that even highly logographic and polyvalent writing systems are communicatively efficient. This suggests that neither logography nor ambiguity are inherently disadvantageous for writing systems, and their presence may even serve to enhance efficiency.

As discussed earlier, the idea of writing systems being shaped by efficiency pressures is not at all new, but more data-driven, quantitative approaches to measuring the communicative efficiency of writing systems have remained elusive. Regardless of whether or not the approach used here proves to be the best option, it is the hope of the current author that researchers interested in writing systems and functional cognitive pressures on human communication will continue to consider how matters of writing system efficiency, development, and linguistic fit can be measured in quantitative, theoretically grounded ways.

A. Glossary and Terminology

The following covers how certain writing systems-related terminology are defined in this paper. Many of the definitions used here are adapted

from Neef (2015) and Weingarten (2011). The definitions used here all intended to be somewhat flexible.

- *Character*: The primary meaning/information-bearing unit of written form in a writing system. Characters typically (but not always): occupy a certain amount of space, can map to some stable portion of linguistic information (such as a phoneme or morpheme), are treated as distinct units in sociological contexts, and are stable in the sense that they can ‘stand on their own’.
- *Spelling*: A sequence of one or more characters which can be cleanly mapped to a morpheme or sound sequence.
- *Script*: A set of written forms, (characters, diacritics, etc.) which are used by a writing system.
- *Written Language*: Language or linguistic communication for which the modality is writing.
- *Non-written Language*: Language or linguistic communication that takes place in any modality other than writing. (Note that this term is *not* being used with the meaning of “a language that doesn’t currently have a writing system or written counterpart”.)
- *Writing System*: A system which maps written forms, composed of components drawn from a script, to units of linguistic information, ultimately to meaning-bearing units such as morphemes. More generally, a writing system consists of a script, a language, and a mapping from one to the other.
- *Phonography and Logography*: Properties and uses of a writing system that primarily pertain to sounds and spoken forms will be considered phonographic. Properties and uses of a writing system that pertain to semantics and/or lexical identity, or which involve a single character mapping to a morpheme or entire word, will fall under the header of logography. Terms such as *semantographic* and *morphographic* may be used to more precisely distinguish between different uses of *logographic*.
- *Syllabary*: A writing system in which a character can map to a syllable or mora.

B. Methods—Similarity

Phonological similarity was calculated as a function of phonological distance. Phonological distance was calculated as feature-weighted Levenshtein edit distance, using methods adapted from Abdullah et al. (2021) and Fontan et al. (2016). The distance between two strings *a* and *b* is based on how many operations (deletion, insertion, or replacement) are needed to turn *a* into *b* and vice versa, with the cost associated with replacement being based on the number of phonological features that are identical between the two sounds involved. More precisely, the similarity between two individual sounds was treated as the number of phono-

logical features for which they had the same value divided by the total number of features which were applicable to both sounds; this results in a distance score between 0 and 1. Feature values for each phone were based on the featural specifications provided by PHOIBLE 2.0 (Moran and McCloy, 2019). These feature values were constrained by which features were distinctive for the target language (for example, since Japanese doesn't have any ejective sounds, features that distinguish between ejective and pulmonic sounds were not included for the feature values of phones in Japanese).

The phonological similarity between two sound strings a and b was handled as follows:

1. Both strings were syllabified. Within each syllable, each segment was marked as either being part of the onset, nucleus, or coda.
2. For each of the syllables $\sigma_{a1} \cdots \sigma_{an}$ of a , the distance was calculated between that syllable and each of the syllables $\sigma_{b1} \cdots \sigma_{bn}$ of b .
3. a and b were aligned so as to minimize the total distance between aligned syllables. If a and b differed in number of syllables, the shorter form was padded with empty syllables.
4. The total distance between a and b was then calculated as the sum of featural distances between aligned syllables.

For example, if the two target strings were /ugula/ and /udu/, the process would: syllabify the strings into /u.gu.la/ and /u.du/; get the distance between each syllable of the first string and each syllable of the second string (i.e., $\text{dist}(u, u)$, $\text{dist}(u, du)$, $\text{dist}(gu, u)$, $\text{dist}(gu, du)$, etc.); align the two syllabified strings so as to minimize the featural distance

between aligned syllables, resulting in the alignment $\begin{array}{ccc} u & gu & la \\ u & du & \emptyset \end{array}$; then sum the featural distance of each aligned syllable pair.

For semantic similarity, morphemes were converted to numerical vectors, with the similarity between two morphemes being a function of the cosine distance between their respective vectors. The pre-trained Sentence-BERT model (Reimers and Gurevych, 2019) was used to convert morphemes to 384-dimensional vector embeddings. Because this model is trained on English, the inputs were English definitions of the target morphemes. For Sumerian, the definitions used were those given by ePSD2's online dictionary (<https://oracc.museum.upenn.edu/epSD2/sux/>). For Japanese, definitions were retrieved using the Jamdict Python library (<https://jamdict.readthedocs.io/en/latest/>) and, for certain Sino-Japanese morphemes, kanjidatabase.com's *jukugo* database (Tamaoka, Makioka, Sanders, and Verdonschot, 2017)¹².

12. This is an imperfect method of quantifying semantics, for a few reasons. The most prominent flaw is that it assumes that a model trained on modern English sen-

To strike a balance between how similar to morphemes are in absolute terms and how similar they are relative to other morphemes, the semantic similarity between two morphemes $\text{sim}(m_1, m_2)$ was calculated as the mean of two similarity measures, sim_{BERT} and sim_{rank} . The sim_{BERT} measure is simply the BERT-based similarity score, as described above. The sim_{rank} measure is based on the rank BERT similarity between the two morphemes, where the similarity rank of morpheme m_2 relative to morpheme m_1 equals 1 if m_2 is the most similar morpheme to m_1 , is 2 if m_2 is the second most similar morpheme to m_1 , etc. To keep the sim measure symmetric (such that $\text{sim}(m_1, m_2) = \text{sim}(m_2, m_1)$), the sim_{rank} measure between two morphemes was taken as the average similarity rank $\text{rank}_{\text{mean}}(m_1, m_2)$ between the two. This score was then normalized, with similar pairs scoring closer to 1 and less similar pairs scoring closer to 0.

C. Hypothetical Sumerian Syllabary

The hypothetical Sumerian syllabary used in the current study was created as follows: For each unique syllable (going in order from most frequent to least frequent), get the list of individual characters that map to that syllable at least once in the corpus and which haven't already been assigned by this syllabary-generation process. Of those characters, choose the one that most often maps to the target syllable and assign it to the target syllable. That character now has the syllabary value of

tences and modern English texts will accurately capture meaning distinctions and associations for morphemes in other languages. This semantics approach also takes at face value the definitions provided by the respective translation dictionaries, but even thorough dictionary definitions can't capture the full extent of a word's meanings. As a result, it is assuredly the case that certain semantic similarities or associations which are present in the target languages will not be captured by the translation-based BERT embeddings, and certain associations which are present only for English will be falsely applied to Sumerian and Japanese. The reasons behind adopting this flawed approach are mostly based in convenience and data availability. Training a new language model on the comparatively small (and genre-imbalanced) Sumerian corpus carries risks of its own; furthermore, modern lexicography of Sumerian word meanings may include information which, by chance, wouldn't be captured in the Ur3Admin Corpus, meaning that translated definitions may actually be more informative than a corpus-trained model, at least in some ways. Overall, the use of translated definitions is somewhat of a necessity for Sumerian. The decision to use the same strategy for Japanese, rather than use existing Japanese-trained models, was made so as to make the treatment of both languages as similar as possible, but it would assuredly be an improvement to approach Japanese semantics using Japanese data. Nonetheless, it is the opinion of the author that, for all its flaws, using English translations and an English-trained model does still capture accurate information about lexical semantics, and while the approach is certainly imperfect, it is not invalid.

that syllable, and cannot be assigned additional syllable values. If there are no available characters for a syllable, either because they have no extant single-character spellings or because all of their candidate characters had already been assigned other mappings, then that syllable is temporarily skipped. Once every syllable has either been assigned or skipped in this way, the not-yet-assigned syllables are mapped as follows: for each remaining syllable, choose a random not-yet-assigned character which has among its syllable values a syllable that has the same onset+nucleus or the same rime as the target syllable, and assign that character to the target syllable. For example, if the target syllable was /bab/, any character that has /ba/ or /ab/ among its values would be a viable candidate. This process still yields a small number of C_1VC_2 syllables which don't get assigned. These remaining syllables get treated as if they were C_1VVC_2 sequences, meaning that they will be spelled as the character that's been assigned to C_1V followed by the character that's been assigned to VC_2 . (The use of this C_1VVC_2 strategy is justified by it being an actual spelling strategy that was used for writing Sumerian and Akkadian.)

This results in a hypothetical Sumerian syllabary for which: every character has exactly one value, and that value is a syllable; and every unique syllable (that occurs in the corpus) has exactly one spelling¹³. In most cases, this spelling is a single character, with the only exceptions being a handful of C_1VC_2 syllables which get 're-analyzed' as C_1VVC_2 sequences, as described above. Note that this system is not optimized for anything other than phonological informativeness: for example, when assigning values to characters, the most common syllables weren't automatically paired with the lowest complexity characters. Instead, this generation process was intended to at least approximately result in a system which could plausibly have arisen from the actual writing system used for writing Ur III Sumerian, and can be used as a stand-in for the 'what if' scenario where the actual Sumerian writing system developed into a dedicated syllabary.

13. While this hypothetical system resembles the generated PGen systems described above insofar as new spellings are created based on existing character-sound mappings, the Sumerian SylS system differs from the PGen systems in some key ways: the SylS system is (almost) completely unambiguous, at the level of both morpheme spellings (from the writer's perspective) and individual syllable spellings (for both writer and reader), whereas the PGen systems maintained varying levels of polyvalence; the SylS system is purely syllabographic, while the PGen systems included mappings such that a single character could map to a string of two or more syllables; and the SylS system isn't randomly generated, while the PGen systems were.

References

- Abdullah, Badr M. et al. (2021). "Do acoustic word embeddings capture phonological similarity? An empirical study". arXiv:2106.08686.
- Aylett, Matthew and Alice Turk (2004). "The smooth signal redundancy hypothesis: A functional explanation for relationships between redundancy, prosodic prominence, and duration in spontaneous speech". In: *Language and speech* 47.1, pp. 31–56.
- Backhouse, A. E. (1984). "Aspects of the graphological structure of Japanese". In: *Visible Language* 18.3, p. 219.
- Baines, John (2004). "The earliest Egyptian writing: development, context, purpose". In: *The first writing: Script invention as history and process*. Cambridge University Press Cambridge, pp. 150–189.
- Baroni, Antonio (2011). "Alphabetic vs. non-alphabetic writing: Linguistic fit and natural tendencies". In: *Rivista di Linguistica* 23.2, pp. 127–159.
- Berg, Kristian and Mark Aronoff (2017). "Self-organization in the spelling of English suffixes: The emergence of culture out of anarchy". In: *Language*, pp. 37–64.
- Black, Jeremy A. (1990). "The alleged "extra" phonemes of Sumerian". In: *Revue d'Assyriologie et d'archéologie orientale* 84.2, pp. 107–118.
- Boltz, William G. (2011). "Literacy and the Emergence of Writing in China". In: *Writing and Literacy in Early China: Studies from the Columbia Early China Seminar*. University of Washington Press Seattle, pp. 51–84.
- Borgwaldt, Susanne R., Frauke M. Hellwig, and Annette MB de Groot (2004). "Word-initial entropy in five languages: Letter to sound, and sound to letter". In: *Written Language & Literacy* 7.2, pp. 165–184.
- Borleffs, Elisabeth et al. (2017). "Measuring orthographic transparency and morphological-syllabic complexity in alphabetic orthographies: a narrative review". In: *Reading and writing* 30, pp. 1617–1638.
- Brochhagen, Thomas (2020). "Signalling under uncertainty: Interpretative alignment without a common prior". In: *The British Journal for the Philosophy of Science*.
- Brochhagen, Thomas and Gemma Boleda (2022). "When do languages use the same word for different meanings? The Goldilocks principle in colexification". In: *Cognition* 226, p. 105179.
- Cahill, Michael and Elke Karan (2008). "Factors in designing effective orthographies for unwritten languages". In: *SIL International*.
- Caplan, Spencer, Jordan Kodner, and Charles Yang (2020). "Miller's monkey updated: Communicative efficiency and the statistics of words in natural language". In: *Cognition* 205, p. 104466.
- Chang, Li-Yun, Yen-Chi Chen, and Charles A. Perfetti (2018). "GraphCom: A multidimensional measure of graphic complexity applied to 131 written languages". In: *Behavior research methods* 50, pp. 427–449.

- Changizi, Mark A. and Shinsuke Shimojo (2005). "Character complexity and redundancy in writing systems over human history". In: *Proceedings of the Royal Society B: Biological Sciences* 272.1560, pp. 267–275.
- Changizi, Mark A. et al. (2006). "The structures of letters and symbols throughout human history are selected to match those found in objects in natural scenes". In: *The American Naturalist* 167.5, E117–E139.
- Chen, Ping (1999). *Modern Chinese: History and Sociolinguistics*. ERIC.
- Chomsky, Noam and Morris Halle (1968). *The sound pattern of English*.
- Civil, Miguel (1973). "The Sumerian writing system: Some problems". In: *Orientalia* 42, pp. 21–34.
- (2004). "The Series DIRI = (w)atru". In: *Materials for the Sumerian Lexicon* XV.
- Cohen Priva, Uriel (2017). "Informativity and the actuation of lenition". In: *Language*, pp. 569–597.
- Cooper, Jerrold S. (2004). "Babylonian beginnings: the origin of the cuneiform writing system in comparative perspective". In: *The first writing: Script invention as history and process*. Cambridge University Press Cambridge, pp. 71–99.
- Coulmas, Florian (2003). *Writing systems: An introduction to their linguistic analysis*. Cambridge University Press.
- (2009). "Evaluating merit—the evolution of writing reconsidered". In: *Writing systems research* 1.1, pp. 5–17.
- (2018). "Writing and Literacy in Modern Japan". In: *The Cambridge Handbook of Japanese Linguistics*. Ed. by Yoko Hasegawa. Cambridge Handbooks in Language and Linguistics. Cambridge University Press, pp. 114–132.
- Coupé, Christophe et al. (2019). "Different languages, similar encoding efficiency: Comparable information rates across the human communicative niche". In: *Science advances* 5.9, eaaw2594.
- Cover, T. M. and Joy A. Thomas (1991). *Elements of information theory*. eng. Wiley series in telecommunications. New York: Wiley. ISBN: 0471062596.
- Daniels, Peter T. (1990). "Fundamentals of grammatology". In: *Journal of the American Oriental Society*, pp. 727–731.
- (1992). "The syllabic origin of writing and the segmental origin of the alphabet". In: *The linguistics of literacy* 21, pp. 83–110.
- (2017). "Writing systems". In: *The handbook of linguistics*. Wiley Online Library, pp. 75–94.
- Daniels, Peter T. and William Bright (1996). *The world's writing systems*. Oxford University Press on Demand.
- Daniels, Peter T. and David L. Share (2018). "Writing system variation and its consequences for reading and dyslexia". In: *Scientific Studies of Reading* 22.1, pp. 101–116.
- Dautriche, Isabelle et al. (2017). "Words cluster phonetically beyond phonotactic regularities". In: *Cognition* 163, pp. 128–145.

- de Voogt, Alex (2024). "The Evolution of Writing Systems: An Introduction". In: *Oxford Handbook of Human Symbolic Evolution*. Oxford University Press.
- DeFrancis, John (1989). *Visible speech: The diverse oneness of writing systems*. University of Hawaii Press.
- (1996). "How efficient is the Chinese writing system?" In: *Visible Language* 30.1, p. 06.
- Denić, Milica, Shane Steinert-Threlkeld, and Jakub Szymanik (2020). "Complexity/informativeness trade-off in the domain of indefinite pronouns". In: *Semantics and linguistic theory*, pp. 166–184.
- Devlin, Jacob et al. (2018). "BERT: Pre-training of deep bidirectional transformers for language understanding". preprint arXiv:1810.04805.
- Diringer, David (1962). *Writing*. Frederick A. Praeger.
- Dye, Melody et al. (2017). "A functional theory of gender paradigms". In: *Perspectives on morphological organization*. Brill, pp. 212–239.
- (2018). "Alternative solutions to a language design problem: The role of adjectives and gender marking in efficient communication". In: *Topics in cognitive science* 10.1, pp. 209–224.
- Edzard, Dietz Otto (2003). *Sumerian grammar*. Vol. 71. Brill.
- Fedzechkina, Maryia, T. Florian Jaeger, and Elissa L. Newport (2011). "Functional biases in language learning: Evidence from word order and case-marking interaction". In: *Proceedings of the Annual Meeting of the Cognitive Science Society*. Vol. 33. 33.
- Fedzechkina, Maryia, Elissa L. Newport, and T. Florian Jaeger (2017). "Balancing effort and information transmission during language acquisition: Evidence from word order and case marking". In: *Cognitive science* 41.2, pp. 416–446.
- Fedzechkina, Masha, Lucy Hall Hartley, and Gareth Roberts (2023). "Social biases can lead to less communicatively efficient languages". In: *Language Acquisition* 30.3-4, pp. 230–255.
- Fontan, Lionel et al. (2016). "Using phonologically weighted Levenshtein distances for the prediction of microscopic intelligibility". In: *Annual conference Interspeech (INTERSPEECH 2016)*, pp. 650–654.
- Fortson, Benjamin W. (2023). "Systems and Idiosyncrasies". In: *The Cambridge Handbook of Historical Orthography*. Cambridge University Press, pp. 183–203.
- Foxvog, Daniel A. (2014). "Introduction to Sumerian grammar". In: *TCS* 1.60, p. 3.
- Frellesvig, Bjarke (2010). *A History of the Japanese Language*. Cambridge University Press.
- Frost, Ram (2012). "Towards a universal model of reading". In: *Behavioral and brain sciences* 35.5, pp. 263–279.
- Futrell, Richard, Kyle Mahowald, and Edward Gibson (2015). "Large-scale evidence of dependency length minimization in 37 languages". In: *Proceedings of the National Academy of Sciences* 112.33, pp. 10336–10341.

- Gahl, Susanne, Yao Yao, and Keith Johnson (2012). "Why reduce? Phonological neighborhood density and phonetic reduction in spontaneous speech". In: *Journal of memory and language* 66.4, pp. 789–806.
- Garrod, Simon et al. (2007). "Foundations of representation: where might graphical symbol systems come from?" In: *Cognitive science* 31.6, pp. 961–987.
- Gelb, Ignace J. (1963). *A study of writing*. University of Chicago Press.
- Gibson, Edward et al. (2019). "How efficiency shapes human language". In: *Trends in Cognitive Sciences* 23.5, pp. 389–407.
- Gildea, Daniel and David Temperley (2010). "Do grammars minimize dependency length?" In: *Cognitive Science* 34.2, pp. 286–310.
- Halliday, M. A. K. (2010). "Ideas About Language (1977)". eng. In: *On Language and Linguistics*. Continuum International Publishing Group, pp. 92–115. ISBN: 1474211933.
- Han, Simon J. et al. (2022). "Simplification is not dominant in the evolution of Chinese characters". In: *Open Mind* 6, pp. 264–279.
- Handel, Zev (2013). "Can a logographic script be simplified? Lessons from the 20th century Chinese writing reform informed by recent psycholinguistic research". In: *Scr. Theol* 5, pp. 21–66.
- (2019). *Sinography: The borrowing and adaptation of the Chinese script*. Brill.
- Hannas, William C. (1997). *Asia's orthographic dilemma*. University of Hawaii Press.
- Hermalin, Noah (2023). "A mutual information-based approach to quantifying logography in Japanese and Sumerian". In: *Proceedings of the Workshop on Computation and Written Language (CAWL 2023)*, pp. 105–110.
- Hermalin, Noah and Terry Regier (2019). "Efficient use of ambiguity in an early writing system: Evidence from Sumerian cuneiform." In: *CogSci*, pp. 422–427.
- Honda, Keisuke (2007). "Homography-induced ambiguity in Japanese kanji and the lexical disambiguating function of okurigana". In: *Gengogaku Ronsō* 26, pp. 17–42.
- (2008). "Okurigana: An Analysis from the Viewpoint of Decoding". In: 筑波応用言語学研究 [*Journal of Applied Linguistics at Tsukuba*] 15, pp. 87–100.
- Houston, Stephen D. (2012a). "The Shape of Script—Views from the Middle". In: *The shape of script: How and why writing systems change*. Ed. by Stephen D. Houston. School for Advanced Research Press. Santa Fe, pp. xiii–xxiii.
- ed. (2012b). *The shape of script: How and why writing systems change*. School for Advanced Research Press.
- Howes, Davis (1968). "Zipf's law and Miller's random-monkey model". In: *The American Journal of Psychology* 81.2, pp. 269–272.

- Jaeger, T. and Roger Levy (2006). "Speakers optimize information density through syntactic reduction". In: *Advances in neural information processing systems* 19.
- Jaeger, T. Florian (2010). "Redundancy and reduction: Speakers manage syntactic information density". In: *Cognitive psychology* 61.1, pp. 23–62.
- Jagersma, Bram (2010). "A descriptive grammar of Sumerian". PhD thesis. Leiden University.
- Joyce, Terry and Dimitrios Meletis (2021). "Alternative criteria for writing system typology: Cross-linguistic observations from the German and Japanese writing systems". In: *Zeitschrift für Sprachwissenschaft* 40.3, pp. 257–277.
- Juba, Brendan et al. (2011). *Compression without a common prior: an information-theoretic justification for ambiguity in language*. Institute for Theoretical Computer Science.
- Justeson, John S. (1978). "Mayan scribal practice in the Classic period: A test-case of an explanatory approach to the study of writing systems". PhD thesis. Stanford University.
- Kageyama, Taro and Michiaki Saito (2016). "Vocabulary strata and word formation processes". In: *Handbook of Japanese lexicon and word formation*. Mouton de Gruyter Berlin, pp. 11–50.
- Karjus, Andres et al. (2021). "Conceptual similarity and communicative need shape colexification: An experimental study". In: *Cognitive Science* 45.9, e13035.
- Katz, Leonard and Ram Frost (1992). "The reading process is different for different orthographies: The orthographic depth hypothesis". In: *Advances in psychology*. Vol. 94. Elsevier, pp. 67–84.
- Kelly, Piers et al. (2021). "The predictable evolution of letter shapes: An emergent script of West Africa recapitulates historical change in writing systems". In: *Current Anthropology* 62.6, pp. 669–691.
- Kemp, Charles and Terry Regier (2012). "Kinship categories across languages reflect general communicative principles". In: *Science* 336.6084, pp. 1049–1054.
- Kemp, Charles, Yang Xu, and Terry Regier (2018). "Semantic typology and efficient communication". In: *Annual Review of Linguistics* 4, pp. 109–128.
- Koshevoy, Alexey, Helena Miton, and Olivier Morin (2023). "Zipf's law of abbreviation holds for individual characters across a broad range of writing systems". In: *Cognition* 238, p. 105527.
- Kuperman, Victor and Raymond Bertram (2013). "Moving spaces: Spelling alternation in English noun-noun compounds". In: *Language and Cognitive processes* 28.7, pp. 939–966.
- Kurumada, Chigusa and T. Florian Jaeger (2015). "Communicative efficiency in language production: Optional case-marking in Japanese". In: *Journal of Memory and Language* 83, pp. 152–178.

- Lee, Hanjung (2009). "Quantitative variation in Korean case ellipsis: implications for case theory". In: *Differential subject marking*. Springer, pp. 41–61.
- Levshina, Natalia (2021). "Cross-linguistic trade-offs and causal relationships between cues to grammatical subject and object, and the problem of efficiency-related explanations". In: *Frontiers in Psychology* 12, p. 648200.
- (2022). *Communicative efficiency*. Cambridge University Press.
- Maekawa, Kikuo et al. (2014). "Balanced corpus of contemporary written Japanese". In: *Language resources and evaluation* 48, pp. 345–371.
- Mahowald, Kyle, Isabelle Dautriche, et al. (2022). "Efficient Communication and The Organization of The Lexicon". eng. In: *The Oxford Handbook of the Mental Lexicon*. Oxford Handbooks. Oxford University Press. ISBN: 9780198845003.
- Mahowald, Kyle et al. (2013). "Info/information theory: Speakers choose shorter words in predictive contexts". In: *Cognition* 126.2, pp. 313–318.
- Majid, Asifa et al. (2018). "Differential coding of perception in the world's languages". In: *Proceedings of the National Academy of Sciences* 115.45, pp. 11369–11376.
- Marjou, Xavier (2019). "Oteann: Estimating the transparency of orthographies with an artificial neural network". arXiv:1912.13321.
- Mattingly, Ignatius G. (1985). "Did orthographies evolve?" In: *Remedial and special education* 6.6, pp. 18–23.
- Meister, Clara et al. (2021). "Revisiting the uniform information density hypothesis". preprint arXiv:2109.11635.
- Meletis, Dimitrios (2019). "Naturalness in scripts and writing systems: Outlining a Natural Grapholinguistics". PhD thesis. University of Graz.
- Michalowski, Piotr (2004). "Sumerian". In: *The Cambridge Encyclopedia of the World's Ancient Languages*, pp. 19–59.
- (2020). "Sumerian". In: *A companion to ancient Near Eastern languages*, pp. 83–105.
- Miton, Helena and Olivier Morin (2021). "Graphic complexity in writing systems". In: *Cognition* 214, p. 104771.
- Mollica, Francis, Geoff Bacon, Yang Xu, et al. (2020). "Grammatical marking and the tradeoff between code length and informativeness." In: *CogSci*.
- Mollica, Francis, Geoff Bacon, Noga Zaslavsky, et al. (2021). "The forms and meanings of grammatical markers support efficient communication". In: *Proceedings of the National Academy of Sciences* 118.49, e2025993118.
- Moran, Steven and Daniel McCloy, eds. (2019). *PHOIBLE 2.0*. Jena: Max Planck Institute for the Science of Human History. URL: <https://phoible.org/>.

- Morin, Olivier (2018). "Spontaneous emergence of legibility in writing systems: The case of orientation anisotropy". In: *Cognitive Science* 42.2, pp. 664–677.
- Morin, Olivier and Alexey Koshevoy (2024). "A Cultural Evolutionary Model for the Law of Abbreviation". In: *Topics in cognitive science*.
- Morita, Aiko and Katsuo Tamaoka (2002). "Semantic involvement in the lexical and sentence processing of Japanese Kanji". In: *Brain and language* 82.1, pp. 54–64.
- Nagano, Akiko and Masaharu Shimada (2014). "Morphological theory and orthography: Kanji as a representation of lexemes". In: *Journal of Linguistics* 50.2, pp. 323–364.
- Neef, Martin (2015). "Writing systems as modular objects: proposals for theory design in grapholinguistics". In: *Open Linguistics* 1.1.
- Osterkamp, Sven and Gordian Schreiber (2021). "<The>e ubi<qu>ity of polygra<ph>y and its significan<ce> for <th>e typology of <wr>iti<ng> systems". In: *Written Language & Literacy* 24.2, pp. 171–197.
- Peloquin, Benjamin N., Noah D. Goodman, and Michael C. Frank (2020). "The interactions of rational, pragmatic agents lead to efficient language structure and use". In: *Topics in Cognitive Science* 12.1, pp. 433–445.
- Piantadosi, Steven T., Harry Tily, and Edward Gibson (2011). "Word lengths are optimized for efficient communication". In: *Proceedings of the National Academy of Sciences* 108.9, pp. 3526–3529.
- (2012). "The communicative function of ambiguity in language". In: *Cognition* 122.3, pp. 280–291.
- Pimentel, Tiago, Clara Meister, et al. (2023). "Revisiting the Optimality of Word Lengths". In: *Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing*, pp. 2240–2255.
- Pimentel, Tiago, Irene Nikkarinen, et al. (2021). "How (non-) optimal is the lexicon?" preprint arXiv:2104.14279.
- Pimentel, Tiago et al. (2020). "Speakers fill lexical semantic gaps with context". preprint arXiv:2010.02172.
- Powlison, Paul S. (1968). "Bases for formulating an efficient orthography". In: *The Bible Translator* 19.2, pp. 74–91.
- Protopapas, Athanassios and Eleni L. Vlahou (2009). "A comparative quantitative analysis of Greek orthographic transparency". In: *Behavior research methods* 41, pp. 991–1008.
- Pulgram, Ernst (1976). "The typologies of writing systems". In: *Writing without letters*. Manchester University Press, Manchester, pp. 1–28.
- Regier, Terry, Alexandra Carstensen, and Charles Kemp (2016). "Languages support efficient communication about the environment: Words for snow revisited". In: *PloS one* 11.4, e0151138.
- Regier, Terry, Charles Kemp, and Paul Kay (2015). "Word meanings across languages support efficient communication". In: *The handbook of language emergence*, pp. 237–263.

- Reimers, Nils and Iryna Gurevych (2019). "Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks". arXiv:1908.10084.
- Rogers, Henry (1995). "Optimal orthographies". In: *Scripts and literacy: Reading and learning to read alphabets, syllabaries and characters*. Springer, pp. 31–43.
- Salomon, Richard (2012). "Some principles and patterns of script change". In: *The shape of script: How and why writing systems change*, pp. 119–133.
- Sampson, Geoffrey (1985). "Writing Systems". In: *London, UK: Hutchinson*.
- (2015). "Writing systems: methods for recording language". In: *The Routledge handbook of linguistics*. Routledge, pp. 47–61.
- (2016). "Typology and the study of writing systems". In: *Linguistic Typology* 20.3, pp. 561–567.
- (2018). "From phonemic spelling to distinctive spelling". In: *Written Language & Literacy* 21.1, pp. 3–25.
- Seeley, Christopher (2000). *A history of writing in Japan*. University of Hawaii Press.
- Seidenberg, Mark S. (2011). "Reading in different writing systems: One architecture, multiple solutions." In: *Dyslexia across Languages: Orthography and the Brain-Gene-Behavior Link*. Paul H. Brookes Publishing, pp. 146–168.
- (2012). "Writing systems: Not optimal, but good enough". In: *Behavioral and Brain Sciences* 35.5, p. 305.
- Shannon, Claude Elwood (1948). "A mathematical theory of communication". In: *The Bell system technical journal* 27.3, pp. 379–423.
- Share, David L. (2014). "Alphabetism in reading science". In: *Frontiers in psychology* 5, p. 752.
- Siegelman, Noam, Devin M. Kearns, and Jay G. Rueckl (2020). "Using information-theoretic measures to characterize the structure of the writing system: the case of orthographic-phonological regularities in English". In: *Behavior research methods* 52, pp. 1292–1312.
- Siegelman, Noam, Jay G. Rueckl, et al. (2022). "Quantifying the regularities between orthography and semantics and their impact on group-and individual-level behavior." In: *Journal of Experimental Psychology: Learning, Memory, and Cognition* 48.6, p. 839.
- Smith, Janet S. (Shibatani) (1996). "Japanese Writing". In: *The world's writing systems*. Oxford University Press, pp. 209–217.
- Sproat, Richard (2023). *Symbols: An evolutionary history from the stone age to the future*. Springer Nature.
- Sproat, Richard and Alexander Gutkin (2021). "The taxonomy of writing systems: How to measure how logographic a system is". In: *Computational Linguistics* 47.3, pp. 477–528.
- Steinert-Threlkeld, Shane (2021). "Quantifiers in natural language: Efficient communication and degrees of semantic universals". In: *Entropy* 23.10, p. 1335.

- Tamaoka, Katsuo et al. (2017). "www.kanjidatabase.com: a new interactive online database for psychological and linguistic research on Japanese kanji and their compound words". In: *Psychological research* 81, pp. 696–708.
- Taylor, Insup and M. Martin Taylor (1995). *Writing and literacy in Chinese, Korean, and Japanese*. Studies in written language and literacy, v. 3. Amsterdam ; John Benjamins Pub. Co. ISBN: 9027217947.
- Taylor, Isaac (1883). *The alphabet: an account of the origin and development of letters*. eng. London: K. Paul, Trench & co.
- Tinney, Steve and Eleanor Robson (2014). *ORACC: The Open Richly Annotated Cuneiform Corpus*. URL: <http://oracc.museum.upenn.edu>.
- Trigger, Bruce G. (1998). "Writing systems: A case study in cultural evolution". In: *Norwegian archaeological review* 31.1, pp. 39–62.
- Trott, Sean and Benjamin Bergen (2020). "Why do human languages have homophones?" In: *Cognition* 205, p. 104449.
- (2022). "Languages are efficient, but for whom?" In: *Cognition* 225, p. 105094.
- Unger, J. Marshall (2011). "What linguistic units do Chinese characters represent?" In: *Written Language & Literacy* 14.2, pp. 293–302.
- (2014). "Empirical evidence and the typology of writing systems: a response to Handel". In: *SCRIPTA, Volume 6*, pp. 75–95.
- Unger, J. Marshall and John DeFrancis (1995). "Logographic and semiographic writing systems: A critique of Sampson's classification". In: *Scripts and literacy: Reading and learning to read alphabets, syllabaries and characters*. Springer, pp. 45–58.
- Vachek, Josef (1973). *Written language: General problems and problems of English*. The Hague: Mouton.
- Van den Bosch, Antal et al. (1994). "Measuring the complexity of writing systems". In: *Journal of Quantitative Linguistics* 1.3, pp. 178–188.
- Veldhuis, Niek (2011). "Levels of literacy". In: *The Oxford handbook of cuneiform culture*, pp. 68–89.
- Veldhuis, Niek C. (2012). "Cuneiform: Changes and developments". In: *The shape of script. How and why writing systems change*. School of Advanced Research Press, pp. 3–23.
- Venezky, Richard L. (1970). "Principles for the design of practical writing systems". In: *Anthropological linguistics* 12.7, pp. 256–270.
- (2004). "In search of the perfect orthography". In: *Written Language & Literacy* 7.2, pp. 139–163.
- Voegelin, Charles F. and Florence M. Voegelin (1961). "Typological classification of systems with included, excluded and self-sufficient alphabets". In: *Anthropological Linguistics*, pp. 55–96.
- Wang, Yamei and Géraldine Walther (2023). "Mandarin classifier systems optimize to accommodate communicative pressures". In: *Findings of the Association for Computational Linguistics: EMNLP 2023*, pp. 12664–12674.

- Wasow, Thomas (2015). "Ambiguity Avoidance is Overrated". In: *Ambiguity: Language and Communication*. Ed. by Susanne Winkler. De Gruyter, pp. 29–47.
- Wedel, Andrew, Scott Jackson, and Abby Kaplan (July 2013). "Functional load and the lexicon: Evidence that syntactic category and frequency relationships in minimal lemma pairs predict the loss of phoneme contrasts in language change". In: *Language and speech* 56.3, pp. 395–417.
- Wedel, Andrew, Abby Kaplan, and Scott Jackson (May 2013). "High functional load inhibits phonological contrast loss: A corpus study". In: *Cognition* 128.2, pp. 179–186.
- Weingarten, Rüdiger (2011). "Comparative graphematics". In: *Written Language & Literacy* 14.1, pp. 12–38.
- Winter, Bodo, Marcus Perlman, and Asifa Majid (2018). "Vision dominates in perceptual language: English sensory vocabulary is optimized for usage". In: *Cognition* 179, pp. 213–220.
- Winters, James and Olivier Morin (2019). "From context to code: Information transfer constrains the emergence of graphic codes". In: *Cognitive Science* 43.3, e12722.
- Woods, Christopher (2006). "Bilingualism, scribal learning, and the death of Sumerian". In: *Margins of Writing, Origins of Cultures*. Ed. by Seth L. Sanders. The Oriental Institute of the University of Chicago Chicago, pp. 91–120.
- (2010). "Visible language: the earliest writing systems". In: *Visible language: Inventions of Writing in the Ancient Middle East and Beyond*. The Oriental Institute of the University of Chicago, pp. 15–25.
- Xu, Yang, Khang Duong, et al. (2020). "Conceptual relations predict colexification across languages". In: *Cognition* 201, p. 104280.
- Xu, Yang, Terry Regier, and Barbara C. Malt (2016). "Historical semantic chaining and efficient communication: The case of container names". In: *Cognitive science* 40.8, pp. 2081–2094.
- Yin, Sora Heng and James White (2018). "Neutralization and homophony avoidance in phonological learning". In: *Cognition* 179, pp. 89–101.
- Zaslavsky, Noga, Karee Garvin, et al. (2022). "The evolution of color naming reflects pressure for efficiency: Evidence from the recent past". In: *Journal of Language Evolution* 7.2, pp. 184–199.
- Zaslavsky, Noga, Mora Maldonado, and Jennifer Culbertson (2021). "Let's talk (efficiently) about us: Person systems achieve near-optimal compression". In: *Proceedings of the annual meeting of the cognitive science society*. Vol. 43. 43.
- Zaslavsky, Noga et al. (2018). "Efficient compression in color naming and its evolution". In: *Proceedings of the National Academy of Sciences* 115.31, pp. 7937–7942.

- Zaslavsky, Noga et al. (2019). "Semantic categories of artifacts and animals reflect efficient coding". In: *Proceedings of the Annual Meeting of the Cognitive Science Society*. Vol. 41.
- Zehentner, Eva (2022). "Ambiguity avoidance as a factor in the rise of the English dative alternation". In: *Cognitive Linguistics* 33.1, pp. 3–33.
- Zipf, George Kingsley (1949). *Human behavior and the principle of least effort: An introduction to human ecology*. New York: Addison-Wesley.

The Antiquity and Timeframe of the *Rongorongo* Script on Rapa Nui (Easter Island)

Gordon G. Berthin & Robert M. Schoch

Abstract. We examine the timeline of the *rongorongo* glyphic script of Rapa Nui (Easter Island) from its possible origins in the ancient indigenous rock art to artifacts collected by non-Rapanui in the 1860s and later. The demonstration of pen and ink writing by Spanish visitors to the island in 1770 may have inspired a prolific classical age of tablet inscriptions, with several large, recovered artifacts ^{14}C (radiocarbon) dated to circa 1820s–1860s. We present a regression model based upon ^{14}C data, tablet physical characteristics, and glyph paleography, to estimate the relative ages of seventeen larger artifacts. Recognized possible *rongorongo* inscriptions pre-dating or contemporaneous to 1770 are limited—perhaps due to environmental decay—to an inscription on a red *scoria* stone *pukao* (head-covering used to adorn or complement the giant *moai* statues) and an inscription on a treaty document produced and collected during the Spanish visit. Blackbird raids (1862–1863) and disease (smallpox was spread by a repatriated Rapanui) apparently decimated those knowledgeable in the script, and thus the *rongorongo* instructional system collapsed, leading to the demise of the script. Nevertheless, an inscribed wooden fish sculpture, possibly dating from the early 1900s, exhibits characteristics of *rongorongo* composition, although not composed using classical *rongorongo* glyphs.

1. Early History

To identify the timeframe for the development and literary lifetime of the *rongorongo* script it is first necessary to determine the initial date of settlement of Rapa Nui (Easter Island) and the place of origin of its first settlers. Sampling of the genetic profile of the indigenous population of Rapa Nui has associated “(about 90% in average) to a Polynesian-like ancestry” (Moreno-Mayar et al. 2024, p. 390). Additionally, the typology of

Gordon G. Berthin  0009-0008-5051-2879
University of Toronto
E-mail: gordon.berthin@utoronto.ca

Robert M. Schoch
Boston University
E-mail: schoch@bu.edu

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 597–632. <https://doi.org/10.36824/2024-graf-bert>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

the Rapanui language is associable to that of the Malayo-Polynesian language family (Figure 1). Again, this indicates a dominantly Polynesian ancestry of the original inhabitants.

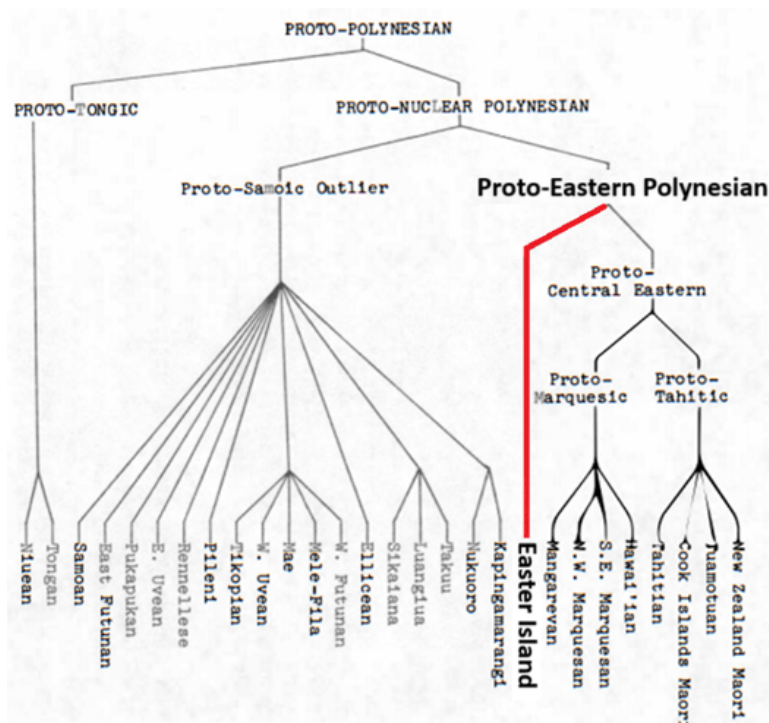


FIG. 1. Tracing the Polynesian settlement pattern based on linguistic relationships. The Rapanui (Easter Island) language is old (isolated for a long time) and descended directly from Proto-Eastern Polynesian. Illustration reference (Biggs 1978, p. 697)

The settlement of the Polynesian people throughout the Pacific Ocean likely originated with the Lapita people of Taiwan and Philippines. They expanded through Indonesia and Fiji by about 1500 BCE, reaching Tonga and Samoa somewhere between 1100 and 800 BCE (Irwin 2017, p. 4). Between 300 and 1000 CE, after a hiatus of 1,000 years, further exploration resumed in a generally eastward direction to Tahiti, the heart of East Polynesia. Perhaps the renewed exploration was driven by the emergence of periods of intense El Niño weather patterns causing “the prevailing south-easterly trade-winds to weaken, while the frequency of westerly winds increases” (ibid., p. 5). Under such conditions voyagers could have reliably sailed or tacked in any direction. More-

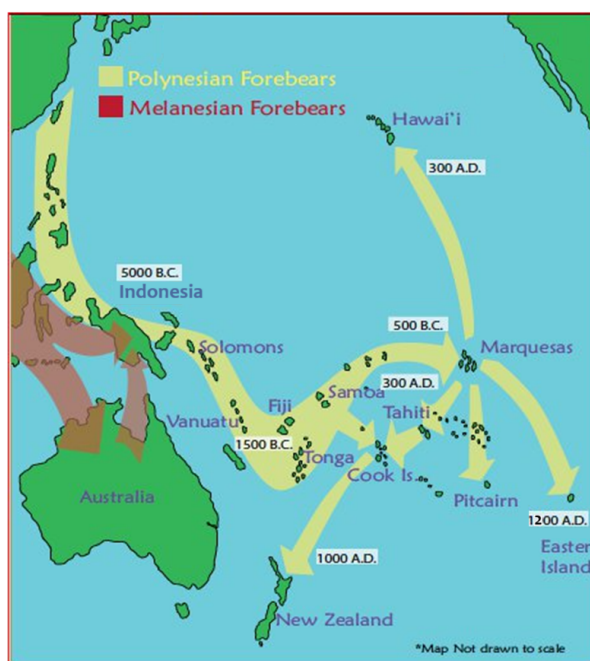


FIG. 2. Polynesian Migration Patterns. Illustration reference: Alan Armstrong, <https://www.quora.com/What-route-did-Polynesians-take-Did-Maori-and-Samoans-come-from-Tonga-Whats-the-dateline-of-the-Polynesian-history>

over, empty, high above sea level, volcanic (resource-rich), well-watered lands having surrounding ocean banks teeming with wholesome (non-toxic) fish stocks were ever-prized territories for new immigrants. To the North, Hawaii, to the Southeast, Rapa Nui, and to the Southwest, New Zealand (the extremities—vertices—of the so-called Polynesian triangle) each afforded these attributes. Rapa Nui was likely explored and occupied (perhaps intermittently) as early as 500 CE and the introduction of the invasive (South American) *Sisyrinchium* weed (blue-eyed grass) at that time raises the possibility of Amerindian sojourns (Rull 2022, p. 296); even more provocative, the presence of the weed *Verbena littoralis* suggests an Amerindian discovery of Easter Island as early as circa 450 BCE (ibid.). Extended Polynesian colonization followed, not later than the 1200s CE after a moistening of the island climate (ibid., pp. 299, 302). Figure 2 shows a feasible progression of Lapitan/Polynesian colonization across the Pacific.

Rapa Nui formed when outflows from three (now extinct) volcanoes (Rano Kao to the Southwest, Poike to the East, and in the North, Maunga Terevaka—the largest, at 511 m) merged to produce a roughly triangular

Fatu Hiva (South Marquesas), and Mangareva. This raises the likelihood of there having been an inter-island confederacy in Eastern Polynesia in the distant past, with indigenous sailors from the archipelago occasionally visiting South or Central America. Any one of those America-bound voyagers (from any of the aforementioned islands) could have established a vital outpost at Rapa Nui along the way.

Eastern Polynesian associations with the settlements at the fringes of their dominion were short lived. When Spanish seafarers reached the region in the 1500s (led by Ferdinand Magellan) they found an archipelago in which the Central-Eastern islands (Society Islands, Cook Islands, Marquesas, Austral Islands) had lost contact with the outlying 'marginal' Eastern Polynesian lands (Rapa Nui, Hawaii, New Zealand, plus the Americas) (Horsburgh and McCoy 2017, p. 14). Horsburgh and McCoy (*ibid.*, p. 7) view this societal retrenchment as being the consequence of evolution away from a colonizing focus and toward a trading focus (*viz.* ships beginning to carry trade items such as stone tools and timbers rather than immigrants). The strengthening of the Tongan Maritime Polity (trading empire) (*ibid.*, p. 14) in Western Polynesia may have quickened this transformative process. Positioned 2,600 km distant, and directly against the trade winds, Rapa Nui and South America (a further 3,800 km) would never have been lucrative destinations for traders. Both apparently became isolated quickly—soon after colonization. In the case of Rapa Nui, its early disengagement from other Polynesian settlements is attested by language phonology (see Figure 1) wherein Rapanui remains the language most closely related to the original Proto-Eastern Polynesian tongue and the other East Polynesian languages were later in diverging from one another (for additional discussion of this topic, see Du Feu and Fischer 1993).

Polynesian settlers to Rapa Nui brought rats with them as a food source. The rats ate the nuts of the palm trees that forested the most arable parts of the island at the time, impairing the ability of the trees to reproduce (Bahn and Flenley 2017, pp. 197, 200). Moreover, trees would have been felled for their wood to build and carve and, perhaps, to provide fuel for fires. Droughts and wildfires additionally caused damage to the palm canopy (Rull et al. 2015, p. 7). By the 1600s, the continuing loss of palms had led to nearly complete deforestation. Besides losing their forests, the burgeoning island population overharvested many bird and fish species leading to extinctions (Bahn and Flenley 2017, p. 108). Turning almost exclusively to raising chickens and farming taro, bottle gourds, sweet potato, sugar cane, and bananas (Roggeveen in Corney 1908, p. 21; Rull 2022, p. 292), the Rapanui reached ecological balance with the land. Their numbers increased and were estimated to be about 3,000 (Jakubowska 2014, p. 72) when Easter Island was discovered by Dutch explorer Roggeveen in 1722 (Roggeveen in Corney 1908, pp. 4-6).

On islands that they settled, the Polynesians constructed *marae* (ceremonial places), which typically included an *abu* - “a platform-like structure made of stone and/or coral slabs” (Molle 2021). Stone assemblages (sometimes in human form) were placed upon the tops of the *abus*. The *marae* also incorporated wooden platforms, upon which portions of food were offered to the deities. “*Unu* [a Tahitian denotation] were upright-standing wooden boards carved with animal motifs symbolising the identity of the social group” (ibid.). They were an additional prominent feature of the *marae* (ibid.).

It seems that the Rapanui began construction of *abus* almost immediately following the establishment of their colony. The stone effigies customarily installed upon the *abus* took the form of massive human head and torso monoliths (*moai*) carved from single volcanic tuff blocks. The *moai* averaged 4 m height and 12.5 tonnes weight (Tribes 2012) and are believed to have been carved primarily between 1250 and 1500 (Fischer 2005, p. 33). To serve as head coverings for certain important *moai*, *pukao* (topknots) were quarried from pumice-like red scoria and carved into cylindrical form. The *pukao* are believed by some to have been added in the 1500s and 1600s CE, after the depletion of structural timber on the island. Per tradition, the *pukao* were raised to the tops of the *moai* using temporary ramps (and possibly ropes in parbuckling arrangement to gain 2:1 mechanical advantage) (Hixon et. al. 2018). Figure 4 shows a possible ramp arrangement for installation of a *pukao* on a *moai*. An included illustration of a traditional fish lookout (*tupa*) affirms the skillfulness of the Rapanui people in constructing elevated ramps from stones. Figure 6 shows an illustration of three *moai* statues on an *abu* with the centre statue adorned by a *pukao*.

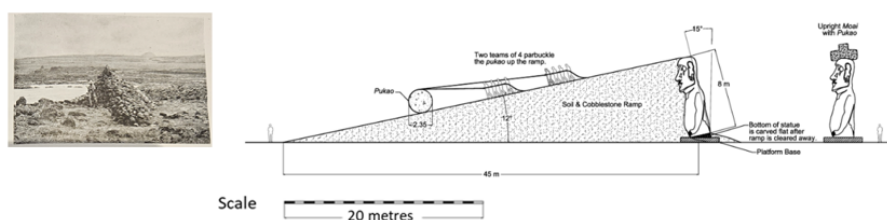


FIG. 4. At left, traditional Rapa Nui ramp-like structure and, at right, similarly constructed (proposed) ramp for installing *pukao* on *moai* statues (illustration references: left, Routledge 1919, p. 172; right, Hixon et. al 2018)

After Roggeveen’s 1722 visit—and perhaps in response to violent experiences with the visiting European or American ships’ crews during the years that followed—inslander leaders increasingly opted for military rule and prosecution of intertribal wars. They pulled down their *moai*

statues and by 1868, in the wake of incessant belligerent campaigns, the last behemoth had fallen (Palmer 1870, p. 177).

2. The Script

Other than on Rapa Nui, there has never been a Polynesian history of writing east of Indonesia prior to modern times (examples of recent scripts are the Woleai or Caroline Islands script, see Riesenbergh and Kaneshiro 1960, and the Eskayan language and script of Bohol, Philippines, see Kelly 2016). The traditional Indonesian Lampung (Lamong) script, a 20-character syllabary enhanced via diacritics (accents) (Pudjiastuti, undated; Pandey 2022) appears, morphologically at least, to be very different from Rapanui *rongorongo*.

Routledge (1919, p. 249)—an early Rapa Nui ethnographer—recounts discussions with an islander who said that, according to tradition, there had been a *rongorongo* board purportedly brought by the first immigrants to the Island. “... Ngaara, trusting him entirely, gave into his care this most valuable kohau [wood] known as ‘ranga’. It was the only one of the kind in existence, and was reported to have been brought by the first immigrants.” Fischer (1997, p. 291) has expressed doubt about such claims, since *rongorongo*-style writing is unattested elsewhere in indigenous Eastern Polynesia.

Acknowledging genetic and botanical evidence for probable contact between the Eastern Polynesians and the Pacific Coast South Americans,¹ it is possible that some coastal Americans may have imparted knowledge of the logo-syllabic Meso-American script to visiting Polynesian explorers and traders. If such education did happen, then it was—at best—confined to the elucidation of basic concepts and never encompassed the specific calligraphy of the writing. Meso-American glyphs bear no more resemblance to *rongorongo* than does the Lampung script. In summation, the Rapanui may or may not have been aware of systems of writing which had been developed at the outer boundaries of their realm. Even if the Islanders did possess this awareness, *rongorongo* was nevertheless a system of glyphs that they devised on their own.²

1. The Quechuan (Peru/Bolivia) word for the sweet potato (an American plant [Horsburgh and McCoy 2017, p. 10]) is *kumar*. It is nearly identical to the Rapanui word for the tuber, which is *kumara*. Thor Heyerdahl (1976) also noted many artistic and cultural similarities between Rapa Nui and the Americas.

2. Here we should mention “for the record” that, although not widely accepted, Robert Langdon in his 1975 book *The Lost Caravel* “suggested that *rongorongo* was derived from the system of writing that castaways from the Spanish caravel *San Lesmes* had brought to the leeward Society Islands in 1526. It was argued that the caravel had run aground on Amanu Atoll, 800 km east of Tahiti; that the crew, which included Basques, saved their ship by pushing their heavy guns overboard; and that they

There are three types of *rongorongo* and related “scripts” (using the term loosely) that developed on Easter Island: Classical, which is generally of most interest to epigraphers and the focus for this paper, *ta’u* which was created for trade purposes (1880s through to early 1900s), and *mama* which was a 20th century creation having a limited number of characters; most specimens of the latter two may not be scripts at all, but fundamentally “decoration” and, therefore, not *rongorongo* per se (see Fischer 1997, and Horley 2021, and references cited in these monographs, for a discussion of the three types of Easter Island “scripts”). The Classical corpus consists of about 14,000 signs or glyphs (the actual count depends on the definition of a sign or glyph) and about 300 different glyph forms, depending upon how one distinguishes distinct glyph forms (the numbers given are estimated by GGB). According to Rapanui tradition, the single or compounded glyphs—everyday indigenous objects, creatures, and astronomical signs—were only taught at special schools to select male cantors. Inscriptions are read horizontally, left to right, from bottom to top with a 180° turn at each line end such that alternate lines are presented upside-down when viewing a tablet as a whole. This arrangement is referred to as ‘inverse boustrophedon’. The variety of glyphs were meticulously catalogued and numbered by Barthel (Barthel 1958, End Pages). We designate Barthel numbers with an ‘RR’ prefix in this paper. A ‘V’ suffix to a Barthel catalogue number denotes a variant of a standard form whereas ‘x’ and ‘y’ suffixes to the catalogue number indicate vertical and horizontal glyph inversions respectively (opposite to the Cartesian coordinate system). Suffixes ‘h’ or ‘t’ indicate superscripted or subscripted forms respectively. Other suffixes denote

then continued on a westerly course until reaching Ra’iatea. There some of the men settled, married local women and produced Hispano-Polynesian descendants. Later, some of those descendants were drifted to Ra’ivavae whence some of their descendants reached Easter Island, probably in the second half of the 17th century. Evidence used to support this scenario included numerous descriptions by the early European explorers of Caucasian-looking people in the Society Islands, Ra’ivavae and Easter Island and the discovery, in 1971, that 18 Easter Islanders with no known non-Easter Island ancestors were carriers of certain genes that are peculiar to Europeans and especially common among Basques.” (summary quoted from Langdon 1996, p. 117). We find this hypothesis interesting but extremely unlikely, and we want to be clear that we do not endorse it. Due to the predominant winds and currents, Polynesian voyagers would not naturally drift east; a skilled crew and a seaworthy vessel would generally be required for an eastward voyage to Easter Island. Furthermore, European crews of the sixteenth and seventeenth centuries most likely had low literacy rates, thus they would be unsuited to the task of teaching non-Europeans about writing, and even if they had introduced the concept of writing, it would most likely have been in the form of a Latin alphabetic system, not a system like *rongorongo*. Regarding the “Basque genes” detected in 1971, we suspect that these were probably the result of interbreeding with European visitors following the “discovery” of Easter Island by Jacob Roggeveen in 1722.

glyph affixes, viz. ‘f’ where fibers are attached to the glyph, and ‘i’ and ‘j’ for lozenges attached on right or left sides of a glyph respectively (‘k’ denotes the total omission of lozenges in situations where lozenges are commonly a part of the glyph form). A colon identifies a vertical stacking of glyphs (catalogued top to bottom but presumably read bottom to top). A period denotes a horizontal fusion of two glyphs. Dashes denote space between glyphs. Twenty-five wooden tablets or carved wooden artifacts, designated by letters of the alphabet A through Y, are used to catalogue important *rongorongo* artifacts. Common names such as the Rapanui word *Mamari* ‘egg’ or the specimen domicile, like ‘Santiago Staff’, are also given to these specimens (Barthel 1958, pp. 14–33). There are various other *rongorongo* objects in addition to those recorded in Barthel (1958), Fischer (1997), and Horley (2021), some of which we shall discuss. The faces of the wooden boards, on which most inscriptions are written, are designated ‘r’, recto, for tablet front, and ‘v’, verso, for tablet back. The designation is ‘a’ for one side, and ‘b’, for the other side, if it is uncertain as to which side is which. Glyphs are incised singly or—importantly—in compound forms.

3. Early Rock Art and *Rongorongo* Inscriptions

There remains ample evidence of a rich history of carving and surface art on Rapa Nui. The wooden carvings of antiquity (viz. *unu* [if such effigies were ever a part of the island’s *abu*-based culture] or drawings painted upon traditional Polynesian *tapa* [bark-cloth]) were vulnerable to degradation by the subtropical heat and humidity of the island climate (Horley 2021, p. 298; many other researchers have made the same point previously) and have, therefore, been largely lost to modern ethnographers. However, stone carvings remain. Indeed, some *moai* bodies retain petroglyph-like patterns, which have been associated with traditional island ring and girdle tattooing motifs (Routledge 1919, p. 220). The British Museum *moai* (Figure 5) displays body art forms, which are evocative of *rongorongo* glyphs; viz. bird (RR600) or vulva (RR51) likenesses perhaps added over the years following the carving of the original statue (Heyerdahl 1976, Plate 5). Of particular interest to us, icons, closely matching to *rongorongo* glyphs, are found on rock art throughout the island. Some of the incisions even appear upon *abus* and possibly date back to the time of construction of the ceremonial platforms. This art has been extensively reported by (among others) Routledge (1919, p. 220), Schulze-Maizier (1926, p. 193), Lavachery (Poussart 2010, p. 122), Lee (1992, pp. 113–116), Lee (1993, pp. 112–121), Bahn and Flenley (2017, p. 239), and Lee et al. (2016, pp. 157–209). Georgia Lee and Paul Horley (Horley 2021, p. 391) have compiled a quite impressive list of rock art icons which match to *rongorongo* glyphs. Table I highlights



FIG. 5. Royal Museum *moai* (rear view showing body art). Photo Credit: Babelstone https://commons.wikimedia.org/wiki/File:Hoa-Hakananai%27a_rear_view.jpg. Usage: Attribution-Share Alike 3.0 Unported License

their findings with rock art forms (at left) compared to glyphs upon *rongorongo* tablets (at right). Icons associated with the ceremonial village of Orongo possibly date to the later era of island birdman competitions (1600s—early and mid 1800s).

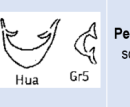
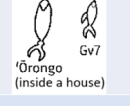
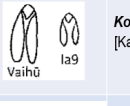
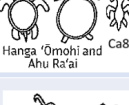
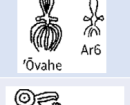
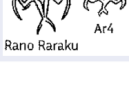
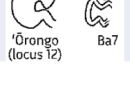
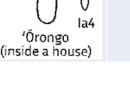
At some point the Rapanui became aware that icons could be associated with abstract concepts such as *komari* (vulva) becoming a traditional synecdoche³ for female ‘coming of age’ (Kaeppler and Van Tilburg 2020, pp. 396, 400). Perhaps the Islanders even considered near-rebus associations (viz. *hōnu* ‘turtle’ versus *hōnui* ‘provider’?).⁴ A further realization

3. An expression where a part is made to represent the whole as in “all hands on deck” (the ‘hand’ signifies the ‘entire crewmember’).

4. GGB observes that, unlike the vulva forms, the contexts of other *rongorongo*-like rock art tropes are usually obscure. It remains speculative as to how often they were ever contemplated in rebus, synecdochic, or metaphoric senses. By contrast, Guy (1990, pp.140-141, 144) has offered evidence that there *was* proxy usage of certain rock art resemblant to *rongorongo* glyph forms in writings upon the Mamari tablet. The apparent *rongorongo* lunar calendar of the Mamari tablet is the only passage of *rongorongo* for which the underlying meaning is somewhat understood. Guy (ibid.) has demonstrated, within the calendar, that ‘crescent moon’ may be a representation for ‘lunar night’, and ‘leaping fish’ and ‘diving fish’ may represent metaphors for the concepts of ‘increasing’ and ‘decreasing’ respectively.

that icons could be lined up one after the other in strings and called out—in succession—either directly, or as proxies, in such manner as to produce intelligible communications, could have led to the genesis of the *rongorongo* script.

TABLE 1. Rapanui Rock Carvings Possibly Showing *Rongorongo*-like Precursors (from Georgia Lee and Paul Horley [Horley 2021, p. 391]). (Snippets in white boxes from Horley [2021, p. 391]; compilation of glossary translations, and likely date estimates for *tangata manu*, *ika*, *mautini* by GGB.)

 Hanga Oteo and 'Anakena Pr9	Human figure. (<i>Tangata</i> [Englert 1974, p. 353])	 Papa Tataku Poki Ia3	Splayed sitting figure	 Hua Gr5	Pectoral reimiro. ('Rei' ≡ canoe sculpture [Chauvet 1935, Fig. 175])
 inland from Ahu Ra'ai Ca9	Roosters. (<i>Moa</i> [Englert 1974, p. 339])	 'Ōrongo (inside a house) Gv7	Generic fish. (<i>ika</i> [Englert 1974, p. 329]) (likely 1600-1700s)	 Vaihū Ia9	Komari. (Vulva ≡ female nubility [Kaepler and Van Tilburg 2020, pp. 396, 400])
 Hanga 'Ōmohi and Ahu Ra'ai Ca8	Turtle. (<i>Hōnu</i> [Englert 1974, p. 323])	 'Ōvahe Ar6	Octopus. (<i>Heke</i> ≡ audacious [Englert 1974, p. 321] or God <i>Tangaroa</i> [Au 2018, p. 26])	 'Ava o Kiri and Ahu Ra'ai Ca8	Moon. (<i>Mahina</i> [Englert 1974, p. 335])
 Rano Raraku Ar4	Frigate bird in diving stance (or [per GGB] taking flight)	 'Ōrongo (locus 12) Ba7	Birdman. (<i>Tangata manu</i> , [Fischer 1997, p. 333]) (likely 1600-1700s)	 'Ōrongo (inside a house) Ia4	Gourd. (<i>Mautini, hue</i> [Churchill 1912, pp. 208, 227]) (likely 1600-1700s)

4. *Moai pukao* 36 *rongorongo* Inscription

In addition to rock art icons, a brief *rongorongo* inscription appears upon a downed *pukao* (designated No. 36 by archaeologists) among the ruins of the Ahu Akahanga *moai* platform on the Easter Island south shore (Figure 7). The photo inset shows the large size of a *pukao* relative to a person. Pukao 36 is in the lower right of the photograph and indicated by an arrow. Inscribed on the *pukao*, left to right, are a two-headed bird RR680 and a single bird (sooty tern) RR600 (Poussart 2010, p. 122). Above the birds is a smaller hominid character—RR385Vy. This human-like form would have been concealed from view when the *pukao* rested atop the standing *moai* (Figure 6). Perhaps RR385Vy is graffiti by the carvers. Figure 8 provides detailed views and drawings of the Pukao 36 inscriptions. Fallen red topknots have proven to be targets for vandals and scavengers and on Pukao 36 a large slab has been broken off the right side of the sooty tern glyph. Fischer (1997, p. 548) has posited that the *rongorongo* glyphs were carved into this *pukao* long after it was toppled. However, the



FIG. 6. Artificial Intelligence conception of *moai* statues as they once stood upon the traditional *abu* at Akahanga. The *pukao topknot* adorning the centre statue is engraved with *rongorongo* characters. Illustration reference: aicreate.com

glyphs are very large and restricted to a 140° sector around the cylinder: evidently meant to be seen and read head-on and from afar (see Figure 6). What a sight it would have been in its golden age: a 5-metre *moai* with infinite blue ocean beyond, flaunting a surmounting red topknot, emblazoned with bold *rongorongo* characters, scribed in the form of beautiful birds!

5. Spanish Visit of 1770

5.1. Treaty Document

In 1770 Spanish visited Rapa Nui and took possession of the land through religious and diplomatic acts, first by planting three wooden crosses (Agüera in Corney 1908, pp. 103-104) and then signing a treaty—“*and for the greater confirmation of so serious an act some of the natives present signed or attested the official document by marking upon it certain characters in their own form of script*” (ibid., p. 104)—and thus came to be the treaty document, which the Rapanui ‘signed’ with three lines of glyphs. Kenneth Emory (1972,



FIG. 7. Pukao 36 (identified by arrow) at its current location among the ruins of the *moai* at the Ahu Anakanga site. Illustration reference: <https://imagarapanui.com>

p. 63) has previously noted the resemblance between the Rapanui signatures and the *rongorongo* script:

What they drew for their “signatures” were petroglyph designs for birds and the vulva, and some other marks which might have been attempts to imitate European writing. The same petroglyph designs appear among the characters of the Easter Island script and could have served as a basis for developing its signs.

Berthin (2024, p. 494) asserts that the first line of glyphs does not resemble *rongorongo*. The second line, on the other hand, consists of four *rongorongo*-style characters, all codable via Barthel’s cataloguing system and all exhibiting axes of symmetry. The first character of the second line appears to be of simplified construction. The third line consists of a single birdman: glyph RR400. A criticism of the chiefs’ signatures is that they do not meet the high standard of calligraphy seen on *rongorongo* tablets. This is expectable. If one scribes something ad hoc (and being unfamiliar with stylus and ink methods of inscription) then the resulting calligraphy will not meet the standard of a formal work such as a *rongorongo* board carving (where inscriptions—per tradition—were first drafted with a pointed stick onto a banana leaf, before being final-copied

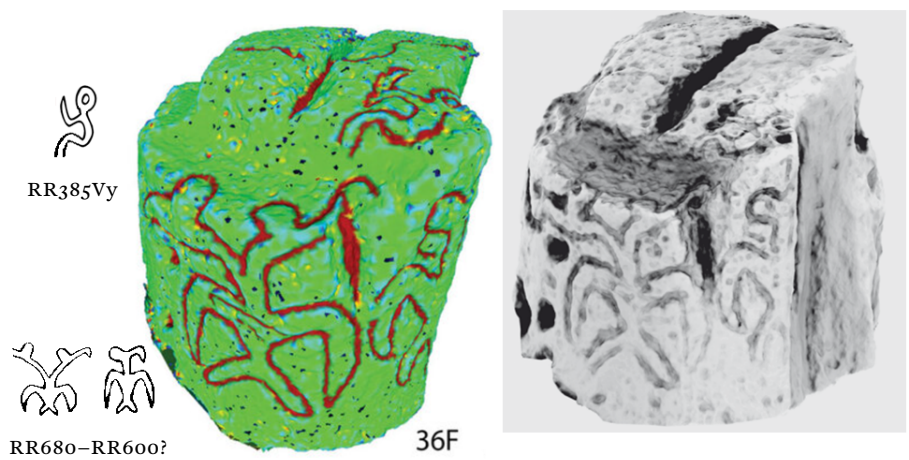


FIG. 8. Details of *Rongorongo* Glyphs (left) and Pukao 36. Illustration references: Computer enhanced image from Hixon et al. (2017) (centre). Pukao 36 photo from Lee et al. 2016, p. 195 (right)

in the wood) (Horley 2021, pp. 384-385, and citations of earlier authors along the same lines therein). De Landa, investigating the Mayan script and obtaining a Mayan-written communication from his informant (Coe and Kerr 1998, p. 228), was likewise in receipt of calligraphy which was inferior to the engravings on the stone monuments (Berthin 2024, pp. 494-495). The Spanish treaty document, and a Barthel cataloguing of its *rongorongo* glyphs, is illustrated in Figure 9.

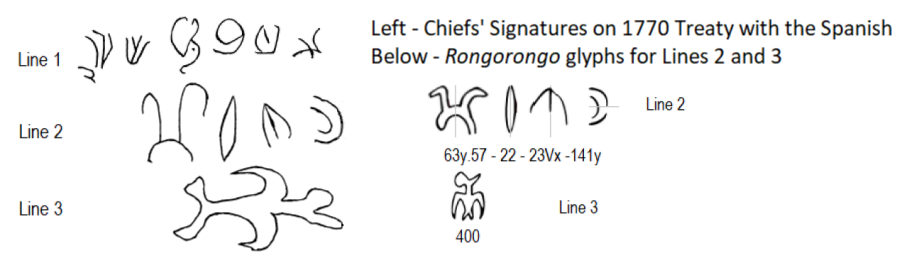


FIG. 9. Spanish Treaty Document of 1770 and morphologically similar *rongorongo* glyphs. Illustration reference: Berthin 2024, p. 493

5.2. Agüera's Numbers

Francisco Agüera, an officer of the 1770 Spanish Expedition, compiled a glossary of the Rapanui language including words for numbers one through ten. He may have inadvertently elicited a few *rongorongo* sign definitions by writing Western Arabic numerals and then noting integer names which Islanders offered for them. Later, it was discovered that their submissions did not even remotely match the Polynesian language words for digits one to nine. Therefore, it's theorized that the Rapanui instead gave names of familiar icons resembling the numerals. Blanco (1994, p. 38) importantly associated the Rapanui's *moroki* (*moroki*) with "small fish that is used for bait", contending that a distorted 8-shape perhaps resembled a small fish (Blanco 1994, pp. 38-39). More importantly, the *Rapanui* word *moroki* also denotes the concept of "make something in perfect condition" (ibid., p. 38). And the figure-eight (8) equally resembles the common "stacked-circle" glyph RR2. Jaussen's List (Jaussen 1893) synonymously interprets that "8" glyph-form as 'what is good' (Chauvet 1935, Fig. 175). Whereas the unreliability of Jaussen's [glyph definition] List is acknowledged, Butinov and Knorozov (1957, p. 8; and earlier work of Métraux 1940) contend that its complete dismissal (as a tool for interpretation of *rongorongo*) is an extreme and incorrect position. Jaussen's informant Metoro often interpreted *rongorongo* glyphs according to their appearances (see additional discussion in, among others, Barthel 1993, Fischer 1997). Hence, the figure-of-eight signifies 'small fish', which signifies '*moroki*', which signifies 'what is good'. Note well that Metoro was apparently primed to associate the icon shape with its intangible (but most useful) definition: 'what is good'.

Table II lists the definitions that Agüera garnered for numbers one to nine. The Spanish 'J' symbol has the same pronunciation as Rapanui 'H'. In addition to the '8', Blanco (1994, p. 38) has also proposed a *rongorongo* glyph morphology which resembles numeral 5. Indeed we (GGB) may suggest that up to five Arabic numerals somewhat resemble *rongorongo* characters. These possible *rongorongo* look-alikes would be the numbers 1, 2, 3, 5, and 8 (see Table II). Two more, 'buoy' for numeral 6, and 'roll-up' for numeral 9, are possible pictographic representations. In the case of numeral 3, perhaps it resembles a vertical compound of two southern hemisphere waning crescent moons. One (GGB) may speculate that since this waning moon style is (from the perspective of a night sky observer) 'going away', then it might be a metaphor for the act of 'going away'. Finally, numeral 10 is not included in Table II. Blanco's (ibid., p. 38) transcription of the pronunciation of this number (*queromata pait-paca quacaxixiva*) is incomprehensible to fluent Rapanui speakers and we are, therefore, unable to evaluate it.

TABLE 2. Agüera's Numbers Compared to RR Glyphs (Blanco 1994, p. 38)

Num- eral	Agüera Word	Rapanui Word & Definition (FMB = Blanco)	Alternative Possibility	<i>Rongorongo?</i> (GGB=Berthin)
1	<i>cojana</i>	<i>ko bana</i> : heat, to be hot	<i>koboa</i> (?): stick (GGB)	
2	<i>corena</i>	<i>ko renga</i> : little girl, pretty	attention-grabbing (=pretty)	𐎔
3	<i>congoju</i>	<i>ko ngobu</i> : eat eagerly	<i>ka obo</i> : go away (FMB)	𐎕
4	<i>quirote</i>	<i>kiróto</i> : toward the inside	?	𐎖
5	<i>majaná</i>	<i>mabana</i> : warm	<i>mabanga</i> : treachery (Maori)	𐎗
6	<i>te úto</i>	<i>te úto</i> : buoy	(obvious pictograph, no RR)	
7	<i>tejèa</i>	<i>te benga</i> : type of fish	?	
8	<i>moroqui</i>	<i>moroki</i> : fish used for bait	make in perfect condition (FMB)	8 (FMB)
9	<i>vijoviri</i>	<i>vebi viri</i> : encircle, roll up a sail	(obvious pictograph, no RR)	

5.3. Cultural Diffusion Theory (Fischer)

... what these aliens [the Spanish] had ritually enacted would doubtless have lent the Rapanui's experience a supernatural solemnity, indeed one of temporarily sharing European *mana* through the act of signing.

The Spanish claim of 1770 was never enforced. The name "San Carlos" for the island was soon forgotten.

But the wonder of writing had arrived on Rapa Nui.

(Fischer 1997, p. 7)

In the preceding quotation, Fischer speculates that the observation of and the participation in the pen-and-ink treaty-signing of 1770 inspired the Rapanui to develop *rongorongo*. A case can be made that all the surviving wooden *rongorongo* artifacts were created post-1770. On the other hand, the perishability of wood or *tapa* artifacts, exposed to the island environment, augurs for natural loss of any such artifact having an age of

some half century or more (the approximate interval between the Spanish visit and the beginning of recovery of *rongorongo* artifacts by Euro-American visitors). Nevertheless, *rongorongo* inscriptions upon the Spanish treaty document and Pukao 36 (in particular) remain physically contradictory to Fischer's hypothesis. The close relationship between rock art icons and *rongorongo* glyphs, coupled with the observed propensity of certain Islanders to associate intangible (non-nounal) terms with such glyph-icons, likewise signifies the potential for there having pre-existed a communication system based upon drawn and etched figures. That said, there have throughout history been countless examples of cultural diffusion. The possibility remains (albeit speculative) that interaction with the Spanish inspired a resurgence or coming of age for the indigenous Rapanui script. At the very least, the three wooden crosses that were planted by the Spanish on Easter Island during their visit could have supplied wood (Orliac 2010, p. 137) for production of novel *rongorongo* compositions (as would have additional raw wood pieces from ship's crews who were anchoring at Easter Island and trading with the Rapanui ever more frequently as the years went by).



RR67

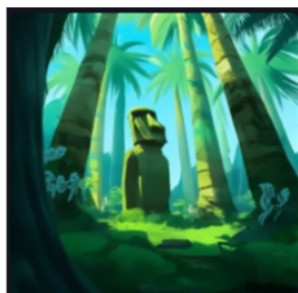


FIG. 10. RR67 glyph compared to forest palms. Illustration reference: www.crayon.com

6. Glyph Morphological Relationship to Anthropological Timeline

It may be possible to benchmark the development of *rongorongo* based upon the morphology of certain glyphs. Perhaps the best example is RR67 which resembles an island palm tree (Figure 10; see Barthel 1958, p. 233; Horley 2021, p. 454; Christenhusz and Govaerts 2024, p. 8). Rapa Nui palms had gone extinct by the middle 1700s at the latest (Christenhusz and Govaerts 2024, p. 8) but most likely a century or more earlier

(see the summary of this subject in Horley 2021, p. 409) and, therefore, the genesis of *rongorongo* likely happened before the loss of the palms and their erasure from memory. Similarly, we may consider traditional Rapa Nui house design. I (GGB) have wondered why there is no *rongorongo* glyph in the shape of a house. Perhaps it is because the general Western preconception of what a house should look like is that of a cube surmounted by a gabled roof (Figure 11- upper left). However, traditional Rapanui houses were built as the one in the photo (Figure 11—upper right). This type of house, known as *bare paenga*, was in the shape of an upside-down canoe with an oblong footing ringed by base-blocks having holes carved/reamed into them. On the long sides, arching tree or bush branches were looped across from one set of base-block holes to those on the opposite side to form the ribs of the upside-down canoe shape. These ribs were then spanned over with reeds and grasses to give protection from the elements. Because this design required no structural timber it would have become dominant once the island supply of wood had been exhausted. Possessing an aerodynamic-like shape, the *bare paenga* design was well-suited to withstanding windy conditions in unsheltered areas.⁵ The appearance of the *bare paenga* form in the *rongorongo* lexicon would likely date from its time of introduction into island life: the late 1500s or beginning of the 1600s at the earliest.

Figure 11 shows some of the glyphs that morphologically resemble elements of canoe house construction: *bare paenga* cross-section (RR27x), long-side foundation base blocks (RR25), foundation plan view (RR22). Some of the *bare paenga* family of glyphs occur quite frequently in the corpus. If added to an already established nucleus of vocabulary, these glyphs would have enhanced the effectiveness with which *rongorongo* was able to present communications. To that end, consider the myriad house glyph synonyms that could be represented by the RR27x *bare paenga* form: niche, harbor, dynasty, enterprise, estate, containment, protection, base, abode, home ... to name but a few. In summation, the palm tree and house glyphs benchmark the classical *rongorongo* script as having undergone significant forward development during the 1500s and 1600s when the palms were yet present but being depleted and *bare paenga* construction was being driven by necessity.

5. In the latter part of the nineteenth century, when vessels laden with timber cargos shipwrecked off Rapa Nui, the Rapanui began to convert from *bare paenga* houses to Western-style home design.

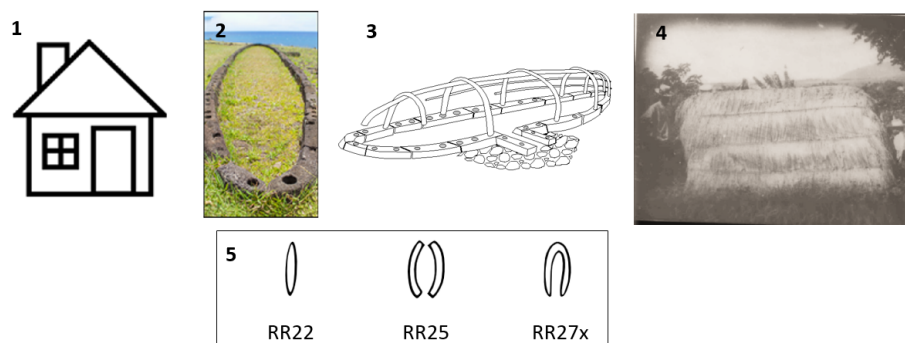


FIG. 11. (1) Generic drawing of 'Western' house. (2) Foundation of Rapa Nui *bare paenga* house (Photograph reference: Kevin Wagar | Wandering Wagars—Adventure Family Travel <https://wanderingwagars.com/>). (3) Framing pattern of *bare paenga* house. (4) Completed *bare paenga*. Photograph reference: Page 63 of Pakarati, C. and R. Wiczorek [2020]. "Identifying Places and People in Walter Lehmann's Photograph Collection of Rapa Nui [Easter Island, 1911]". In: *Rapa Nui Journal* 33.1, 33.2, pp. 44-83. (5) *Rongorongo* glyphs exhibiting similarity to *bare paenga* components

7. Estimating the Production Dates of the *Rongorongo* Tablets

7.1. ^{14}C Radiocarbon Dating

The ages of the surviving *rongorongo* wooden artifacts may be estimated by several means including ^{14}C radiocarbon dating, assessment of physical characteristics of the specimens themselves, and paleography of the recorded inscriptions.

As of early 2025, ^{14}C dating had been conducted on six artifacts. There were no lumberyards on Rapa Nui circa 1650 through the 1860s. Native wood was precious. It was apparently used immediately upon becoming available, and there would have been lively competition among tradespeople for procurement of any discovered flat slab of significant surface area. Completed *rongorongo* tablets were hung from the ceilings of the *bare paenga* houses, in reed wrappings (Routledge 1919, p. 244). Whereas this afforded protection from the elements, the wood yet remained vulnerable to degradation by insects, rainfall and moisture, salt and air-sprays from the Pacific Ocean, and Polynesian rats. Rats gnaw on wood, are very agile, and could possibly climb up walls and onto items hanging from ceilings. Tablet F (Chauvet Fragment), for instance, bears the marks of gnawing rats, although this may have also happened in a cave or some other area where the tablet was stored (Orliac and Orliac 2008, p. 261).

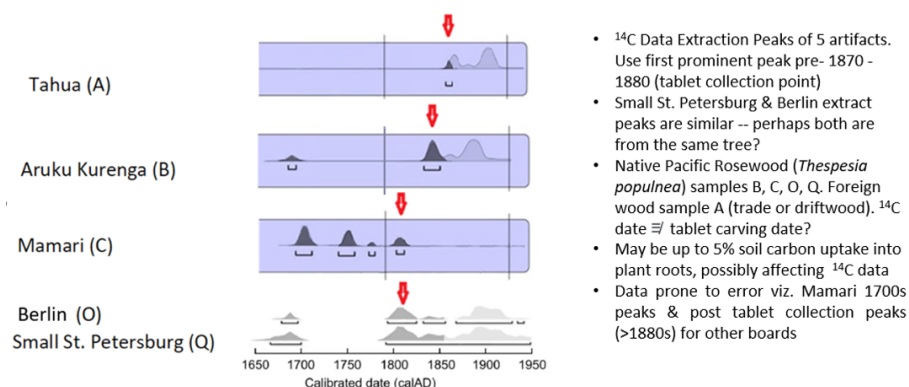


FIG. 12. ^{14}C radiocarbon extraction data peaks for five *rongorongo* tablets. D (Échancrée) is not shown but has been radiocarbon dated to the late fifteenth century. Illustration graphical data: Tablets A, B, C from Ferrara et al., 2024, p. 5; Tablets O, Q from Wieczorek et al., 2023, p. 324

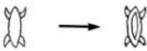
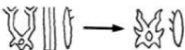
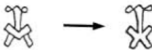
Figure 12 presents ^{14}C radiocarbon extraction data peaks for five tablets, specifically A (Tahua), B (Aruku Kurenga), C (Mamari), O (Berlin), and Q (Small St. Petersburg). The 1476 ^{14}C date for D (Échancrée) demonstrates that it is older than the other radiocarbon-dated tablets by several centuries (Ferrara et al., 2024, pp. 4-5). However, botanical identification has revealed the Échancrée wood to be a species of *Podocarpus*—an evergreen genus not native to Rapa Nui. The possibility remains that this specimen might have originated from driftwood or as an article obtained from visiting Euro-American seafarers. As such, Échancrée may have been incised a great many years after its mother tree was felled. For this reason, we do not consider the Échancrée ^{14}C results to be reliable proxies for the dating of its *rongorongo* inscription. Four tablets derive from native *Thespesia populnea* (Pacific rosewood) and are, therefore, more likely to have originated on Rapa Nui and been promptly worked and finished into *rongorongo* artifacts. These may all date to the nineteenth century, although it is possible that C (Mamari) dates to the eighteenth century based on the earlier radiocarbon peaks (shown in Figure 12). The Tahua tablet is carved from foreign wood but ^{14}C dated no earlier than circa 1861. All five sample extraction results are multi-peaked. For further analysis in this paper, we tentatively picked as the possible/probable artifact inscription date the most recent significant extraction peak which is older than the date of procurement of the *rongo-rongo* artifact by Euro-American interests. There may be up to 5% uptake of carbon via tree root systems, and this may produce small peaks that are older than most of the data. Moreover, some of the ^{14}C extraction peaks are implausible since they happen after the dates at which their

respective tablets were documented as having been collected by Euro-Americans. In Figure 12, such peaks are shown in lighter color, and they are not considered in our analysis. Finally, we concede that this methodology, at best, affords only an estimate of the date of inscription. The date can be older or younger, as the ¹⁴C laboratory procedure and/or calibration can be vulnerable to error, or an inscription could have been added to a re-purposed old tablet.

7.2. Physical characteristics of the boards

Rongorongo board physical characteristics include botanical identification (wood species) and artifact condition. Because of the possibility of continuing trade in foreign wood with Euro-American seafarers, contrasted with the likelihood of native Pacific rosewood tablets predating foreign contact, the native-wood assortment of tablets may, on average, be expected to be older than the foreign-wood collection. However, numerous exceptions to this generalization are to be expected (see further discussion in Section 7.4). Finally, and with respect to the matter of artifact condition, crisp clean tablets would likely be newer than worn, distressed ones.

TABLE 3. *Rongorongo* Glyph Paleography (Wieczorek 2011, p. 37)

base of difference		older than →	← newer than	reference
form of RR70		B, N, Q, R	E, I, P, T	Barthel 1958 page 159
general economics of glyph usage		H, P, Q	A	Guy 1985 page 387
form of RR99 & RR522		D, F, M, N, Q, R, S	B, C, E, G, H, I, K, P	Wieczorek 2011 page 37

7.3. Paleography

We develop two paleographic proxies. Firstly, *rongorongo* characters may simplify over time and the simplifications would then become incorporated into subsequently incised texts. Secondly, novel characters might be invented. Wieczorek (2011) has studied the paleography of *rongorongo* artifacts, specifically the evolution of glyph shapes. Table III presents three of his most credible endorsements for glyph evolution, including

material from studies by Barthel and Guy. The RR70 form (first row) appears to have been redrawn to present a concentric-oval centrepiece in later similar texts. The (presumed archaic) ‘collapsing stool’ form in Table III row three is superseded by the ‘X’ form in newer texts. Within Table III, Wieczorek divides the tablets (each identified by its alphabetic identifier) into two camps: “older than” or “newer than”.

Table IV records the prevalence of the ‘hollow’ RR28/RR29 glyphs. Presence or absence of the 76 ‘penis’ glyph is also indicated. The RR28/RR29 family and the RR76 glyph occur upon some tablets but not others. There appears to be some commonality as to which boards display them, and which do not (see Figure 13). Some tablets (such as A) show usage of all four glyph types, other tablets (such as O) show none. The most recent tablets are assumed to make widest use of the four glyphs. The oldest are assumed to have been incised before the RR28, RR29, RR76 glyph styles entered the *rongorongo* lexicon.

TABLE 4. Appearance of RR28/RR29 variants (✓) or RR76 (■) glyph on major artifacts

Tablet/ Artefact	 RR28	 RR28x	 RR29	 RR29y	 RR76
A	✓	✓	✓	✓	■
B	✓			✓	■
C	✓		✓		
E	✓	✓			■
G				✓	■
H	✓	✓		✓	■
I	✓			✓	■
K					
N					■
O	✓				
P	✓	⌔ ⌔ RR25			■
Q		✓			■
R	✓				
S					
T					
Y		⌔ ⌔ = RR28x?		✓	

Note: RR25 appears in place of RR28x on Tablet P (Great St. Petersburg).
RR25 appears on artifact Y (Paris Snuff Box) whereas RR28x does not.

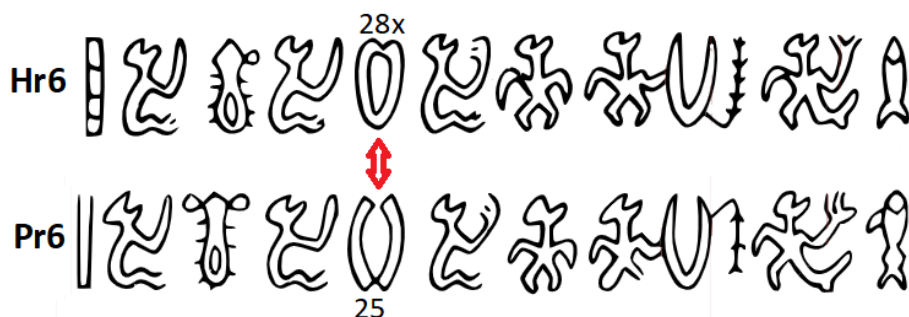


FIG. 13. RR25, appearing on the Great St. Petersburg tablet line Pr6, is replaced with RR28x (of the RR28/RR29 glyph family) on the Great Santiago tablet line Hr6. Characters from Spaelti 2012

7.4. A Model for Estimating *Rongorongo* Tablet Age

To develop a model which estimates the production dates of *rongorongo* tablets that have not been radiocarbon dated, ^{14}C results may be compared to the previously discussed proxy attributes: tablet physical and paleographic characteristics. We limited the artifacts eligible for such comparison to those having 85 legible glyphs or more, to assure that at least a few of the paleographic variations shown in Tables III and IV might have the opportunity to present themselves. Physical characteristics included in our model were tablet condition and botanical identification. We used the classification posted by Spaelti (2012, Tablets) as a representation of general tablet condition. Rankings were: Very Fine = 0.5, Fine = 0.375, Good = 0.175, Poor = 0. A further physical characteristic was investigated by the authors. Namely, special attention was given to visible surface wear along artifact edges, as this was largely attributable to 'Handling Wear' by *rongorongo* board readers. The 'Handling Wear' category was scored between 0.5 (perfect condition) and 0.0 (worn to the point of serious glyph illegibility). All tablets exhibited some degree of wear attributable to handling and the ones in the best condition were only scored 0.35. No estimates of 'Handling Wear' were submitted for the Great Washington (S) (later re-worked into a canoe hull plank) or the Paris Snuff Box (Y) since both artifacts had been repurposed (and their edges significantly altered) at some point after glyph incising. 'Wood Species' (botanical identification) was the final physical attribute which was assessed. Each artifact was rated 0.4 if being of foreign wood and 0.0 if being of native Pacific rosewood (native tablets presumed to be older). There is no information pertaining to the wood species of the Atua-Mata-Riri / Small Washington (R) tablet and, therefore, no 'Wood Species' score was entered for this object.

Three elements of paleography were incorporated into the regression model: the results published by Wieczorek in Table III, the presence or absence of the RR76 glyph, and the extent of representation of the four different glyphs of the RR28/RR29 family. Wieczorek's newer *versus* older assessments were transformed into a ranking of the tablets by rating them as 0 whenever listed as 'older than' in Table III. New tablets were awarded 1.0 wherever they were listed as 'newer than' in the table. Ratings were then totalled for each artifact, and the data from the entire group of objects was collectively normalized to span a 0 to 1.0 range. Artifacts not graded by Wieczorek were not given a score. Tablets displaying the RR76 glyph and glyphs of the RR28/RR29 family were each awarded a score of 1.0 if these glyphs appeared once or more on the artifact and 0 if they did not appear. Since there are four glyphs in the RR28/RR29 family then a total score of 4.0 was possible for this attribute. Shorter legible inscriptions of less than 200 glyphs (viz. Berlin [O] and Snuff Box [Y]), which each exhibited one glyph from the RR28/RR29 family, were awarded a bonus of 0.5 point 'benefit of the doubt', conceding that the small number of total characters upon these boards afforded a less-than-average opportunity to display further RR28/RR29 glyph family members.

The final age attribute score for each tablet is the average score of each of the physical elements (Spaelti's tablet condition, handling wear, botanical identification) and the paleographic elements (Wieczorek's coded ratings, RR76 presence, RR28/RR29 family presence). This age attribute score retains our general principle that a lower score is consistent with an older artifact, and a higher score is representative of a newer one. In the case of the five artifacts for which ^{14}C results were available (not including the outlier Échancrée tablet), it becomes possible to produce ordered data pairs directly, by matching the artifact ^{14}C date to its age attribute score. Moreover, having such data pairs enables the estimation of a statistical best fit linear equation and regression coefficient (Figure 14). For the tablets evaluated, the regression coefficient was a respectable 0.94.

The regression equation, fitted for the five ^{14}C -sampled artifacts may be applied to any artifact having an age attribute score, to produce a numerical estimate of its age. This enables creation of a table for the group of artifacts having calculated age attribute scores in which they may be ranked from the (probable) most recent date of production to the (probable) oldest date of production. Table V lists these estimated production dates with accompanying age attribute scoring data.

Horley (2021, pp. 426-428) has presented estimates for the relative ages of tablets P, Q, H, K, G. He determined that among the tablets P, Q, and H, which display substantially parallel texts (as in Figure 13), the P and Q boards may have inspired the presumed later-edited, tablet H. Additionally tablet K may have offered material for the possibly later

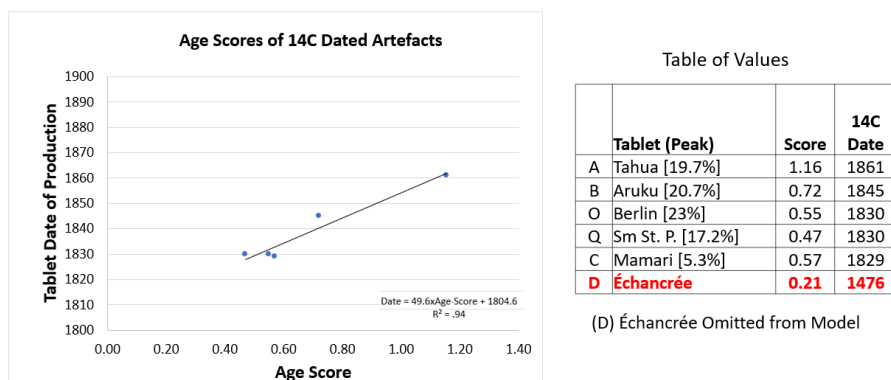


FIG. 14. Data regression of Artifact Age Score predicts the ^{14}C -related production date

written tablet G. Table V data agree with Horley's determinations insofar as Q (1828) and P (1836) pre-date H (1848). Moreover, K (1806) appears to be older than G (1829). Yet it may be possible to "fool the system". Among the seventeen artifacts that were graded, the London tablet (K) is graded as the oldest. However, Barthel (1958, p. 158), Fischer (1997, p. 488), and Wiczorek (2011, p. 38) rate it as a newer board, perhaps an example of the "*Verfallszeit*" (declining period—latter era of *rongorongo* inscriptions, characterized by mediocre calligraphy). ^{14}C testing would settle this issue.⁶ Excepting, perhaps, the Mamari tablet and Échancrée tablet (see the radiocarbon peaks in Figure 12), all artifacts date from the 1800s. Any older ones were probably lost due to decay, wear, repurposing, or vandalism.

Tablet paleographic attributes of the average age model score are better predictors of production date than are the tablet physical characteristics. The presence or absence of some members of the RR28/RR29 glyphs within a tablet inscription proves to be the best predictor of relative tablet age from among any of the attributes considered—paleographic or physical. The RR28/RR29 Top Eight total age score to Bottom Eight total age score ratio (Table V bottom row) is 5.8. At the opposite extremity, Wood Species is the poorest predictor of production date: The respective numbers of native and foreign boards in the oldest half of the population were the same as the numbers in the youngest half (Top Eight to Bottom Eight ratio of 1.0). Well-conceived techniques of

6. Early *rongorongo* writings would display a less developed lexicon than classical age tablets. On the other hand, *Verfallszeit* inscriptions would also be inferior to those of the classical age. Hence, the conundrum of the London tablet. Its mediocre lexicon could place it either at the beginning or the end of the classical age.

paleographic analysis would, therefore, seem to be methods of choice for successfully estimating relative ages of *rongorongo*-bearing artifacts.

8. Euro-American Discovery and the End of the Age of *Rongorongo*



FIG. 15. The Kotzebue Hair Amulet (Endcap shown centre and sideview at right). Details of *rongorongo* glyph drawings are at left. The arrow indicates the RR24.RR400 compound. Illustration reference: (Melka and Schoch 2024a, pp. 14-15) © R. M. Schoch, taken with the permission of the anonymous owner

Finally, we summarize the Euro-American discovery of the indigenous Rapanui script and the conclusion of the classical *rongorongo* timeline. Melka and Schoch (2024a, p. 13) describe the Kotzebue Hair Amulet (KHA) (Figure 15): a cylindrical artifact collected by a crewmember “of the brig *Rurik*, captained by Otto von Kotzebue, during the ship’s visit to Easter Island in 1816” (ibid., p. 13). The end cap of the KHA displays three *rongorongo*-like glyph tropes. This artifact is important as a surviving wood specimen from an early era. Its presentation of anthropoid/zoomorphic glyph forms affirms knowledge of sophisticated glyphs in the second decade of the nineteenth century. The encircled RR400 is an example of the Barthel RR148–RR156 series: all of which feature glyphs infixed within an oval. Melka and Schoch report that (to the best of their knowledge) none of the subsequent handlers of the piece prior to their study recognized its symbols as being *rongorongo* and—at least with respect to the earliest owners of the artifact—this is not surprising since awareness of *rongorongo* did not exist outside of Easter Island at the time of the KHA’s collection.

Code	Name	Wood Species	# of Glyphs	Condition (Spalti) D=Destroyed	Coded Condition (Spalti)	Handling Wear (GGB)	Wood Species	RR76 Glyph	RR28/29 Glyph	Model Wleczorek	Condition, Wear, Wood Average	76, 28/29 Average Text Score	Combined Average Score for Model	Carbon Dating & Chosen Peak % of Sample	Best Fit Age
A	Tahua	Fraxinus excelsior	1825	Very Fine	0.50	0.23	0.4	1.00	4.00	0.8	0.38	1.93	1.16	1861-19.7%	1862
H	Great Santiago	Native Thespesia populnea	1580	Good	0.17	0.35	0.00	1.00	3.00	0.7	0.17	1.57	0.87		1848
E	Keiti	Foreign unidentified	822	D(Fine)	0.38	0.23	0.4	1.00	2.00	1	0.34	1.33	0.83		1846
I	Santiago Staff	Native Thespesia populnea	2920	Good	0.17	0.35	0.00	1.00	2.00	1	0.17	1.33	0.75		1842
B	Aruku-Kurenga	Native Thespesia populnea	1135	Fine	0.38	0.23	0.00	1.00	2.00	0.7	0.20	1.23	0.72	1845; 20.7%	1840
P	Great St. Petersburg	Podocarpus sp. cf. Latifolia	1163	Fine	0.38	0.35	0.4	1.00	1.00	0.7	0.38	0.90	0.64		1836
Y	Snuff Box	Proteaceae sp.	85	Fine	0.38		0.40	0.00	1.50		0.39	0.50	0.57		1833
C	Mamari	Native Thespesia populnea	1000	Fine	0.38	0.23	0.00	0.00	2.00	0.8	0.20	0.93	0.57	1829; 5.3%	1833
O	Berlin	Native Thespesia populnea	172	Good	0.17	0.35	0.00	1.00	1.50	0.3	0.17	0.93	0.55	1830; 23%	1832
G	Small Santiago	Native Thespesia populnea	720	Fine	0.38	0.23	0.00	1.00	1.00	0.3	0.20	0.77	0.48		1829
Q	Small St. Petersburg	Native Thespesia populnea	218	Poor	0.00	0.115	0.00	1.00	1.00	0.7	0.04	0.90	0.47	1830; 23%	1828
R	Atua-Mata-Riri	unidentified	357	Good	0.17	0.35		0.00	1.00	0	0.26	0.33	0.30		1820
T	Honolulu Tablet	unidentified - possible Euro oar	163	Good	0.17	0.35	0.40	0.00	0.00	0.7	0.31	0.23	0.27		1818
N	Small Vienna	Podocarpus sp. cf. Latifolia	718	Good	0.17	0.23	0.40	0.00	0.00	0.2	0.27	0.07	0.17		1813
D	Échancrée	Podocarpus sp. cf. Latifolia	270	Good	0.17	0.115	0.40	0.00	0.00	0.2	0.23	0.07	0.15	1476	1812
S	Great Washington	Latifolia/Picea sp.	600	Good	0.17		0.40	0.00	0.00	0	0.28	0.00	0.11		1810
K	London	Native Thespesia populnea	499	Poor	0.00	0.115	0.00	0.00	0.00		0.04	0.00	0.02		1806
TOTALS					4.08	3.825	3.2	9	22	8.1	3.97	13.03	8.61	Average >	1830
New 8 / Old 8					2.2	1.3	1.0	3.0	5.8	2.7	1.4	4.1	3.1		

TABLE 5. Artifact Date Estimation by Physical and Paleographic Assessment

Horley (2021, pp. 358-359) implies a discovery date of 1845 for an artifact (the Annapolis bird) inscribed with *rongorongo* glyphs collected by Americans and formerly stored at the Naval Lyceum in Brooklyn, New York (the current whereabouts of the object, if it still exists, are unknown). The documented date noted by Horley refers to a similar (but by no means identical) bird sculpture and there is no evidence that the two pieces were obtained at the same time.



FIG. 16. Left, HMS Topaze Fragment. Right, Rangitoki Bark-cloth Fragment. Possible glyph catalogue identifications are given for both artifacts. Pertaining to the coding of the two rare glyphic forms on the Rangitoki Bark-cloth Fragment, RMS suggests as possibilities RR7? instead of RRV27 and RR87?/RR88?/RR127? instead of RR39_{Top}:107 (see the discussion in Schoch and Melka 2019, pp. 137-140, 414; Schoch and Melka 2020, pp. 28-30). Illustration references: Topaze Fragment (Melka and Schoch 2024a, p. 2). Rangitoki Bark-cloth Fragment: (Schoch and Melka 2019, p. 413). Both photographs © R. M. Schoch, taken with the permission of the anonymous owners

The classical board Tahua (A) is likely the newest of the remaining major artifacts; collected in 1870 and carbon dated to the 1860s. Blackbirder slave raids occurred 1862 to 1863. Approximately 1,500 able-bodied workers were removed, the majority (1,282) to indentured servitude as agricultural laborers or domestic servants, a few to the *guano* deposits of the Chincha Islands off the coast of mainland Peru (Fischer 2005, p. 89). Almost all died of disease in South America from lack of natural immunity, “poor nutrition, overwork, lack of hygiene, crowded accommodation, the harsh climate of plantation heights and especially ‘nostalgia’ (clinical depression)” (ibid., p. 89). About a dozen survived the ordeal to the point of repatriation, and one of those was infected with smallpox. About half the Rapanui population subsequently died from the epidemic that ensued when the carrier entered their midst and the remaining elderly *rongorongo* sages were especially hard hit (ibid., p. 90). In 1866 Missionary Eugène Eyraud first published a journal entry noting his observation of the *rongorongo* script (Fischer 1997, p. 12).

The HMS Topaze Fragment with a three-glyph inscription (Figure 16 left) was gifted or traded to a ship's crewman in 1868 (Melka and Schoch 2024a, p. 2). There are differing opinions on whether the brief glyph triad represents the full intended inscription; there are wide spaces of un-incised wood to the left and right of the carved glyphs. It could have been an inscribed fragment from a larger artifact, such as a shaft or handle of some sort of implement. Nor can the time of manufacture of this artifact be precisely ascertained. It may have been scribed in the late 1860s around the time the artifact was received by the crewman. Alternatively, it could have been produced earlier and later retrieved for the purpose of gifting or trading. (It should be noted that the Indigenous Rapanui may have had a totally different notion regarding "gifts", "transactions", "trading", and the like, compared to the norms of Euro-Americans; for a discussion of such issues, see Ferdon 1966, pp. 92-102.)

In March 1869 sailor Albert Van Houten acquired a piece of a skirt from Rangitoki—a native woman—with ten *rongorongo* glyphs written upon it (Figure 16 right) (Schoch and Melka 2019, pp. 117-121, 413). A short note, written by Van Houten and accompanying the piece, indicates that it was a special gift to him from his beloved Rangitoki. In his 1872 sketches showing Indigenous Rapanui men and women and their apparel (or lack thereof), artist Pierre Loti showed no designs or inscriptions on the garment that he illustrated (Bahn and Flenley 2017, p. 111). Roggeveen (in Corney 1908, p. 13) noted that indigenous textile dyes were not colour-fast: "one finds the colour come [*sic*] off one's fingers, not only after touching new articles but also from old and worn ones". Any glyphs written upon a frequently worn skirt would have surely smudged (and, based on RMS's examination of the artifact directly, the glyphs on the Rangitoki Bark-cloth Fragment do show some degree of smudging), becoming indistinct after a short time. It, therefore, seems plausible that Rangitoki's skirt was unadorned and that she tore a piece from it for the express purpose of inscription and presentation to her lover. This would imply that the artifact creation date was nearly the same as the time at which the piece was received. On the other hand, it is possible that Rangitoki possessed a separate beautiful, glyph-inscribed and infrequently worn, garment from which the *rongorongo* piece was taken. In this scenario, the skirt and its inscription could have been several years old in 1869. At this point, with only the evidence at hand, we cannot be certain which scenario is closer to the truth.

In June of 1869 Bishop Tepano Jaussen officially discovered *rongorongo* when he received the Échancrée tablet (see Figure 17) spooled with braided hair. He publicized his acquisition, and both tablet collecting and *rongorongo* epigraphy began in earnest (Jaussen 1893; for a recent recounting, see Horley 2021, pp. 16-17). In 1871 on account of disease ravaging their island, all but 175 Rapanui fled to Mangareva (Fischer 1997, pp. 34-35). The combined impact of the decimations of the blackbird



FIG. 17. Échancrée (D) *rongorongo* tablet side b. Illustration reference: Chauvet, Stephen. 1935. *L'Île de Pâques et ses mystères*. Paris: Éditions "Tel". On-line translation by Ann Altman (2004)

raids and consequent islander mortality from disease, coupled with competition from the Latin alphabet—which missionaries freely taught to any who desired to learn—would have greatly impaired further *rongorongo* education and scholarship. And—as is apparently the stance of many Easter Island scholars and enthusiasts—the demise of the classical script was effectively sealed from that point forward. Those literate few who might have survived, lacking the tutelage of the former *rongorongo* master scribes, and pressured by lifestyle changes brought about by exposure to Euro-American customs and technologies (which archaized certain glyph forms and writing strategies), may have been drawn into the *ta'u* writing movement. Per Table VI, Berthin has arranged a line-by-line transcription of an early 1900s CE *ta'u rongorongo* specimen (Blanco 1996, pp. 57–59). This *ta'u* inscription includes features generally associated with the classic script, viz. glyph near-repetitions in stanza-like forms, and special signs, which might indicate the reading direction for the inscription. Authorship of this artifact (the Madrid Fish Sculpture—Figure 18) is attributed to Tomenika who lived from approximately 1843 to 1914 (Fischer 1997, p. 289).⁷ Routledge (1919, p. 252 and Fig. 99), con-

7. RMS considers the Madrid Fish Sculpture to be somewhat removed from the *rongorongo* phenomenon per se as he does not consider the *ta'u* “script” to be *rongorongo* although the creators of *ta'u* were inspired by *rongorongo* glyphs (see the discussion in Fischer 1997, pp. 528–537). Furthermore, RMS is uncertain regarding the date of the Madrid Fish, and he wonders if it could be from the 1910s or later. Another late piece, the *Routledge* Miniature Tablet with six *rongorongo*-like glyphs, was collected in 1914–1915 (Melka and Schoch 2024b).

sulted with Tomenika during his last year of life, and received *rongorongo* writing samples from him, but they too were rendered in *ta'u* form. Yet, the existence of the Madrid Fish teases of the possible existence of further recent (early 1900s) *rongorongo*-inspired artifacts, possibly even classical pieces. The search for these continues and remains an active field of ethnography (Melka and Schoch 2024b).

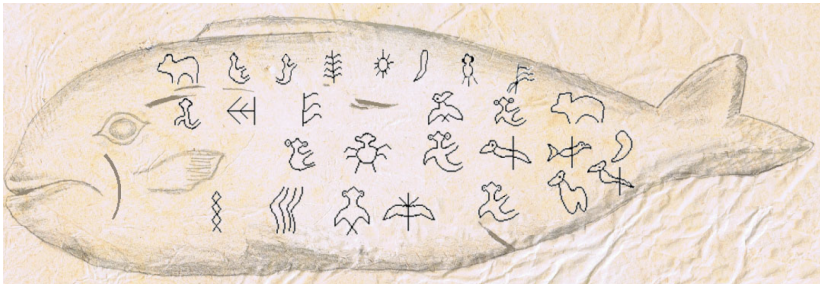


FIG. 18. Madrid Fish Sculpture—Side a. Artwork of GGB. After photograph and sketches by Blanco (1996, pp. 57, 59)

TABLE 6. Madrid Fish Sculpture *ta'u rongorongo* transcription (from Berthin [2024, p. 486])

Side a Line a1								(some before much following)
Line a2								
Line a3								
Line a4								
Side b Line b1 (some before)								
Line b2								
Line b2 and b3								(well filled)

9. Conclusions

The first stone carvings of icons having *rongorongo*-like imagery were possibly being carved concurrently with construction of the *abu* platforms on Rapa Nui in the later part of the thirteenth century. During the 1600s, as attested by the Pukao 36 inscription, *rongorongo* had already

become highly developed. One of the Rapanui chief's signatures on the 1770 treaty document with the Spanish Expedition seems to be a short sequence of *rongorongo* glyphs. Expedition member Agüera possibly uncovered a few *rongorongo* glyph definitions when he showed pictures of Arabic numbers to the Islanders in 1770, and they may have given names of *rongorongo* characters resembling our numbers. At minimum, Agüera's findings showed that the Rapanui possibly associated graphic images with intangible concepts, which did not obviously match to the morphology of the symbol. Per ^{14}C dating, a classical age of *rongorongo* was flourishing between 1800 and 1860, yielding the preponderance of the surviving *rongorongo* corpus. Perhaps the earlier contact with the Spanish and the witnessing of their writing inspired the Rapanui, ushering in an era of prodigious indigenous authorship. The surviving classical wooden *rongorongo* tablets have feasible radiocarbon dates from the early 1800s to the 1860s and people may have been composing *rongorongo* in the classical style, possibly even in 1869. Combined mass mortality from old world diseases and competition from the Latin alphabet greatly impaired further *rongorongo* instruction and scholarship. One of the last artifacts seemingly inspired somewhat by knowledge of classical *rongorongo*, the Madrid Fish Sculpture, may date to the very early 1900s. The search for even newer artifacts continues.

Note on Authorship

This paper is primarily the work of the first author, Gordon G. Berthin, who is responsible for its final form, language, and editing. The second author, Robert M. Schoch, has collaborated with the first author; however, as with many scholarly subjects, various *rongorongo* researchers have different levels of comfort and affinity with specific hypotheses, as well as what might be considered a fact or a valid assumption. RMS finds the material throughout this paper thought-provoking; however, he is not as confident or as comfortable with some of the proposals put forward in this paper as is GGB. Therefore, in some cases the material is explicitly labelled as from, or suggested by, GGB. It is important to give credit where credit is due, so in this sense RMS believes, and insists, that the reader consider GGB the author of the novel contributions found in this paper.

References

- Agüera, Francisco (1908). "[Account of the voyage to Easter Island]". In: *The Voyage of Captain Don Felipe Gonzalez in the Ship of the Line San Lorenzo, with the Frigate Santa Rosalia in Company, to Easter Island 1770–1: Preceded by an Extract from Mynbeer Jacob Roggeveen's Official Log of his Discovery of and Visit to Easter Island, in 1722*. Ed. by Bolton Glanvill Corney. Vol. 13. Hakluyt Society, Second Series. Cambridge: Hakluyt Society.

- Au, Jane (2018). "He Huliko'a Kanaloa – Seeking the Depths of Kanaloa". University of Hawai'i. URL: <https://core.ac.uk/download/pdf/211329254.pdf>.
- Bahn, Paul and John Flenley (2017). *Easter Island, Earth Island: The Enigmas of Rapa Nui*. 4th ed. Lanham, Maryland: Rowman and Littlefield.
- Barthel, Thomas (1958). *Grundlagen zur Entzifferung der Osterinselschrift*. Hamburg: Cram, de Gruyter.
- (1989). "Eingekerbte Vergangenheit. Die Zukunft der Rongorongo-studien". In: *1500 Jahre Kultur der Osterinsel: Schätze aus dem Land des Hotu Matu'a*. Ed. by H-M. Esen-Baur. Mainz am Rhein: Philipp von Zabern, pp. 125–133.
- (1993). "Perspectives and Directions of the Classical Rapanui Script". In: *Easter Island Studies: Contributions to the History of Rapanui in Memory of William T. Mulloy*. Ed. by S. R. Fischer. Oxbow Monograph 32. Bloomington, Indiana: Oxbow Books, pp. 174–176.
- Berthin, Gordon (2024). "Qualitative and Quantitative Validation of Rongorongo Glyph Strings on Easter Island Artifacts". In: *Grapholinguistics in the 21st Century 2022. Proceedings of Grapholinguistics and Its Applications*. Ed. by Y. Haralambous. Vol. 10. Brest, France: Fluxus Editions, pp. 471–500.
- Biggs, Bruce (1978). "The History of Polynesian Phonology". In: *Second International Conference on Austronesian Linguistics: Proceedings*. Ed. by S. A. Wurm and L. Carrington. Vol. C-61. Pacific Linguistics. The Australian National University, pp. 691–716. DOI: 10.15144/PL-C61.691.
- Blanco, Francisco (1994). "Rapa Nui interpretation of written numerals by the Spanish in 1770". In: *Rapa Nui Journal* 8.2, pp. 37–39.
- (1996). "A fish (ika) tablet with hieroglyphic writing from Isla de Pascua discovered in Madrid". In: *Rapa Nui Journal* 10.3, pp. 57–59.
- Butinov, Nikolay and Yuri Knorozov (1957). "Preliminary Report on the Study of the Written Language of Easter Island". In: *Journal of the Polynesian Society* 66.1, pp. 5–17.
- Chauvet, Stéphen (1935). *L'Ile de Pâques et ses Mystères*. Paris: Éditions Tel.
- Christenhusz, Maarten and Rafaël Govaerts (2024). "Plant Extinction in the Anthropocene". In: *Botanical Journal of the Linnean Society* 20, pp. 1–14.
- Churchill, William (1912). *Easter Island; the Rapanui Speech and the Peopling of Southeast Polynesia*. Washington: The Carnegie Institution.
- Coe, Michael and Justin Kerr (1998). *The Art of the Maya Scribe*. New York: Harry N. Abrams, Inc.
- Du Feu, Veronica M. and Steven Roger Fischer (1993). "The Rapanui Language". In: *Easter Island Studies: Contributions to the History of Rapanui in Memory of William T. Mulloy*. Ed. by S. R. Fischer. Oxbow Monograph 32. Bloomington, Indiana: Oxbow Books, pp. 165–168.
- Emory, Kenneth (1972). "Easter Island's Position in the Prehistory of Polynesia". In: *Journal of the Polynesian Society* 81, pp. 57–69.

- Englert, Sebastian (1974). *La tierra de Hotu Matu'a: Historia, etnología y lengua de la Isla de Pascua*. 6th edition published 1993. Padre Las Casas, Santiago de Chile: Editorial Universitaria.
- (1980). *Leyendas de Isla de Pascua*. Santiago, Chile: San Francisco / Editorial Universitaria.
- Ferdon, Edwin (1966). *One Man's Log*. London: George Allen & Unwin LTD.
- Ferrara, Silvia et al. (2024). "The invention of writing on Rapa Nui (Easter Island). New radiocarbon dates on the Rongorongo script". In: *Nature: Scientific Reports* 14.
- Fischer, Steven Roger (1997). *Rongorongo, The Easter Island Script: History, Traditions, Texts*. Oxford: Clarendon Press.
- (2005). *Island at the End of the World*. London: Reaktion Books Ltd.
- Guy, Jacques (1985). "On a Fragment of the "Tahua" Tablet". In: *Journal of the Polynesian Society* 94, pp. 367–387.
- (1990). "The Lunar Calendar of Tablet Mamari". In: *Journal de la Société des Océanistes* 91, pp. 135–149.
- Heyerdahl, Thor (1976). *The Art of Easter Island*. London: George Allen and Unwin Limited.
- Hixon, Sean et al. (2017). "Using Structure from Motion Mapping to Record and Analyze Details of the Colossal Hats (Pukao) of Monumental Statues on Rapa Nui (Easter Island)". In: *Society for American Archeology* 28.
- Hixon, Sean et al. (2018). "The colossal hats (pukao) of monumental statues on Rapa Nui (Rapa Nui, Chile): Analyses of pukao variability, transport, and emplacement". In: *Journal of Archaeological Science* 100, pp. 148–157.
- Horley, Paul (2021). *Rongorongo: Inscribed Objects from Rapa Nui*. Viña del Mar, Chile: Rapanui Press.
- Horsburgh, Katherine Ann and Mark McCoy (2017). "Dispersal, Isolation, and Interaction in the Islands of Polynesia: A Critical Review of Archaeological and Genetic Evidence". In: *Diversity* 9.37, pp. 1–21. DOI: 10.3390/d9030037.
- Irwin, Geoff (2005). *Pacific migrations – Pacific navigation and exploration*. Reviewed and revised 2017. In: Te Ara – the Encyclopedia of New Zealand. URL: <http://www.TeAra.govt.nz/en/pacific-migrations/page-5> (visited on 01/10/2025).
- Jakubowska, Zuzanna (2014). "The Forsters back in the spotlight: Unknown manuscript on Easter Island discovered in Poland". In: *Rapa Nui Journal* 28.1, pp. 68–77.
- Jaussen, Florentin-Étienne (Tepano) (1893). *L'Ile de Pâques: Historique et Écriture*.
- Kaeppler, Adrienne and Jo Anne Van Tilburg (2020). "Carved komari (vulva) stones from Rapa Nui: Museum objects, legacy data and

- contemporary local history". In: *Journal of the Polynesian Society* 129.4, pp. 383–406.
- Kelly, Piers (2016). "Introducing the Eskaya writing system: A complex Messianic script from the southern Philippines". In: *The Australian Journal of Linguistics* 36.1, pp. 131–163.
- Langdon, Robert (1975). *The Lost Caravel*. Sydney: Pacific Publications.
- (1996). "Easter Island's 'Deed of Cession' of 1770 and the Origin of its Rongorongo Script". In: *The Journal of the Polynesian Society* 105.1, pp. 109–124.
- Lee, Georgia (1992). *Rock Art of Easter Island: Symbols of Power, Prayers to the Gods*. Los Angeles: Cotsen Inst. of Archaeology.
- (1993). "The Rock Art of Rapanui". In: *Easter Island Studies: Contributions to the History of Rapanui in Memory of William T. Mulloy*. Ed. by S. R. Fischer. Oxbow Monograph 32. Bloomington, Indiana: Oxbow Books, pp. 112–121.
- Lee, Georgia et al. (2016). "Secondary applications of rock art at coastal sites of Easter Island (Rapa Nui)". In: *Almogaren (Wien)* 46–47, pp. 157–209.
- Melka, Tomi S. and Robert M. Schoch (2024a). "The 'Topaze stick fragment'—a newly discovered *rongorongo*-inscribed artifact collected during the Rapa Nui (Easter Island) visit of HMS *Topaze* in 1868". In: *Cryptologia*. Online first, pp. 1–43. DOI: 10.1080/01611194.2024.2340478.
- (2024b). "The Persistence of the Grapholinguistic *Rongorongo* Tradition on Rapa Nui (Easter Island) during the Late Nineteenth and Early Twentieth Centuries". In: *Grapholinguistics in the 21st Century 2024—From Graphemes to Knowledge*. URL: <https://grafematik2024.sciencesconf.org/>.
- Métraux, Alfred (1940). *Ethnology of Easter Island*. Bernice P. Bishop Museum Bulletin 160. Honolulu: Bernice P. Bishop Museum Press.
- Molle, Guillaume (2021). *Polynesian expansion across the Pacific (c. 700–1756)*. National Library of Australia. URL: <https://www.library.gov.au/learn/digital-classroom/polynesian-expansion-across-pacific-c700-1756/religious-and-social>.
- Moreno-Mayar, José et al. (2024). "Ancient Rapanui genomes reveal resilience and pre-European contact with the Americas". In: *Nature* 633, pp. 389–397. DOI: 10.1038/s41586-024-07881-4.
- Orliac, Catherine (2010). "Botanical Identification of 200 Easter Island Wood Carvings". In: *The Gotland Papers: Selected Papers from the VII International Conference on Easter Island and the Pacific Migration, Identity, and Cultural Heritage*. Ed. by Paul Wallin and Helene Martinsson-Wallin. Visby: Gotland University Press, pp. 125–139.
- Orliac, Michel and Catherine Orliac (2008). *Trésors de l'Île de Pâques / Treasures of Easter Island*. Genève / Paris: Editions D – Frédéric Dawance / Editions Louise Leiris.

- Palmer, John (1870). "A visit to Easter Island, or Rapa Nui, in 1868". In: *Journal of the Royal Geographical Society* 40, pp. 167–81. DOI: 10.2307/1798641.
- Pandey, Anshuman (2022). *Revised proposal to encode the Lampung script in Unicode*. URL: <https://www.unicode.org/L2/L2022/22044-lampung.pdf>.
- Poussart, Annick (2010). *Easter Island. An Epic Voyage*. Trans. by Rachel Martinez, Pamela Ireland, and Terry Knowles. Pointe-à-Callière: Montréal Museum of Archaeology and History.
- Pudjiastuti, Titik (n.d.). *Lampung scripts: The Writing tradition that almost disappear*. URL: https://lingdy.aa-ken.jp/wp-content/uploads/2014/02/140227-intl-symp-and-ws_titik_pudjiastuti_paper.pdf.
- Riesenberg, Saul H. and Shigeru Kaneshiro (1960). "A Caroline Islands Script". In: *Smithsonian Institution, Bureau of Ethnology, Bulletin* 173.60, pp. 269–333.
- Roggeveen, Jacob (1908). "An Extract from the official log of Mynheer Jacob Roggeveen in 1722". In: *The Voyage of Captain Don Felipe Gonzalez in the Ship of the Line San Lorenzo, with the Frigate Santa Rosalia in Company, to Easter Island 1770–1*. Ed. by B. Corney. Vol. 13. Hakluyt Society, Second Series. Cambridge: Hakluyt Society.
- Routledge, Katherine (1919). *The Mystery of Easter Island. The Story of an Expedition*. London: Hazell, Watson and Viney.
- Rull, Valentí (2022). "Prehistoric Paleoecology of Easter Island". In: *The Prehistory of Rapa Nui (Easter Island)*. Ed. by V. Rull and C. Stevenson. Cham, Switzerland: Springer.
- Rull, Valentí et al. (2015). "Late Holocene vegetation dynamics and deforestation in Rano Aroi: Implications for Easter Island's ecological and cultural history". In: *Quaternary Science Reviews* 126, pp. 219–226.
- Schoch, Robert M. and Tomi S. Melka (2019). "The *Rangitoki* (Rangitoki) Bark-cloth Piece: A Newly Recognized *Rongorongo* Fragment from Easter Island". In: *Asian and African Studies (Bratislava)* 28.2, pp. 113–148 and 413–417 (plates).
- (2020). "The *Rangitoki* (Rangitoki) Fragment: Further Analysis of a Short *Rongorongo* Sequence on Bark-cloth from Easter Island". In: *Asian and African Studies (Bratislava)* 29.1, pp. 26–41 and 113–118 (plates).
- Schulze-Maizier, Friedrich (1926). *Die Osterinsel*. Leipzig: Insel.
- Spaelti, Philip (2012). *Kobaumotu—a site dedicated to the study of rongorongo*. URL: <http://kobaumotu.org/Rongorongo/tablets.html>.
- Tribes Travel (2012). *The mystery of the Easter Island moai*. URL: <https://www.tribes.co.uk/experiences/the-moai-statues-of-easter-island>.
- Wieczorek, Rafał (2011). "The double body glyphs and paleographic chronology in the rongorongo script". In: *Rapa Nui Journal* 25.2, pp. 31–40.
- Wieczorek, Rafał et al. (2023). "The rongorongo tablet from Berlin and the time-depth of Easter Island's writing system". In: *The Journal of Island and Coastal Archaeology* 16, pp. 1–20.

Rethinking Unicode: How to Digitally Encode Non-Linear Written Artefacts?

A Tentative Encoding of Codex Mendoza, Folio 2r

Antonio Perri, Luciano Perondi & Daniele Capo

Abstract. Unicode encoding, even after 23 years of development since the release of version 1.0, continues to reflect the limitations of analog and alphabetic typography, emphasizing a linear and analytic structure where characters are arranged in a mechanistic sequence based on the arbitrary segmentation of speech inherent in alphabetic systems. In critically assessing this aspect, at the same time we address the main problem of avoiding the bias of *homo alphabeticus*, and of course *typographicus*.

As several scholars argued, Aztec, Mixtec, and other non-Maya Mesoamerican pictographic writing systems (often considered as basically non-glottographic systems) cannot be reduced to linear sequences of isolated characters; rather, their graphic plasticity conveys semantic (and linguistic) contents through conventional patterns of units arranged in graphic space according to non-linear principles. This, in fact, explains the enduring opposition to accepting such a notation as writing “proper”; however, this account still suffers from a theoretical bias according to which only more or less systematic phoneticism defines “true writing”. In contrast, any accurate consideration of the ways in which writing works in specific visual artifacts shows that writing, unlike speech, does not need to represent phonetically an utterance in order to provide a complete encoding of linguistic content.

We argue that the relevant visual values in this system are ordered in subsets (topological, spatial, and logical) according to the variables devised by Bertin. We suggest then that each unit is a “character” (in the Unicode vocabulary), but it could be coded either as a positive unit (i.e., a graphic sign) or as an “empty” spatial, topographical relation between visually expressed and coded signs. Following the digital method aimed at processing sets of basic graphic features as non-linear combinations of variables, we pointed out that Aztec pictorially agglutinated complexes (or multi-unit arrangements forming perceptually autonomous units, e.g., a toponym or a proper name) display an overall structure

Antonio Perri  0000-0002-0453-4849
Università degli Studi Suor Orsola Benincasa - Napoli, Italy
E-mail: antonio.perri@unisob.na.it

Luciano Perondi  0000-0002-7198-4030
Università Iuav di Venezia, Italy
E-mail: luciano.perondi1@gmail.com

Daniele Capo
Università degli studi Sapienza Università di Roma, Italy

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 633–660. <https://doi.org/10.36824/2024-graf-perr>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

similar to Unicode encoding of emoji since it is a combination of different layers of variables. However, as more complex and higher-ranked coded variables are needed to account for broader textual compositions, we suggested that the coding systems available so far in the Unicode standard (including the one devised for emojis) are still not flexible enough to accommodate an appropriate encoding of Aztec textual units, above all the spatial arrangement.

In this paper, we will sketch the guidelines for an exhaustive coding of the perhaps most iconic page of Codex Mendoza: the folio 2r, which relates the founding of Mexico-Tenochtitlan and has been studied extensively by Joaquín Galarza and his research group at the beginning of the 1980s.

A Speculative Hypothesis for Encoding Non-Linear Scripts in Mesoamerican Writing Systems

This article addresses the complexities involved in digitally encoding non-linear written artefacts, particularly historical documents such as the *Codex Mendoza*.

Unicode is crucial for accurately representing diverse writing systems, particularly in a multilingual context. Prior to its establishment, many writing systems were constrained by limited encoding options, typically supporting only two scripts, which created challenges for documents that included multiple languages. The introduction of Unicode (Dombrowski, Goregaokar, Joeng, and Kamran, 2024) has resolved many of these compatibility issues, allowing for a more coherent approach to text encoding that supports the display and processing of complex characters and scripts, including those that require bidirectional text rendering. While Unicode has transformed the digital representation of text by encompassing over 128,000 characters from various scripts and languages into a coherent digital framework, its application often falls short when dealing with non-linear texts that incorporate intricate layouts and visual elements. While it has succeeded in providing a foundation for representing a vast array of scripts, the system inherently inherits limitations from its origin in linear and alphabetic paradigms. These limitations are particularly evident when attempting to encode complex systems that require bidirectional text rendering or contextual markers, as is often the case with historical and non-linear writing systems like *non-Maya Mesoamerican ones*.

Non-linear texts often involve complex layouts and visual elements that standard Unicode encoding does not adequately address. As noted by Perri et al. (2024), *Aztec writing* shows a more or less systematic (but not merely phonetic) alignment between graphic elements and linguistic content, where *visual variables* and layout composition integrate a semantic content which must be expressed linguistically.

In critically assessing this aspect, at the same time we address the main problem of how to avoid the bias of *homo alphabeticus* (Brokaw,

2022)—and, of course, *typographicus*. Folio 2r of *Codex Mendoza* is a prominent example of the resources visually encoded by images-glyphs, since it is structured as an historical and geographical account based on a specific spatial arrangement of signs (Bleichmar, 2015).

As several scholars argued, Aztec, Mixtec, and other *non-Maya Mesoamerican pictographic writing systems* (often considered as basically non-glottographic systems) cannot be reduced to linear sequences of isolated characters; rather, their graphic plasticity conveys semantic (and linguistic) contents through conventional patterns of units arranged in graphic space according to non-linear principles (Zamora Corona, 2022).

When analyzing Mesoamerican writing systems, it is important to note that iconic representations are inherently two-dimensional and, in some cases, may incorporate a 'coded' third dimension. This third dimension emerges through the sequencing of visual layers or superimposed levels, achieved via relative dimensional contrasts on the inscribed surface (Fedorova and Perri, 2022).

For example, in folio 2r of *Codex Mendoza*, the upper section of the planar textual space—which at first glance appears as a diagrammatic and cartographic layout—in fact articulates a narrative of the founding of Tenochtitlan. This area is divided into four sections by streams of water, whose diagrammatic and planar arrangement conveys clear linguistic information in a visual form.

Case Study: Folio 2r of *Codex Mendoza*

We selected folio 2r of the *Codex Mendoza* (Figure 1) for its highly complex layout, including various features characteristic of *Aztec writing*; indeed, it is an ideal stress test for our provisional hypothesis of encoding non-linear Aztec and other non-linear writing systems.

The *Codex Mendoza* (Berdan and Anawalt, 1992) is a significant Aztec early colonial codex drawn around 1541, shortly after the Spanish conquest of the Aztec Empire. Commissioned by Antonio de Mendoza, the first Viceroy of New Spain, this document played—and still plays—the role of a vital record of Aztec history, culture, and social structure. It is formed by three main sections (two of them copies of pre-Hispanic documents), each providing distinct insights into Aztec history, economy, and society intended to be of use by the new Spanish administration during the early colonial period.

The first section of the *Codex Mendoza* chronicles the history of the Aztec rulers from the founding of Tenochtitlan in 1325 up to the conquest by the Spanish in 1521. It details the reigns of various rulers and the towns they conquered, illustrating the progressive expansion and consolidation of the Aztec Empire. The second section focuses on the



FIG. 1. Codex Mendoza, folio 2r. Public domain image, sourced from the Bodleian Libraries

tribute system established by the Aztecs. This economic and administrative information is closely related to the so-called *Matrícula de Tributos*, another pre-Hispanic document that also detailed tribute payments. The third section of the *Codex Mendoza*—which many scholars assume does not follow a traditional model but was conceived for use by the Conquerors while adhering to the pictographic rules of the system—provides an account of everyday life among the Aztecs.

The codex combines Aztec pictograms with Spanish text and glosses and is among the most extensively studied manuscripts of the *Nabuatl* pictorial tradition. This ‘bilingual’ nature of the manuscript enhanced scholarly studies of the Mendoza, soon making it a vital resource for historians, linguists, and anthropologists alike.

Folio 2r of the *Codex Mendoza* (Galarza et al., 1983a,b) provides a critical glimpse into the founding of Tenochtitlan, the capital of the Aztec Empire. It specifically captures the momentous event of Tenochtitlan’s founding, embodying the cultural significance of this event in Aztec history by showing (and narrating) the foundational myth and rituals crucial to the Aztecs’ identity and governance. The visual text of folio 2r articulates at once geographic space, key figures, and events involved in the establishment of the city.

Graphic elements such as colors, positions, orientations, and attire of pictorial characters are not merely decorative or generic expressions of a visual storytelling; on the contrary, each unit integrates one (or more) linguistic roles. Any alteration of the arrangement of these elements, then, would result in a change of textual meaning and linguistic content. This shows that the overall linguistic content to be spoken is inherently encoded within these visual features.

The *Codex Mendoza* exemplifies a sophisticated integration of graphic and linguistic elements in a spatial organization, revealing the *synsemic* nature of its graphic structure. The codex employs a multidimensional approach where elements are arranged in ways that encode multiple layers of meaning simultaneously. This is particularly evident in the ability of writers-painters to merge topography, chronology, and sociopolitical hierarchies within a single compositional framework.

For instance, the spatial arrangement of folio 2r narrates the founding of Tenochtitlan, the central political and cultural site of the Aztec Empire. The representation of the city is sectioned into four quadrants by water channels, a configuration that acquires a linguistic value inasmuch as it integrates the *Nabuatl* phrase *in atl quinxexeloa nabui calpulli* (‘the water divides the space into four districts’). This graphic division is not merely decorative but conveys critical geographic and administrative information, illustrating the early city’s organization into *calpulli* (districts) governed by specific noble lineages.

Moreover, chronological information is also integrated into the visual narrative. A frame of glyphs enumerating years surrounds the cen-

tral imagery, anchoring the depicted events within a specific temporal flow. The emplacement and sequencing of these year-glyphs are devised according to the Aztec calendrical system, in which cyclical time structured both historical narration and ritual practices. Notably, the glyph marking the *xiubmolpilli* ('binding of the years') highlights the completion of a calendric cycle, reinforcing the temporal depth of this narrative.

Hierarchical relationships among figures, such as nobles and warriors, are visually expressed in the layout through size, position, and orientation. Thus, for example, the central depiction of the eagle perched on a cactus—the latter transcribing the place name of Tenochtitlan—is surrounded by warriors and district leaders, whose spatial arrangement diagrammatically expresses their roles and status within the Aztec sociopolitical hierarchy.

The *Codex Mendoza*, thus, demonstrates how what we elsewhere called *synsemia* (Perondi, 2012), i.e., a deliberate spatial (and non-linear) articulation of elements, is devised to encode complex, multilayered meanings that transcend linear textual conventions. This specific feature underscores the need for encoding models that are able to preserve not only the visual integrity of such artifacts but also their semantic and cultural contexts.

Exploring *Synsemia* and *Entaxis*: Visual Approaches to Non-Linear Linguistic Structures in *Aztec writing*

Unlike phonetic alphabets, *non-Maya Mesoamerican writing systems* operate through a combination of smaller graphic elements (what we may call "glyphs") and spatial configurations. Both of them express systemically relevant linguistic contents.

This page of the *Codex Mendoza* can be analyzed at two levels: we will label them the *entactic* level and the *synsemic* level. The relevant framework for analyzing *Aztec writing* articulates these two distinct levels. The entactic level, as described by Vaillant (1999), involves the composition of graphic units into coherent forms, representing smaller linguistic components such as morphemes or syllables, and may also explain the structural composition of glyphs. In contrast, the synsemic level, outlined by Perondi and Romei (2010), encompasses the broader spatial and relational arrangements that convey meaning through contextual and hierarchical relationships, effectively describing the 'toposyntax' of the text.

To encode these levels effectively, this study leverages the semiology of Bertin (2011), highlighting key visual variables such as shape, color, texture, orientation, and position. These variables interact hierarchically, facilitating graphical "association" and "dissociation," which enable the construction of complex graphic structures at both the entactic and synsemic levels (Bertin, 2011; Perri, 2006; Vaillant, 1999). This

model incorporates spatial and relational markers to preserve the non-linear semantics of *Aztec writing* in a multilayer framework. It demands considerable flexibility to account for the distinctive features of *Aztec writing* in the *Codex Mendoza*. At the entactic level, this is necessary to address the agglutinative structure of the *Nabuatl* language, and at the synsemic level, to accurately capture the spatial and hierarchical relationships between units.

A key feature of *Nabuatl*, as an agglutinative and polysynthetic language, is its direct role in shaping the intricate relationship between glyphs and language in the *Codex Mendoza*. In polysynthetic systems, words are formed incorporating two or more lexical morphemes, each carrying specific semantic or grammatical functions. This morphological characteristic, together with its omipredicativity (Launey, 1994)—, the syntactic property according to which the names could act as predicates in a given sentence, if conjugated to a given grammatical person (incidentally, for the third person of any narrative, a zero morpheme)—is aptly mirrored in the visual composition of glyphs, where multiple graphic elements are agglutinated into complex units to convey layered meanings and narratives. For example, the glyph for *Ocelopantzin* (Noble Lord of the Jaguar Banner) integrates distinct components: a banner (*pantli*), adorned with jaguar spots, and the noble suffix (*-tzin*), each corresponding to individual morphemes in *Nabuatl*. This seamless integration of linguistic and visual elements illustrates how Aztec glyphs encode both structural and semantic principles of the *Nabuatl* language. This system leverages spatial and graphic configurations to encapsulate meaning, highlighting the critical role of linguistic agglutination in any effort to digitally encode such systems (Perondi, Perri, et al., 2018; Zamora Corona, 2022).

However, current Unicode standards are inadequate for encoding the continuous variability and relational complexity of Aztec graphemics. For instance, variables such as shape demonstrate virtually infinite variability, highlighting the need for innovative encoding approaches. Since the structure of these writing systems is mapped onto the agglutinative nature of languages transcribed, Unicode encoding on a character-by-character basis would result in the generation of thousands of characters; moreover, it would not solve the problem of giving a readable linguistic value to the spatial arrangement of elements.

The proposed encoding model is built on the principles of relational encoding and hierarchical composition encoding. *Relational encoding*, related to the associative variables following the terminology introduced by Bertin (2011, pp. 42–48), involves the use of “connecting characters” and agglutination markers to link distant units and articulate their semantic relationships. This encoding reflects the use of associative variables (e.g., objects of the same color, orientation, and shape are related) and graphic connectors to establish relationships within the visual text.

This approach also enables the representation of elements such as paths or sequences, exemplified by the glyph *otbli* for “road,” which visually connects starting and ending points. *Hierarchical composition encoding*, related to the dissociative variables (Bertin, 2011), employs differences in size and position to signify priority and establish hierarchy within texts, akin to the layering commonly used in graphical interfaces.

The proposed encoding model not only might enable the digital preservation of the non-linear nature of *Aztec writing* but also provides valuable insights for encoding other non-alphabetic systems, such as modern visual artifacts like infographics and flowcharts. This approach aligns with the theories of Harris (Harris, 1986; 2000) and Klinkenberg and Polis (Klinkenberg and Polis, 2018), which conceptualize writing as a semiotic system distinct from speech.

Hypothesis for a Descriptive Metalanguage

To implement the encoding principles outlined in the previous chapter, it was necessary to incorporate features that are currently absent (or only partially present) in the Unicode standard. Specifically, these include:

- a counter,
- seven distinct layers for the graphic attributes of the elements (covering color, orientation, value, texture, relative position, number, and shape),
- three synsemic composition layers addressing absolute orientation, absolute position, and absolute size.

The system is structured into two primary levels: entactic and synsemic. The entactic level is designed to encode agglutinated units, while the synsemic level focuses on the overall organization of these units. To facilitate this, two pairs of character markers are incorporated: one pair for marking the beginning and end of agglutination, and another for marking the beginning and end of *synsemia*. Furthermore, character-counters are proposed to act as pointers to specific sections of the encoded text.

The encoding of simple units relies on characters representing seven graphic attributes: Shape, Color, Texture, Amount, Position, Orientation, and Value. This mechanism exhibits similarities to the Unicode approach for encoding colors in emoji characters (Consortium, 2024), in particular Emoji Modifiers (1.4.4) and Emoji Sequences (1.4.5). Since this is a speculative hypothesis, we did not fully adhere to Unicode notation, but we assume it is possible to at least adapt the notation for *entaxis*.

To represent the encoding, we devised a metalanguage where the markers are represented between two | and the units carry the infor-

mation about the graphic attributes that apply to the unit. The syntax for each unit takes this form:

```
Unit A (NAME, name in Nahuatl)
  [layer a.1 -- Shape (SHAPE, name in Nahuatl),
   layer a.2 -- Color (COLOR, name in Nahuatl),
   layer a.3 -- Texture (TEXTURE, name in Nahuatl),
   layer a.4 -- Amount (NUMBER, number in Nahuatl),
   layer a.5 -- Position (AROUND, position in Nahuatl),
   layer a.6 -- Orientation (AROUND, position in Nahuatl),
   layer a.7 -- Value (PERCENTAGE)];
```

The counter A identifies the element itself inside the text encoding. NAME is the Unicode name of the character, followed by the name to be read in *Nahuatl*. After the unit, in brackets, the seven graphic attributes are listed as layers with their names always in *Nahuatl*.

The marker of agglutination takes this form:

```
| initial marker of agglutination [A #counter of agglutinations#]
(NAME OF THE UNIT A+NAME OF THE UNIT 1+...+NAME OF THE UNIT M,
name in Nahuatl)|
```

The counter between brackets identifies the agglutination itself inside the text encoding. After the counter, in parentheses, the units enclosed by the agglutination are rendered explicitly with their Unicode name and joined with the addition sign. After this, the name in Nahuatl of the whole agglutination is also given.

The syntax for the synsemic marker takes this form:

```
| initial marker of synsemia [N #counter of synsemia#]
[M #number of agglutinations#]
  [Layer b.1 Orientation (-) - Layer b.2 Size (x; y) - Layer b.3
   Position (#main object#; #verse#; #relative position of other
   objects#)]
```

The counter N refers to the synsemic group itself, while the counter M refers to the number of agglutinated units contained inside the synsemic group. Synsemic layers (like unit layers) are listed between brackets. The syntax of Layer b.3 (Position) identifies the position of elements (agglutinations and units) enclosed by the synsemic group. The first attribute refers to the position of the main element inside the synsemic group, the second attribute identifies the verse in which the elements are meant to be displayed. Finally, the third attribute gives the position of the other elements enclosed relative to the main object.

An example of the use of this metalanguage is given below:

```
| initial marker of synsemia [N #counter of synsemia#]
[M #number of agglutinations#]
[Layer b.1 Orientation (-) - Layer b.2 Size (x; y) -
 Layer b.3 Position (#main object#; #verse#;
 #relative position of other objects#)]
```

```
| initial marker of agglutination [A #counter of agglutinations#]
  (NAME OF THE UNIT A+NAME OF THE UNIT 1+...+NAME OF THE UNIT M,
   name in Nahuatl)|
Unit A (NAME, name in Nahuatl)
[layer a.1 -- Shape (SHAPE, name in Nahuatl),
 layer a.2 -- Color (COLOR, name in Nahuatl),
 layer a.3 -- Texture (TEXTURE, name in Nahuatl),
 layer a.4 -- Amount (NUMBER, number in Nahuatl),
 layer a.5 -- Position (AROUND, position in Nahuatl),
 layer a.6 -- Orientation (AROUND, position in Nahuatl),
 layer a.7 -- Value (PERCENTAGE)];
| end marker of agglutination [A] |
| end marker of synsemia [N] |
```

For brevity, the full code is not included; instead, [...] is used to indicate sections that are repetitive and have not been explicitly detailed.

Hypothesis for Segmenting and Encoding Folio 2r

Folio 2r of *Codex Mendoza* provides an overview where the warriors are positioned inside a specific portion of the landscape, which is sectioned by water. In turn, the warriors surround Tenochtzin, with all of them focused on the depiction of the Tenochca war at the center. The hypothesis suggests that both an entactic level and a synsemic level could be utilized in the encoding process. While this dual-level approach might be implemented in editing software, it has been coded here as a speculative hypothesis in order to code also the linguistic dimension of synsemic composition.

The Reckoning of Years

On the page, the chronological framework is meant to be read first (Figure 2), either by fully phonetizing the fifty-one years of the count or by identifying the year at the beginning (*Ome Calli xibuitl*, ‘Two House year’) and the year at the end of the count (*Matlactli Omeyi Acatl*, ‘Thirteen Reed year’). Additionally, the year Two Reed is marked to signify the conclusion of an Aztec calendric century of fifty-two years, known as the *xiubmolpilli* (‘the binding of the year’).

Ome acatl xibuitl, ipan in yancuican oqu-ilpique in inxiub in buehuetque Mexica ye intoca Tenochca in oncan atlitic Tenochtitlan.

‘Year Two Reed, for the first time the Old Mexicans called Tenochca did the binding of their years in the water [the lagoon] of Tenochtitlan.’



FIG. 2. The reckoning of years, section of the folio 2r

```
| initial marker of synsemia [1-52 (list of agglutinations)]
[...]|
| initial marker of agglutination [1] (TWO+HOUSE+YEAR, ome calli xihuitl)|
[...]|
| end marker of agglutination [1] |
[...]|
| end marker of synsemia [1-52 (list of agglutinations)]
```

Year Two House (Figure 3)

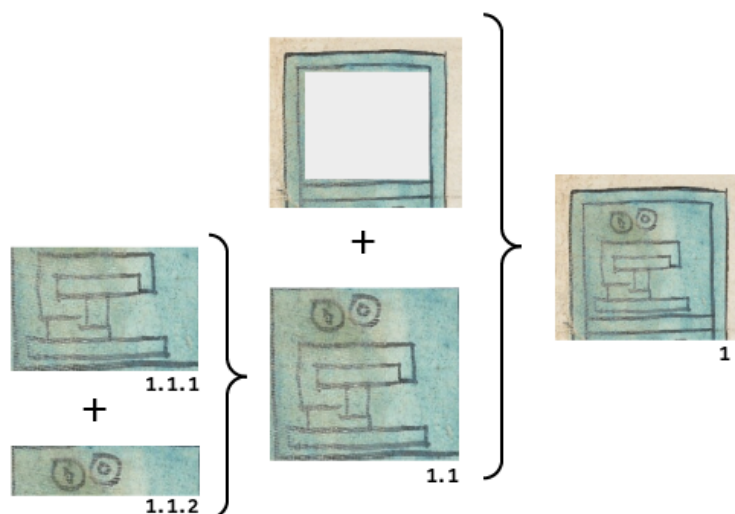


FIG. 3. Year Two House, glyph decomposition, section of the folio 2r

```
| initial marker of synsemia [52 (list of agglutinations)]
[Layer b.1 Orientation (UPRIGHT) - Layer b.2 Size (1/12; 1/18) -
Layer b.3 Position (AROUND; FROM UPPER LEFT; COUNTERCLOCKWISE)]

| initial marker of agglutination [1] (TWO+HOUSE+YEAR, ome calli xihuitl)|
Unit 1.1 (YEAR, xihuitl)
  [layer a.1 -- Shape (SQUARE, xihuitl),
  layer a.2 -- Color (TURQUOISE, xihuitl),
  layer a.3 -- Texture (-),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (AROUND),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%)];
```

```
| initial marker of agglutination [1.2] (TWO+HOUSE, ome calli)|
Unit 1.2.1 (HOUSE, calli)
    [layer a.1 -- Shape (A HOUSE, calli),
    layer a.2 -- Color (TURQUOISE),
    layer a.3 -- Texture (-),
    layer a.4 -- Amount (1),
    layer a.5 -- Position (BELOW),
    layer a.6 -- Orientation (-),
    layer a.7 -- Value (100%) ];
Unit 1.2.2 (TWO, ome)
    [layer a.1 -- Shape (CIRCLE),
    layer a.2 -- Color (TURQUOISE),
    layer a.3 -- Texture (-),
    layer a.4 -- Amount (2, ome),
    layer a.5 -- Position (ABOVE),
    layer a.6 -- Orientation (-),
    layer a.7 -- Value (100%)]
| end marker of agglutination [1.2] |
| end marker of agglutination [1] |
[...
| end marker of synsemia [1-52 (list of agglutinations)]
```

Year Two Reed (Figure 4)

```
| initial marker of synsemia [1-52 (list of agglutinations)]
[...

| initial marker of agglutination [27] ({inin}+YEAR+REED
+TWO CIRCLES+BINDING, Ome Acatl xihuitl)|
[...];

| initial marker of agglutination [27.1] |
Unit 27.1.1 (REED, acatl)
[...];

Unit 27.1.2 (TWO, ome)
[...];

Unit 27.1.3 (BINDING, ipan tlaxiuh molpilli)
[...];
| end marker of agglutination [27.1] |

Unit 27.2 (...)
    [layer a.1 - Shape (STROKE, AZTEC CONNECTING CHARACTER)
    ...
    layer a.5 - Position (INBETWEEN)];

| initial marker of agglutination [27.3] (PRECIOUS+ARROW+SMOKES
+ONTO THE HEAT OF THE YEAR TO COME, xiuhtlacoctli) |
```

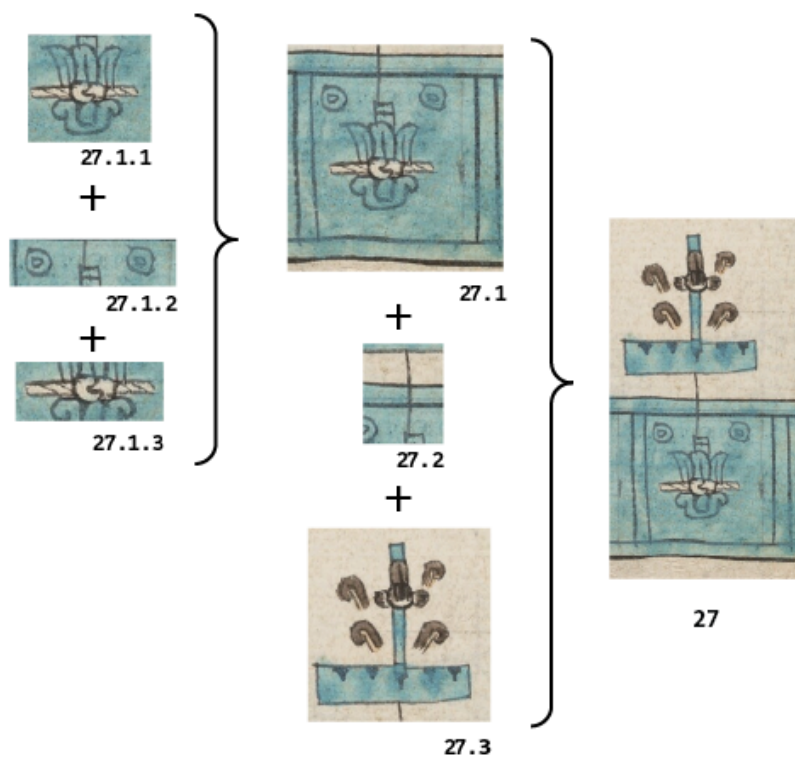


FIG. 4. Year Two Reed, section of the folio 2r

Unit 27.3.1 (ARROW, tlacochtli)
[...];

Unit 27.3.2 (PRECIOUS, xihuitl)
[...];

Unit 27.3.3 (SMOKES, popoca);

Unit 27.3.4 (ONTO THE HEAT OF THE YEAR TO COME, ipan in xiuhtlatlaliztli);

| end marker of agglutination [27.3] |

| end marker of agglutination [27] |



FIG. 5. Divided in four by water, section of the folio 2r

Divided in Four by Water (Figure 5)

```
| initial marker of synsemia [2] [1 (list of agglutinations)]
  [Layer b.1 Orientation (-) -
  Layer b.2 Size (2/3; 7/8) -
  Layer b.3 Position (INSIDE UP; FROM OUTSIDE; ONE INSIDE THE OTHER)]

| initial marker of agglutination [1] (DIVIDED+IN FOUR+BY WATER,
in atl quinxexeloa nahui calpulli)|
Unit 1 (SURROUNDED BY WATER, inten atl apano)
  [layer a.1 -- Shape (SQUARE, nohuiampa ixquich),
  layer a.2 -- Color (TURQUOISE, xihuitl),
  layer a.3 -- Texture (WAVING EDGE, apano #flowing water#),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (AROUND),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%)];

| initial marker of agglutination [1.1] (INTO FOUR PARTS, -)|
Unit 1 (INTO TWO PARTS, -)
  [layer a.1 -- Shape (A CANAL, apantli),
  layer a.2 -- Color (TURQUOISE, xihuitl),
  layer a.3 -- Texture (WAVING EDGE, apano),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (BELOW),
  layer a.6 -- Orientation (FROM UPPER RIGHT TO BOTTOM LEFT),
  layer a.7 -- Value (100%)];
Unit 2 (INTO TWO PARTS, -)
  [...];
| end marker of agglutination [1.1] |
  [...]
| end marker of agglutination [1] |
| end marker of synsemia [2] |
```

Tenochtitlan (Figure 6)

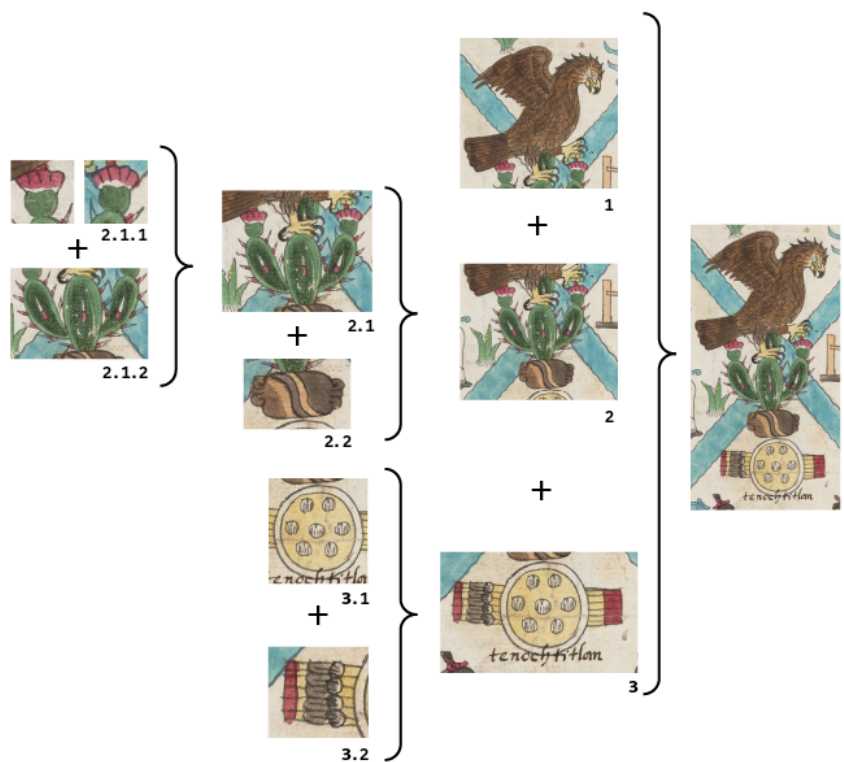


FIG. 6. Tenochtitlan, glyph decomposition, section of the folio 2r

In buey quaubtli motlalia ipan in tenochtli, motlalia Tenochtitlan in xochilē nopalli, aub in buey Tenochca chimalli ipan in mitl, in Tenochca yaoyotl

‘The big eagle rests onto a stone cactus, rests in the midst of a Stone Cactus with many cactus flowers, at Tenochtitlan, and the big Tenochca shield is on the arrows, there is the war of the Tenochca.’

| initial marker of synsemia [3] [1-3 (list of agglutinations)]
[Layer b.1 Orientation (UPRIGHT) -
Layer b.2 Size (1/5; 3/8) -
Layer b.3 Position (IN THE CENTER; FROM UP; ONE BELOW THE OTHER)]

| initial marker of agglutination [1] |
Unit 1.1 (EAGLE, quauhtli)


```

    [...];
| end marker of agglutination [1] |

| initial marker of agglutination [2] (FLOWERS+CACTUS+STONE,
Tenochtitlan in xochilê nopalli)|
| initial marker of agglutination [2.1] (FLOWERS+CACTUS, xochilé nopalli) |
    Unit 2.1.1 (FLOWERS, xochilê;
    [...];

    Unit 2.1.2 (CACTUS, nopalli);
    [...];
| end marker of agglutination [2.1] |

Unit 2.2 (STONE, tetl)
    [...];

| end marker of agglutination [2] |

| initial marker of agglutination [3] |
Unit 3.1 (TENPOCHCA SHIELD, Tenochca chimalli)
    [...];

Unit 3.2 (ARROWS, mitli)
    [...];

| end marker of agglutination [3] |
| end marker of synsemia |

```

Tenochtzin Speaks Preciously (Figures 7 and 8)

Ipan in mictlampa calpopan nepantla apantli, tollantzalan, xiubacatzalan, tlanabua-tia Teochtzin in buey teopixqui aub buey tlatoani; ybuan Tenochtzin motlalia inquax in eyi pilli teyaochibuanimé: Acacitlitzin, Mexcalmetzitzin, Xocoyotzin [...] quittä in Tenochitlan yaoyotl

‘In the northern subsection surrounded by water canal, in the middle of reeds, in the middle of canes, Tenochtzin rules, the high priest and high nobleman; furthermore Tenochtzin is seated in front of three noble warriors: the revered Reed Rabbit, the revered Little Maguey, the revered Foot Bell [...] they look at the war of Tenochtitlan.’

```

| initial marker of synsemia [4] [1-4 (list of agglutinations)]
    [Layer b.1 Orientation (TOWARD SYNSEMIA [3] (they look)) -
    Layer b.2 Size (2/3; 5/16) -
    Layer b.3 Position (ON THE LEFT/NORTH SUBSECTION [2], mictlampa;
    SCATTERED; SURROUNDING)]

| initial marker of agglutination [1] (NOBLE PRIEST STONE CACTUS
SPEAKS PRECIOUSLY, Tenochtzin xiuhtlatoani)|
[...];

```



```
| end marker of agglutination [3] |

| initial marker of agglutination [4] (NOBLE WARRIOR REED RABBIT,
Acatochtzin)|
[...];
| end marker of agglutination [4] |

| initial marker of agglutination [4] (NOBLE WARRIOR LITTLE MAGUEY,
Mexcalmetzintzin)|
[...];
| end marker of agglutination [4] |

| initial marker of agglutination [5] (NOBLE WARRIOR FOOT BELL,
Xocoyotzin)|
[...];
| end marker of agglutination [5] |

| end marker of synsemia [4] |
```

Tenochtzin (Figures 7 and 8)

Tenochtzin, xochilê nopaltzin, iitzon bueyac in iztacmolpilli, inacaz, in tlatlaubqui aub iztac, iicxi in tlilli, iizti in tlilli aub caccopinquê, in buey teopixqui, in iztactilmatini, in molalia petlaicpalpan, in buey pilli, aub in xiubtlatoa, in buey tlatoani

‘The revered Stone Cactus, the revered Cactus with flowers, his hair is long and bent with a white knot, his ear is red and white adorned, his face is dark, his feet are dark and bare, the high priest, the one who wears a white cloak, who is seated onto a mat of reeds, is a high nobleman, and he is the one who speaks preciously, the Great Lord.’

```
| initial marker of agglutination [1] (NOBLE PRIEST+STONE+CACTUS
SPEAKS PRECIOUSLY, teopixqui Tenochtzin xiuhtlatoani?)|
...

| initial marker of agglutination [1.1] (NOBLE PRIEST+STONE+CACTUS,
teopixqui Tenochtzin)|
| initial marker of agglutination [1.1.1] (FLOWERS+CACTUS+STONE,
Tenochtitlan in xochilê nopalli)|

Unit 1.1.1.1 (STONE CACTUS, tenochtli)
[...];
| initial marker of agglutination [1.1.1.1] |
    Unit 1.1.1.1.1 (FLOWERS, xochilê)
    [layer a.1 Shape (FLOWERS, xochilê),
    ...];
    Unit 1.1.1.1.2 (CACTUS, nopalli)
    [layer a.1 Shape (CACTUS, nopalli),
    ...];
| end marker of agglutination [1.1.1.1] |
```



FIG. 8. Tenochtzin, section of the folio 2r

```

Unit 1.1.1.2 (STONE, tetl)
[layer a.1 Shape (STONE, tetl),
...];
| end marker of agglutination [1.1.1] |

Unit 1.1.2 (NAME-OF-PERSON CONNECTOR)
[...];

| initial marker of agglutination [1.1.3] |
  Unit 1.1.3.1 (PRIEST teopixqui (hair))
    [layer a.1 Shape (A PRIEST (hairstyle)),
    ...];
  Unit 1.1.3.2 (ARISTOCRAT, -tzin)
    [layer a.1 Shape (WITH NAKED FEET, iicxi -tzin),
    layer a.2 -- Color (WHITE, iztactilmatli, -tzin),
    ...];
| end marker of agglutination [1.1.3] |

Unit 1.1.4 (MAT OF WOVEN RUSH STRAW (rules) cozticpetlatl)
[layer a.2 -- Color (YELLOW),
...];
| end marker of agglutination [1.1] |

Unit 1.2 (SPEAKING PRECIOUSLY, xihutlaoa)
[layer a.2 -- Color (Turquoise, xihuitl),
...];
| end marker of agglutination [1] |

```

Ocelopantzin (Figure 9)

```

| initial marker of agglutination [1] (NOBLE+WARRIOR+OCELOT FLAG,
Ocelopantzin)|
Unit 1.1 (FLAG)
[layer a.1 -- Shape (A FLAG, pantli),
layer a.2 -- Color (YELLOW),
layer a.3 -- Texture (OCELOT-SKIN, ocelo-),
layer a.4 -- Amount (1),
layer a.5 -- Position (ON THE SIDE-LEFT),
layer a.6 -- Orientation (-),
layer a.7 -- Value (100%)]];

Unit 1.2 (NAME-OF-PERSON CONNECTOR)
[layer a.1 -- Shape (STROKE, AZTEC CONNECTING CHARACTER),
layer a.2 -- Color (-),
layer a.3 -- Texture (.),
layer a.4 -- Amount (-),
layer a.5 -- Position (INBETWEEN),
layer a.6 -- Orientation (-),
layer a.7 -- Value (100%)]];

```

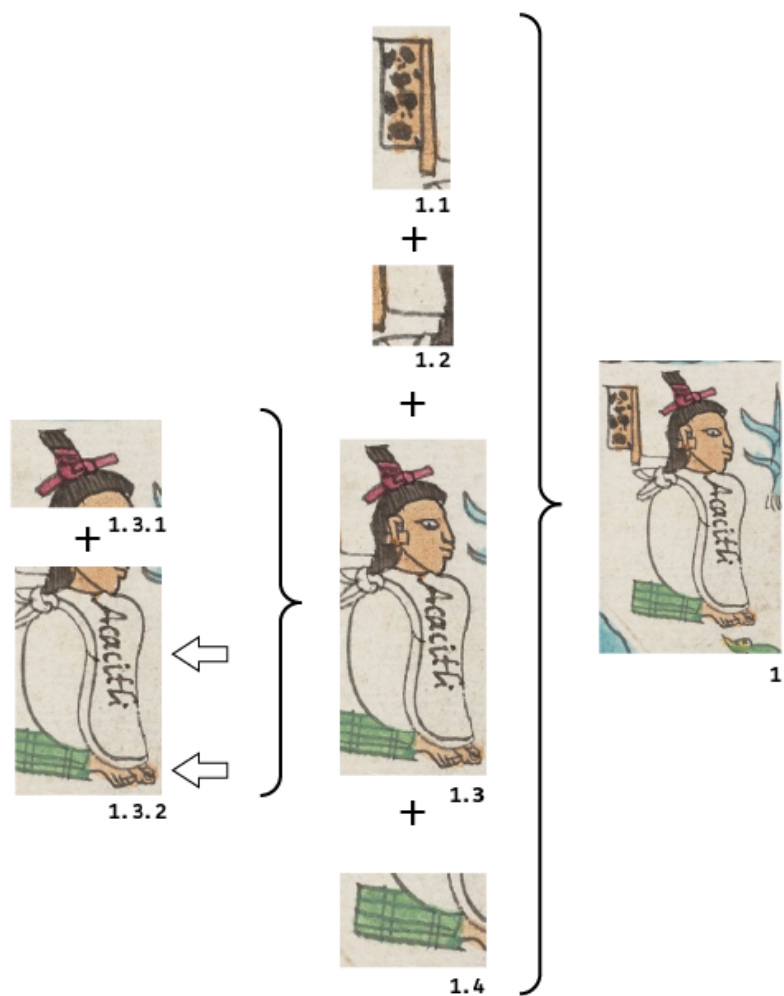


FIG. 9. Ocelopantzin, glyph decomposition, section of the folio 2r

```
| initial marker of agglutination [1.3] (NOBLE+WARRIOR) |
  Unit 1.3.1 (WARRIOR (hair))
    [layer a.1 -- Shape (A WARRIOR (hairstyle)),
      ...];

  Unit 1.3.2 (NOBLE, -tzin)
    [layer a.1 -- Shape (WITH NAKED FEET, -tzin),
      layer a.2 -- Color (WHITE (dress), -tzin),
      ...];
| end marker of agglutination [1.3] |
```

```
Unit 1.4 (WICKER MAT)
[layer a.1 -- Shape (A WICKER MAT),
  layer a.2 -- Color (GREEN),
  layer a.3 -- Texture (STACKED STICKS),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (BELOW),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%)];

| end marker of agglutination [1] |
```

The Defeat of Colhuacan (Figure 10)

In tolcozticcalquaitl in teocalli mopechteca iyecapan, uetzi, in teocalli popoca, tlatla icampa, in montemayabui, tepebualitztl Colhuacan altepetl

‘The yellow roof made by reeds of the temple leans ahead, falls, the temple goes up in smoke, in flames, it is the conquest, the defeat of the village of Colhuacan.’

Notice that while the following pages of *Codex Mendoza* have extensive lists of conquest, only in this f. 2r the conquest glyph is placed on a different layer, “above” the place-name referred to. Maybe this is a visual device used to maintain the multilayered map-style of the overall page.

```
| initial marker of synsemia [8] [1-3 (list of agglutinations)]
[Layer b.1 Orientation (ONE AGAINST THE OTHER) - Layer b.2 Size
(2/5; 1/5) - Layer b.3 Position (ON THE LOW SIDE; FROM LEFT TO RIGHT;
ONE AFTER THE OTHER)]
```

```
| initial marker of agglutination [1] (NOBLE+AZTEC+WARRIORS,
Tenochca tecatl)|
Unit 1.1 (WARRIOR, tecatl)
[layer a.1 -- Shape (HUMAN FIGURE, tecatl),
  layer a.2 -- Color (RED, tecatl),
  layer a.3 -- Texture (ARMOR, tecatl),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (CENTER),
  layer a.6 -- Orientation (-),
```

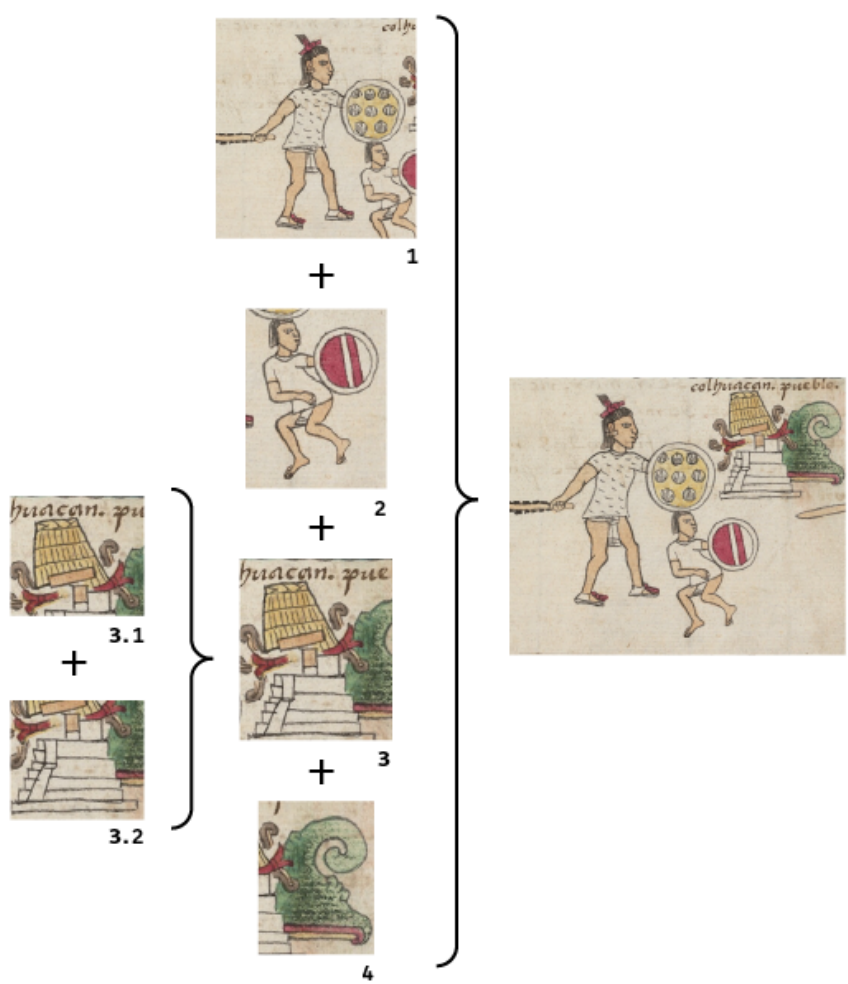


FIG. 10. The defeat of Colhuacan, glyph decomposition, section of the folio 2r


```

    layer a.7 -- Value (100%]);
| end marker of agglutination [1] |

| initial marker of agglutination [2] (NOBLE+COLHUACAN+WARRIORS,
Colhuacan tecatl)|
Unit 2.1 (WARRIOR, tecatl)
[layer a.1 -- Shape (HUMAN FIGURE, tecatl),
  layer a.2 -- Color (BLUE, tecatl),
  layer a.3 -- Texture (ARMOR, tecatl),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (LEFT),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%]);
| end marker of agglutination [2] |

| initial marker of agglutination [3] (YELLOW ROOF+OF THE TEMPLE
+MADE BY REED+LEANS AHEAD, tolcotziccalquaitl)|
Unit 3.1 (YELLOW ROOF OF THE TEMPLE, tolcozticcalquaitl)
[layer a.1 -- Shape (TEMPLE WITH ROOF, teocalli tolcozticcalquaitl),
  layer a.2 -- Color (YELLOW, coxtic),
  layer a.3 -- Texture (MADE BY REED),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (AFTER UNIT [2]),
  layer a.6 -- Orientation (LEAN AHEAD),
  layer a.7 -- Value (100%]);

| initial marker of agglutination [3.2] (THE TEMPLE GOES UP IN SMOKE,
IN FLAMES, popoca, tlatla)|
Unit 3.2.1 (SMOKE, popoca)
[layer a.1 -- Shape (SMOKE, popoca),
  layer a.2 -- Color (GRAY, popoca),
  layer a.3 -- Texture (CURLING),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (UPWARD),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%]);
Unit 3.2.2 (FLAMES, tlatla)
[layer a.1 -- Shape (FLAME, tlatla),
  layer a.2 -- Color (RED, tlatla),
  layer a.3 -- Texture (BLAZING),
  layer a.4 -- Amount (1),
  layer a.5 -- Position (UPWARD),
  layer a.6 -- Orientation (-),
  layer a.7 -- Value (100%]);
| end marker of agglutination [3.2] |
| end marker of agglutination [3] |

Unit 4 (CURVED MOUNTAIN, Colhuacan)
[layer a.1 -- Shape (MOUNTAIN, Colhuacan),
  layer a.2 -- Color (BROWN, Colhuacan),
  layer a.3 -- Texture (ROCKY),
  layer a.4 -- Amount (1),

```

```
layer a.5 -- Position (BELOW),
layer a.6 -- Orientation (-),
layer a.7 -- Value (100%)];
```

```
| end marker of synsemia [8] |
```

Conclusion

This paper suggests a speculative approach to encoding non-linear written artifacts, using folio 2r of the *Codex Mendoza* as a case study. The limitations of existing Unicode standards, which are rooted in the constraints derived from alphabetic and linear typographic traditions (Lussu, 2007), are critically assessed in light of the complex visual and semantic demands of *Aztec writing*.

The tentative system we devised would enable an encoding of writing by overcoming the main issue that a relevant part of the text is written through graphic composition, which cannot be fully represented with a mere linear sequence of characters-codes.

Our tentative model provides a multi-layered framework that integrates relational encoding, hierarchical composition, and visual variables. This approach allows for the representation of both entactic and synsemic levels, thus ensuring that spatial arrangements, relational markers, and hierarchical relationships intrinsic to Aztec graphemics are preserved. By addressing the agglutinative nature of *Nabuatl* and the non-linear, multidimensional layout of Aztec texts, the model provides a novel method for encoding the linguistic and visual complexity of these artifacts.

Folio 2r, as a critical and emblematic page, highlights the potential of this model. Its intricate spatial organization, chronological framework, and rich interplay of visual and linguistic content make it an ideal stress test for encoding non-linear texts. The method shows how graphic elements such as color, position, orientation, and texture are not merely decorative, but fundamental to conveying semantic and linguistic content.

This work underscores the importance of rethinking text encoding to accommodate non-linear systems, bridging the gap between the needs of historical artifact preservation and modern digital technologies. Beyond its application to *Aztec writing*, the principles and techniques proposed here may inform the development of encoding systems for other complex, non-alphabetic, and visual notations (including sign languages), or even a non-linear use of conventional linear script, contributing to a more inclusive and comprehensive digital representation of human linguistic diversity.

References

- Berdan, Frances F. and Patricia R. Anawalt (1992). *Codex Mendoza: Four-Volume Set*. University of California Press.
- Bertin, Jacques (2011). *Semiology of Graphics: Diagrams, Networks, Maps*. Redlands, CA: Esri Press.
- Bleichmar, Daniela (2015). "History in pictures: translating the Codex Mendoza". In: *Art History* 38.4, pp. 682–701.
- Brokaw, Galen (2022). "Homo Alphabeticus, Glottographic Exceptionalism, and the Ethnocentric Definition of Writing". In: *PMLA* 137.1, pp. 163–170.
- Consortium, Unicode (2024). *Unicode® Technical Standard #51: Unicode Emoji*. URL: <https://unicode.org/reports/tr51/> (visited on 01/06/2025).
- Dombrowski, Quinn et al. (2024). "Encoding Multilingualism: Technical Affordances of Multilingual Publication from Manuscripts to Unicode and OpenType". In: *The Journal of Electronic Publishing* 27.1.
- Fedorova, Liudmila L (2009). "The emblematic script of the Aztec codices as a particular semiotic type of writing system". In: *Written Language & Literacy* 12.2, pp. 258–275.
- Fedorova, Liudmila L. and Antonio Perri (2022). "Emblematic techniques as textual strategies in non-linear and linear scripts". In: *Proceedings of Grapholinguistics in the 21st Century, 2022*. Ed. by Yannis Haralambous. Vol. 9. Grapholinguistics and Its Applications. Brest: Fluxus Editions, pp. 75–99. DOI: <https://doi.org/10.36824/2022-graf-perr>.
- Galarza, Joaquín et al. (1983a). *Codex Mendoza, 1^{re} page, f. 2r. Lecture nabuatl*. Paris.
- (1983b). *Codex Mendoza, 1^{re} page, f. 2r. Méthode d'analyse*. Paris.
- Harris, Roy (1986). *The origin of writing*. Chicago and La Salle, IL: Open Court.
- (2000). *Rethinking Writing*. London: Athlone Press.
- Klinkenberg, Jean-Marie and Stéphane Polis (2018). "On scripturology". In: *Signata. Annales des sémiotiques/Annals of Semiotics* 9, pp. 57–102.
- Launey, Michel (1994). *Une grammaire omniprédicative: essai sur la morphosyntaxe du nabuatl classique*. Collection sciences du langage. CNRS Éditions.
- Lussu, Giovanni (2007). "The Form of Language". In: *Typography Papers* 7, pp. 139–147.
- Perondi, Luciano (2012). *Sinsemie. Scrittura nello spazio [Synsemiae. writing in the space]*. Viterbo: Nuovi Equilibri.
- Perondi, Luciano, Antonio Perri, et al. (2018). "Configurare lo spazio nella scrittura azteca: il Codice Mendoza come modello di trasposizione e oltre [Framing space in Aztec writing: the Codex Mendoza as a model of transposition and beyond]". In: *XY* 3.5, pp. 40–53.
- Perondi, Luciano and Leonardo Romei (2010). "Letture da recuperare [Readings to retrieve]". In: *Il sole 24 ore* 245, pp. 12–13.

- Perri, Antonio (2006). "Dire o mostrare? L'immagine-testo ei paradossi della pittografia-come-notazione [To Say or to Show? The Image-Text and the Paradoxes of Pictography-as-Notation]". In: *Centro internazionale di Semiotica e linguistica-Università di Urbino-Documenti e pre-pubblicazioni* 350, pp. 51–75.
- Perri, Antonio et al. (2024). "Alternative graphemics. Aztec writing system as a case study towards an integrated, digitalised model of non-typographic graphemics". In: *Ocula* 24.30, pp. 43–64.
- Vaillant, Pascal (1999). *Sémiotique des langages d'icônes*. Bibliothèque de grammaire et de linguistique. Paris: Éditions Honoré Champion.
- Zamora Corona, Alonso Rodrigo (2022). "Towards a Complex Theory of Writing: The Case of Aztec and Mixtec Codices". In: *Signata* 13. doi: 10.4000/signata.3866. (Visited on 01/13/2025).

Braille as Writing

Evidence and Lessons for Grapholinguistic Theory

Arvind Iyengar

Abstract. The inventory of embossed symbols known as Braille is widely used by Blind and Visually Impaired (BVI) users for touch-reading and information exchange. In permitting communication through the tactile-graphical mode, Braille acts as an alternative to the visual-graphical mode employed by sighted persons for the same purpose. Since its creation two centuries ago, this tactile symbol inventory has enabled BVI users around the world to access information that might otherwise have been inaccessible or unavailable to them. Braille has been widely admired for its simplicity and emancipatory potential. Yet, most sighted users know little about the symbol inventory or its underlying workings as a graphical form of spoken language. The lack of awareness extends to scholarly circles, with Braille remaining an outlier in grapholinguistic and related research endeavors. Consequently, the insights that Braille potentially offers for refining our understanding of writing remain largely unknown. Of late, Blind and sighted advocates have been calling for greater attention to be given to Braille in grapholinguistic contexts, and for it to be considered a valid form of writing. This article addresses the fundamental question of whether Braille text can be considered ‘writing’ that is analogous and equivalent to print text. To this end, the article investigates whether linguistic content in Braille meets the definitions of key grapholinguistic concepts, and identifies outliers and edge cases. The article concludes that Braille text not only fulfils the definition of ‘writing’ under contemporary grapholinguistic theory, it also helps clarify hitherto ambiguous or debated concepts.

1. Introduction

1.1. Background and Motivation

For most sighted people across the world, Braille exists largely on the peripheries of their imaginations. Among this cohort, knowledge about Braille, its functioning and its applications has generally been minimal.

Arvind Iyengar  0000-0002-7303-1524

Discipline of Linguistics, University of New England, Armidale NSW 2351, Australia
E-mail: arvind.iyengar@une.edu.au

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 661–688. <https://doi.org/10.36824/2024-graf-iyen>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

There exists a minority of sighted Braille users, many of whom are engaged as pedagogues, advocates and allies with the Blind and Visually Impaired (BVI) community. Regardless, it appears uncontroversial to state that most of the world's sighted population—comprising the vast majority of humanity—know little about how Braille actually 'works'.

Regrettably, the epistemological marginalization of Braille also holds true within academic circles, including in grapholinguistics. Despite being hailed as "a lighthouse to pierce the darkness of the blind" (Keller in Mackenzie, 1954, p. 5), "a vital tool of literacy" (Dixon in Perkins et al., 2013, p. viii) and "the first effective digitization of writing" (Daniels and Bright, 1996, p. 886), Braille continues to be sidelined in scholarly research and remains chronically understudied (Englebretson, Holbrook, and Fischer-Baum, 2023, p. 402). Consequently, it remains largely unknown what lessons Braille may hold for refining our understanding of 'writing' in graphematic and sociolinguistic contexts.

The resultant misconceptions about Braille have prompted otherwise well-meaning sighted authors to unwittingly characterize it as an embossed notation or code for the visual or INKPRINT writing system of a language, to enable Blind users to read by touch.¹ Such characterizations have been critiqued as visuocentric, since they depict Braille as "a code for print, as derived from print [and] dependent on print" (ibid., p. 407). Along similar lines, Braille is sometimes considered a secondary or auxiliary notation system, implying that it acts as a subordinate alternative for a corresponding 'primary' writing system. Such portrayals belie the reality of Blind users for whom a Braille-based system is very much their primary mode of reading and writing, and may be the only one they are literate in (Daniels (1996b, p. 818). Besides, there exists little to no methodical analysis or reliable evidence attesting to Braille's supposed secondary or subsidiary status, because of which such a characterization essentially remains an opinion. Yet, the numerical dominance of sighted scholars in the academic community has elevated the majority opinion to quasi-consensus status, in the process percolating into BVI authors' own stances on the issue (Englebretson, 2009, p. 69; Englebretson, Holbrook, and Fischer-Baum, 2023, p. 408).

Against this background, scholars, pedagogues and advocates have been increasingly calling for Braille to receive greater prominence in academic and popular spheres alike. Within grapholinguistics, Meletis (2020, p. 32, footnote 35) argues that, from a structural standpoint, Braille as used in representing spoken language qualifies as 'language writing' and should be considered as such. In the sociolinguistic realm,

1. In Braille-related contexts, the conventionalized term <inkprint> denotes any writing meant to be sight-read, even if not printed as such (e.g., electronic text). The equivalent French term is <en noir>, literally 'in black'. Such text is contrasted with material meant to be touch-read, namely in Braille.

Klein and Spitzmüller (2022) compare the relative prominence of and discourse patterns around Braille and sign language in the German-language press, with the aim of identifying the underlying ideologies in each case.² They conclude that:

As opposed to sign languages, Braille is still very much *stigmatized* both in society and academic literature. While sign languages are (rightly) celebrated as languages proper and sign language users as a vivid and strong community, Braille is still perceived as an *auxiliary and pathological* form of writing/reading of *individual persons* ... (ibid., 21:13; emphasis in original)

In calling for Braille's removal from "the blind spot of communication theory and practice", Klein and Spitzmüller (ibid., 21:46) highlight its status as "a proper, and extremely interesting, form of graphic communication".

A seminal argument to this end is that of Englebretson, Holbrook, and Fischer-Baum (2023), who make a compelling case for researching Braille as "a writing system worthy of study in its own right and on its own terms" (p. 400). In addition to their distinct backgrounds in linguistics, education and psychology, the authors of this study represent a mix of Blind and sighted users of Braille at varying levels of proficiency. Drawing on their diverse areas of expertise and lived experiences, they eloquently argue in favor of "decentering the sighted norm" in academic research, highlighting the ramifications of not doing so for BVI and sighted communities alike. Aside from the need to ensure equity and social justice, Englebretson et al. assert that centering Braille and Blind users in pedagogical, cognitive and grapholinguistic investigations would lead to new and insightful findings in these spheres.

The arguments in Englebretson, Holbrook, and Fischer-Baum (ibid.) serve as motivation for the present article. My intention is for this article to serve as an initial step towards the ultimate aim of normalizing Braille as a subject of inquiry in grapholinguistic research. I further hope that the article's subject matter and findings act as impetus for subsequent efforts of a similar kind, to bring the discipline of grapholinguistics closer to the stated aim.

1.2. Objectives

The prediction in Englebretson, Holbrook, and Fischer-Baum (ibid.) that foregrounding Braille in research efforts would yield promising outcomes has been partly vindicated by recent work in the pedagogical and

2. In the Anglophone literature, sign languages may also be termed *signed languages*. I am not (yet) aware of any noteworthy differences in connotation between the nomenclatural variants.

cognitive domains (see, e.g., Hoskin et al., 2024; Martiniello and Wittich, 2022; Sheffield, D'Andrea, Morash, and Chatfield, 2022). Progress on the grapholinguistic front, however, has been slow. Building on the findings of Meletis (2020) and Klein and Spitzmüller (2022), there have been welcome forays of late into unpacking Braille as used in depicting languages other than English (Fetnaci, Haralambous, and Varin, 2022; Iyengar, in press). Nevertheless, such works remain few and far between, and Braille is yet to become a routine subject of grapholinguistic exploration comparable to its inkprint counterparts. In particular, there is as yet no dedicated cross-linguistic analysis of Braille that examines its grapholinguistic properties by applying state-of-the-art theory in a rigorous and consistent manner.

Against this background, I investigate in this article how Braille is deployed in transcribing or graphizing various spoken human languages worldwide (henceforth 'Braille text'). In doing so, I gauge how Braille text might fit into current graphematic and sociolinguistic frameworks and, conversely, how these frameworks account for the manifestations of Braille text across languages. To this end, the specific questions I address are:

1. To what extent does Braille text meet the requirements of GLOTTOGRAPHY, SCRIPT and WRITING SYSTEM as laid out in the academic literature?
2. With reference to the Modular Theory of Writing Systems (MT) (Meletis, 2020; Neef, 2015), how neatly is Braille text compartmentalizable into the MT's envisaged modules of GRAPHEMATIC SYSTEM and ORTHOGRAPHY? If edge cases emerge, what can they tell us about the underlying properties of Braille text, and about contemporary grapholinguistic theory?
3. Are typological labels like LOGOGRAPHIC and PHONOGRAPHIC applicable to Braille text? If yes, how does Braille text lend itself to the application of granular typological category labels such as ABUGIDA, ALPHASYLLABARY and ALPHABET (Bright, 1999; Gnanadesikan, 2017; Iyengar, 2023)?
4. What lessons emerge from analyzing Braille text using contemporary sociolinguistic approaches such as BISCRIPITALITY (Bunčić, Lippert, and Rabus, 2016)? How does this analysis validate, contradict and/or refine our current understanding of sociolinguistic phenomena?

By identifying areas of congruence and dissonance between existing theory and Braille-based data, I make observations and preliminary conclusions on the relation of Braille and inkprint text, especially on the appropriateness of characterizing Braille text as 'language writing' in the conventional sense.

For consistency with established anglophone grapholinguistic practice, I spell all script names with an initial uppercase letter, as in <Hiragana>,

<Devanagari> and <Bopomofo>. Since Braille will be discussed in a similar context, the word <Braille> is also spelled with initial uppercase . This is also the casing convention adopted by Sir Clutha Mackenzie in his seminal reference work, *World Braille Usage* (Mackenzie, 1954).

1.3. Limitations

The story of Braille's invention (§2) highlights the value of end-user involvement when designing a solution, in light of such users' intimate familiarity and nuanced experiential knowledge with the issue at hand. It follows that touch-readers of Braille would possess subtle insights into the underlying workings of Braille text that may not be readily evident to sight-readers of Braille text like myself. That said, ideational refinement requires collective input, especially on under-researched topics like the current one. It is, therefore, imperative that Blind and sighted researchers of Braille jointly contribute to their shared topic of interest, be it on conceptual questions as in this article, or on real-world practice as in Englebreton, Holbrook, and Fischer-Baum (2023). In any event, my conclusions in this article are necessarily preliminary, remain open to ongoing scrutiny, and will inevitably be refined, modified or superseded by future research.

2. Braille: An Overview

The symbol inventory today known as Braille is named after Frenchman Louis Braille (1809–1852), who lost his eyesight in a domestic accident aged three (Australian Braille Authority, 2024a; Mellor, 2006). At ten years old, Braille enrolled at the *Institut National des Jeunes Aveugles* (INJA; 'National Institute for the Young Blind') in Paris, where he learnt to touch-read his native French transcribed in embossed Latin-script letters (Campsie, 2021). He also acquainted himself with tactile transcription systems invented by soldier-turned-philanthropist Charles Barbier, which eschewed Latin-script letters in favor of graphically simple combinations of dots and dashes (Barbier, 1809; 1815). Building on Barbier's concept of embossed dot-and-dash symbols, Braille began exploring ways to improve the symbols' tactile perceptibility. By 1825, aged sixteen, he had a prototype ready (Henri in Mackenzie, 1954, p. 18; Tomic, 2025). Soon after, he became a tutor at his alma mater, while continuing to work on his symbol inventory (American Foundation for the Blind, 2024b).

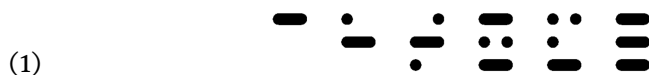
By 1829, Braille had simplified the design template of an individual tactile symbol into a matrix or CELL of six dot positions, arranged in three rows and two columns. By raising different dot combinations

within a cell, one could create up to 63 distinct embossed symbols. For reference purposes, the six dots were numbered top-to-bottom and left-to-right, as shown in Figure 1.



FIG. 1. Standard numbering pattern of a Braille cell. Source: Wikimedia Commons. Copyright 2010 by DePiep. Modified and used under CC BY-SA 3.0

In place of two dots, a row could comprise a continuous raised dash. Permitting dashes and dots to co-occur within a cell generated an additional 61 symbol options. Together with a blank space, Braille's inventory provided for 125 unique tactile symbols formed from just two design elements: a dot and a dash. Moreover, the 3×2 cell configuration ensured every single symbol would fit neatly under an adult human fingertip, facilitating efficient decipherment (Mackenzie, 1954, Chapter 2). A selection of symbols from Braille's prototype featuring various dot-and-dash combinations is shown in (1).



By mapping individual embossed symbols onto French-in-Latin letters, digits and punctuation marks, Braille effectively created a parallel standalone transcription system tailor-made for touch-reading. Along similar lines, he harnessed his symbol inventory to devise a tactile system of musical notation. In 1829, the twenty-year-old Braille unveiled his creations in a 32-page booklet, titled *Procédé pour écrire les Paroles, la Musique et le Plain-chant au moyen de points*, 'Procedure for writing words, music and plain-song using dots' (Braille, 1829). The booklet featured embossed samples of his notation systems with accompanying explanatory text in embossed-type French-in-Latin.

Notwithstanding the design simplicity of his creations, Braille was apparently aware that the dash element was not as tactually perceptible as the individual dots. In the booklet's explanatory text, he concedes:

Le trait qui entre dans la composition des signes ... pouvant présenter quelques difficultés a plusieurs de ceux qui étudieront ce procédé;

[The dash that enters into the composition of the signs ... can present some difficulty to many of those who will study this procedure;]

(ibid., p. 12; translation by National Federation of the Blind, n.d.)

By the time the first book-length work typeset in his system appeared in 1837 (American Foundation for the Blind, 2024a), Braille had eliminated the raised-dash symbols from his inventory. His streamlined symbol set now featured 63 distinct cells founded upon a sole design element—a raised dot (Mackenzie, 1954). A century down the line, the INJA's Pierre Henri would note how his predecessor Louis Braille's lived experiences as a Blind person were indispensable in informing the symbols' final design:

[O]nly a blind man [*sic*] could have arranged dots in groups which exactly correspond to the requirements of the sense of touch. Reduce the number of dots and the available signs become obviously insufficient; add to their number, and the signs can no longer be covered by the finger-tip, nor so easily read ... (Henri in Mackenzie, 1953, p. 18)

Louis Braille died young at just 43 years of age, but his creation lived on. Over the following century and a half, his now-eponymous inventory of raised-dot cells became the basis of tactile representation schemes for over a hundred languages globally (Perkins, International Council on English Braille, and National Library Service, 2013; ScriptSource, 2025). The number continues to increase; in the twenty-first century, Braille representations have been proposed for languages like Inuktitut, Cherokee and even Klingon (Kearney, 2012; 2014; 2019). Louis Braille's musical notation has also endured, and has been supplemented by analogous notations in mathematics and phonetics (Englebreton, 2008; 2009; Nemeth, 1973).

With a view to examining the compatibility of Braille text and contemporary grapholinguistic frameworks, Sections 3 to 6 outline relevant terminology and theoretical concepts, and assess their applicability to Braille text. In doing so, relevant insights including noteworthy areas of incongruence are highlighted. The findings are consolidated and summarized in Section 7.

3. Script, Writing System and Glottography

The grapholinguistic term for a discrete unit of writing is a GRAPH. It serves as an all-encompassing term that is also less ambiguous than the lay alternatives *sign*, *letter*, and *character* (Iyengar, 2023; Meletis, 2020). For clarity, graphs may be shown enclosed in pipes, as in |A|. An inventory of graphs used to represent human speech in graphical form is termed a SCRIPT, with the script-language pair constituting a writing system (henceforth 'WS') (Iyengar, 2023; in press; Meletis, 2020; Neef, 2015; Weingarten, 2013). A WRITING SYSTEM, therefore, comprises two mandatory and distinct components: a *spoken* language and a *written*

script. The three entities of writing system, language and script “undeniably represent an elusive trinity”, according to Joyce and Masuda (2019, p. 248). Despite the ostensible elusiveness of these intertwined entities, it is imperative that they be clearly identified and conceptually distinguished, particularly in the context of this article. All three concepts fall under the umbrella of GLOTTOGRAPHY or ‘language writing’—namely the use of graphical symbols to represent units of spoken language, where the spoken units might range from individual speech sounds to entire morphemes and words (Iyengar, in press; Sampson, 2015, 21ff). Glottography is distinguished from *semasiography* or ‘meaning writing’ (Gelb, 1963; Sampson, 2015), wherein graphical symbols denote fuzzy concepts or ideas rather than specific sounds or words. Notations that are partially or wholly semasiographic include mathematical formulae, traffic signage and emojis. In deciding if a set of graphical symbols is glottographic or semasiographic, the mode of decipherment—whether visual or tactile—does not play a part (Iyengar, in press).

Per the above, the graph inventories known as Latin (or Roman), Arabic and Canadian Syllabics (or simply ‘Syllabics’) are scripts, whereas Swahili-in-Latin, Mandarin-in-Arabic and Inuktitut-in-Syllabics are WSs. It follows that a particular script may be used to graphize multiple languages, as in Swahili-in-Latin and Indonesian-in-Latin. Likewise, a particular language may be graphized in multiple scripts, as in Mandarin-in-Arabic and Mandarin-in-Bopomofo. Each of these language-script pairs constitutes a unique WS. For compactness in writing, a WS’s components may be denoted by standardized codes or *tags* (Raymond, 2020) approved and overseen by the Internet Engineering Task Force (IETF) (Iyengar, 2023; Phillips and Baker, 2009). Thus, Inuktitut-in-Syllabics and Mandarin-in-Arabic may be represented by the tags *iu-Cans* and *cmn-Arab*, respectively. Such a double-barreled nomenclature transparently reveals the underlying language and script components for every WS, with the presence of the language component attesting to the WS’s glottographic status. Furthermore, the nomenclature reinforces the conceptual distinction between *script* and *writing system*, and the possibility of pairing any language with any script. In doing so, the binominal format underscores the fact that any language could theoretically be written in any script, subtly negating notions of intrinsic or structural inseparability between a particular language and script. The IETF’s format permits optional components to be suffixed as *subtags* to further delimit the WS based on fine-grained properties, such as geographical region or orthographic variant (Iyengar, 2023; Phillips and Baker, 2009).

The concepts of script, WS and glottography are all applicable to Braille text. As already mentioned, Louis Braille’s eponymous symbol set of 63 raised-dot cells is used to transcribe a hundred-plus human languages. In tacit recognition of this fact, the IETF and related standards

The fact that Braille satisfies the accepted grapholinguistic definitions of script, WS and glottography is also consistent with historic—if isolated—observations of the phenomenon. In *Writing Systems of the World*, Daniels (1996b, p. 818) asserts that English-in-Braille as used in the United States (en-Brai-US) is not simply “a variety of English[in-Latin] orthography, but rather an independent writing system”. In her textbook on writing systems, Gnanadesikan (2009) alludes to Braille text to demonstrate that the mode of decoding is inconsequential to a WS’s glottographic status:

More recently, Honda (2021, p. 631, footnote 13) notes that “Japanese braille (点字 *tenji*) constitutes a separate tactile writing system which has different formal and functional properties from its multi-script visual writing system”. Fetnaci, Haralambous, and Varin (2022) demonstrate the systematic similarities and differences between the Arabic language transcribed in Braille (ar-Brai) and in the homonymous inkprint script (ar-Arab), and in doing so explicitly describe Arabic-in-Braille as a writing system. These recent conclusions are especially valuable as they at-

test to and affirm Braille's ongoing usage as a glottographic script for a variety of mutually unrelated languages across the world.

4. Graphematic System and Orthography

Within a writing system, the correlation of written units from the script component to spoken units from the language component is termed the **GRAPHEMATIC SYSTEM**, or simply **GRAPHEMATICS** (Iyengar, in press; Meletis, 2020; Neef, 2015). The representational possibilities offered by the graphematic system may be constrained and occasionally overridden by the optional layer of **ORTHOGRAPHY** (Honda, 2021; Iyengar, 2023; 2024). For instance, the 'bare' en-Latn graphematic system may permit or *license* multiple ways of graphizing a particular word, as in <color> and <colour>. A superimposed orthographic layer often limits the range of written forms available to users by prescribing one and proscribing the others. The choice of orthography depends on the text's intended users and use. Thus, an English-in-Latin text written by or for American users would typically feature the written form <color>. Put differently, a bare graphematic system may have different orthographic 'veneers' applied by different user groups. A particular graphematic system subject to distinct orthographic layers—as in en-Latn-US and en-Latn-GB—represent distinct sets of *spelling rules* within a given WS (Iyengar, in press, Chapter 2).

4.1. Orthographic Variants

The concepts of orthography and spelling apply neatly to Braille-based writing systems. Until the turn of the twenty-first century, countries around the world used en-Brai with distinct but mutually intelligible conventions. In other words, countries utilized en-Brai under distinct but mutually intelligible *orthographies*, not unlike the contemporary usage of en-Latn globally. As with en-Latn, the most prominent English-in-Braille orthographies were those followed in the United States and United Kingdom—en-Brai-US and en-Brai-GB, respectively (Bogart and Koenig, 2005; Cranmer and Nemeth, 1991; International Council on English Braille, 2012). Following sustained effort and collaboration over several years, a revised and consolidated set of written conventions was released and steadily adopted around the world over the first two decades of the twenty-first century (Australian Braille Authority, 2024b). The revised set of conventions is known as *Unified English Braille* (UEB) and essentially constitutes a new English-in-Braille orthography

4.2. Graph Inventories

(2)

[illegible]

3. IETF rules specify that subtags for writing systems that are not listed in the official registry are considered ‘private use’ subtags, and must be prefixed with x- (Phillips and Baker, 2009, pp. 8–9). Regrettably but not surprisingly, no Braille-related subtags were listed in the registry at the time of writing this article (Internet Assigned Numbers Authority, 2025). Consequently, the code for English-in-Braille’s “universal” orthography qualifies as ‘private’ and needs to be formulated as en-Brai-x-ueb.

orthographic or graphematic proves contentious, as no consensus exists on determining the boundary between a WS's graphematic system and orthography (Honda, 2021; Iyengar, in press, Chapter 2; Meletis, 2020). Indeed, the dilemma may well remain unresolved until theoretical advancements are made and more sophisticated analytical tools are developed.

The above finding also dovetails with the core reason for the disparity between Pakistani and Indian Urdu-in-Braille. Whereas ur-Brai-PK is modelled on Arabic-in-Braille, ur-Brai-IN is based on a common set of graphematic principles and orthographic conventions for transcribing the official languages of India into Braille. These pan-Indian Braille conventions are officially known as *Bharati Braille* (IIT Madras, 2020; Iyengar, 2023; 2024) and represent a noteworthy instance of a graphematic-system-plus-orthography being employed by multiple WSs. In principle, a person literate in *any* Bharati-Braille-based WS could be considered literate in *all* of them.⁴ Identifying a comparable example among inkprint WSs proves elusive. Nor does there appear to be an equivalent among inkprint WSs for the paradox embodied by Urdu-in-Braille, wherein an Urdu speaker from India literate in ur-Brai-IN may struggle to comprehend same-language or HOMOGLOTTAL text transcribed in ur-Brai-PK conventions, but could in principle decipher other-language or HETEROGLOTTAL text transcribed in Bharati Braille WSs. The noteworthy instance of a given language-script pair manifesting in two starkly divergent variants with limited mutual intelligibility reiterates the classificatory dilemma identified earlier: Are ur-Brai-PK and ur-Brai-IN instances of the same writing system differing only in their orthographic veneers, or does the divergence go deeper? If the latter, in which layer of the writing system is the difference supposed to exist, and why? These questions may have never arisen had our focus been restricted to inkprint WSs.

Regardless of inventorial differences between ur-Brai-PK and ur-Brai-IN, individual graphs in both variants are exclusively six-dot (Iyengar, in press, Chapter 11). This contrasts with the situation of Japanese-in-Braille (ja-Brai), which may manifest in three different avatars—the official *tenji* variant, and the unofficial *tenkanji* and *kantenji* variants. Of these, the graph inventories of *tenji* and *tenkanji* only comprise six-dot cells (Dasgupta, 2002; Dixon, 2007), while *kantenji* employs eight-dot cells (Dixon, 2007; Nagoya Braille Network, 2006).⁵ The inventorial diversity among the ja-Brai variants reiterates the classificatory dilemma posed by ur-Brai—do these inventorial distinctions exist within the orthogra-

4. In practice, there exist minor customizations within individual Bharati Braille WSs that require targeted learning. In any event, any putative pan-systemic literacy assumes practical relevance only if the person is also orate in the target language(s).

5. 'Six-dot' and 'eight-dot' refer to the underlying cell matrix, wherein the *maximum* number of raised dots is six and eight, respectively.

phy, graphematics, or some other layer? As already noted, this question may not be satisfactorily addressable at the current level of grapholinguistic theory, and likely requires developing innovative analytical approaches. It is in posing such classificatory conundrums that Braille-based WSs demonstrate their value to grapholinguistics. By exhibiting behavior unattested among inkprint WSs, Braille-based WSs challenge the status quo and invariably spur conceptual refinements.

4.3. Paralinguistic Features

In spite of their divergent inventories, ur-Brai-PK and ur-Brai-IN are both written left-to-right, top-to-bottom (LR-TB), in contrast to the right-to-left (RL-TB) directionality of their inkprint counterpart of Urdu-in-Arabic (ur-Arab; see (2)). Although seemingly anomalous at first glance, the differing directionalities of ur-Brai and ur-Arab is actually consistent with historical and current practice across WSs. Mandarin-in-Han characters (cmn-Hani) and Mandarin-in-Bopomofo (cmn-Bopo) can be written LR-TB or top-to-bottom, right-to-left (TB-RL), as can the related WSs of Japanese in Kanji-and-Kana (ja-Jpan), and Korean in Hanja-and-Hangeul (kr-Kore).⁶ Mandarin-in-Latin variants such as Hànyǔ Pinyin (cmn-Latn-pinyin) and Wade-Giles (cmn-Latn-wadegile) are written LR-TB in line with Latin-script WSs worldwide. Mandarin-in-Arabic (cmn-Arab) or Xiǎo'érjīng is written RL-TB consistent with other Arabic-script WSs, including ur-Arab. In short, the directionality of a WS is more often conditioned by the directionality of homographic WSs than homoglottal ones. It is, therefore, normal and consistent for Urdu-in-Braille to follow the canonical LR-TB directionality of Braille-based WSs worldwide, independently of the directionality of Urdu-in-Arabic. The fact that Braille systems are no different from their inkprint counterparts on matters of writing directionality only underscores the systemic equivalence of the two. These underlying parallels were not lost on the BVI pioneers of Braille standardization, who noted in a 1949 UNESCO report that:

6. The subtag Jpan is an “alias” for the blend of Kanji (Hani), Hiragana (Hira) and Katakana (Kana) characters used to graphize spoken Japanese, while the subtag Kore is an alias for the composite of Hanja (Hani) and Hangeul (Hang) employed to write Korean. Hira, Kana and Hang, as well as Bopomofo (Bopo) for Mandarin, were or are considered subsidiary to Hani and unsuitable as standalone scripts for writing their respective languages. However, if one disregards the ever-evolving sociolinguistic status and adopts a purely graphematic approach, one would deem cmn-Bopo, ja-Hira, ja-Kana, and kr-Hang standalone writing systems (Iyengar, in press, Chapter 2). A similar dichotomy of ‘sociolinguistically subsidiary but graphematically independent’ applies to Braille-based WSs, in that they are considered subordinate to their homoglottal inkprint counterparts despite being ostensibly self-standing (§1.1).

[t]he script of every language is both written and read in a traditional direction—Chinese from top to bottom of the page, Persian, Urdu and Hebrew from right to left, Roman, Greek and Devanagari from left to right. Braille is traditionally read from left to right, and the Brailles of Japanese, Korean, Chinese, Malay, Urdu, Persian and Hebrew conform, not to the conventions of their visual scripts, but to the Braille convention. (Advisory Committee on Braille Problems, 1949, quoted in Mackenzie, 1954, p. 34)

Despite their systemic equivalence, a conspicuous difference between inkprint and Braille-based WSs is the latter's limited inventory size, especially the six-dot variant. While the former allows the creation of arbitrary graphs as required, Braille's design simplicity and typographical constraints rule out the option of conjuring up arbitrary derivative graphs. As a result, Braille-based WSs may convey paralinguistic information through novel bespoke conventions. Where the inkprint WS is bicameral and distinguishes between uppercase and lowercase letterforms, the corresponding Braille WS may feature a standalone capital marker graph. The capital marker usually precedes a regular 'lowercase' graph, with the resultant digraph interpreted as the 'uppercase' equivalent. A string of uppercase letters, as in heading text, may be portrayed by two or more instances of the capital marker placed at the start and end of the string. While the specific Braille cell chosen as the capital marker may differ across WSs, the underlying operation remains consistent and comparable. Thus, Dot-6 ⠠ serves as the capital marker in Armenian (hy), Bulgarian (bg) and English in Braille, whereas Dots-46 ⠠ fulfils the same role in Greek (el), French and Ukrainian (uk) in Braille (Perkins, International Council on English Braille, and National Library Service, 2013). To clarify, the existence of a Braille capital marker suggests that the corresponding inkprint *writing system* is bicameral. The *script* component of the inkprint WS is inconsequential, be it Armenian (Armn), Cyrillic (Cyr1), Greek (Grek), Latin or any other. Similar to the capital marker, bold and italic typeface in inkprint may be denoted by standalone graphs in Braille, indicating emphasis or distinctness from the surrounding text.

Although conveying paralinguistic cues through standalone graphs may seem unusual to some readers, there exist comparable practices in inkprint WSs. For instance, inkprint text representing a verbatim quote is enclosed within standalone quotation marks. In setting off the target text in a perceptibly distinct manner, the effect of graphically standalone quotation marks is akin to that of graphically superimposed bold or italic typeforms. Similarly, standalone question marks and/or exclamation marks may be used to convey surprise or incredulity, much like uppercase typeforms are used to convey heightened emotions. In short, peripheral semantic and phonological information across Braille and inkprint WSs may be encoded as dedicated standalone graphs or as typographical variants of existing graphs. Each manifestation has advantages that influence its adoption and use. Uppercase, bold and italicized type-

forms are visually conspicuous but cause inventorial bloat, as equivalent typeforms must be designed for every lowercase graph in the script. In contrast, quotation and punctuation marks may be visually understated, but prove inventorially economical. Considering the inventorial constraints on Braille-based WSs and the exigencies of touch-reading, it is unsurprising that standalone graphs are the preferred method of conveying paralinguistic information in Braille text.

5. Contractions

A corollary of indicating linguistic and paralinguistic information through standalone graphs is a concomitant increase in text length, which may potentially increase writing effort and slow down reading (Englebretson, Holbrook, and Fischer-Baum, 2023, p. 406; Fischer-Baum and Englebretson, 2016, p. 163). Previously, it also meant increased costs of publishing and disseminating hard copy, potentially impacting the affordability of Braille publications. To mitigate these issues, Braille user communities or graphospheres (Franklin, 2011; Iyengar, in press, Chapter 2) may devise shorthand methods of representing certain sound and letter sequences, along with abbreviated forms of commonly occurring words. A shorthand or abbreviated form is known as a **CONTRACTION**. A standardized set of permissible contractions and spelling rules is termed a **GRADE**. ‘Full’ or uncontracted spelling is customarily labelled Grade 1 and its contracted counterpart Grade 2 (*ibid.*, Chapter 11). Both grades may be taught to school-age and adult learners as standard components of Braille literacy curricula. Certain graphospheres may employ multiple grades with increasing levels of contracted spelling (Mackenzie, 1954, Chapter 8). As evident, the higher the grade, the greater the literacy skills required to decipher it. Thus, a Braille text intended for beginner readers might feature uncontracted Grade 1 spelling, whereas material for fluent readers might be in Grade 2 (or Grade 3 where applicable) (Englebretson, Holbrook, and Fischer-Baum, 2023, pp. 406–407; Perkins et al., 2013, p. 46).

5.1. Grades as Orthographies

In Section 4.1, *en-Brai-GB*, *en-Brai-US* and *en-Brai-x-ueb* were described as having mutually differing written conventions, and were labelled orthographies of English-in-Braille. The ‘written conventions’ in question also encompass contraction rules, which suggests that the various grades of a Braille-based WSs constitute distinct orthographies within that system. The graphematic categorization of grades as orthographies is consistent with the portrayal of contractions in Englebretson, Holbrook,

and Fischer-Baum (ibid., pp. 406–407) under the heading “Braille orthography”. Deploying contractions as standard practice has normalized their presence in Braille text. While debate may exist on granular aspects of contractions, the practice of using contractions in Braille-based WSs is commonplace and, consequently, uncontroversial. The sociolinguistic legitimacy of abbreviated forms in Braille text stands in stark contrast to corresponding situations in inkprint contexts, where adhering to standardized uncontracted spellings is typically the unquestioned norm. Compared to Braille text, standardized abbreviations in inkprint text are far fewer in number and typically restricted to specific domains or contexts, such as personal or professional titles like <Mrs.> or <Dr.>. In general, sighted readers of inkprint text would be less tolerant of abbreviations in running text than BVI users of Braille text would. The former would tend to view contracting or truncating as unacceptable or shoddy practice. The sociolinguistic disdain for abbreviated writing may spill over onto the author of such text, leading to negative assumptions about the writer’s skill, educational background or moral character. Indulgence in such gratuitous assumptions betrays the comparative facility of reading and writing in uncontracted spelling for sight-readers of inkprint text, compared to touch-readers of Braille text. The relative ease of reading and writing in uncontracted spelling frees sighted users from the need to devise contracted written forms for expediency, and spares them the added pedagogical burden of learning two orthographies for the same WS. Consequently, when confronted with the task of deciphering shorthand writing, a sighted reader might subconsciously resist the cognitive load it entails, and express their displeasure in the form of *ad hominem* value judgements—say, that the writer is choosing to be lazy. For Braille users, however, laziness may not be an option. Depending on the graphosphere, not being proficient in both grades, uncontracted and contracted, would effectively amount to incomplete literacy acquisition and likely pose real-world hurdles for the Braille user in question.

5.2. Typological Categorization

The above observations on ‘full’ and contracted writing are primarily applicable to PHONOGRAPHIC writing systems or phonographies—WSs that aim for a ‘one-letter-one-sound’ representation of speech (Iyengar, 2023). Gnanadesikan (2017) dubs such systems *vowelled segmentaries*. In the literature, they are often labelled *alphabetic* (Daniels, 1996b), though alphabetic systems are better understood as a specific subtype of phonographic WSs (Bright, 1999; Gnanadesikan, 2017; Iyengar, 2023). At the other end of the typological spectrum are LOGOGRAPHIC writing systems or logographies. They embody the principle of ‘one-letter-one-word’, where an individual written graph typically maps onto a spoken word

Regardless of their nominal grain size, individual WSSs invariably feature graphs at various levels of granularity, spanning the typological spectrum from phonographic to logographic. Thus, en-Latn canonically comprises phonograms like <n> that stand for a single speech sound, but also features logograms like the ampersand symbol <&>, denoting an entire spoken word or morpheme. The logographic form <&> co-exists with the phonographic form <and>, with the two constituting distinct written representations of the same spoken entity. Likewise, en-Brai primarily comprises phonograms like <𐤁 /n/ but also features logograms like the ampersand <𐤁𐤁>, equivalent to en-Latn <&>.⁷ The graph <𐤁𐤁> is the logographic counterpart to the phonographic form <𐤁𐤁𐤁> corresponding to en-Latn <and>. In addition, the vast majority of WSSs, whether tactile or visual, comprise a set of digits or numerals that serve as logograms for ‘number words’ in the corresponding spoken language (ibid., Chapter 2). Thus, en-Latn <5> and <five> are logographic and phonographic representations, respectively, of the English word pronounced /faɪv/, as are en-Brai <𐤁𐤁𐤁> and <𐤁𐤁𐤁𐤁>.⁸ Hence, en-Latn and en-Brai are both predominantly phonographic WSSs with a notable subset of logograms. Needless to say, their manifestation in inkprint or tactile format is irrelevant to their typological classification, and to their status as full-fledged standalone writing systems.

Despite their systemic equivalence, en-Brai differs from en-Latn in its range and applicability of contracted forms. Besides the ampersand symbol $\langle \text{⌘} \rangle$, the Grade 2 orthography of en-Brai also licenses $\langle \text{⌘} \rangle$ as a contracted alternative to the sequence $\langle \text{⌘} \text{⌘} \rangle$. Whereas $\langle \text{⌘} \rangle$ denotes the English word pronounced /ænd/, $\langle \text{⌘} \rangle$ is a purely graphical substitute for the written sequence $\langle \text{⌘} \text{⌘} \rangle$ wherever it may occur.

8. While the written forms <5> and <𐌺𐌹> are indubitably logographic, the forms <five> and <𐌺𐌹𐌺𐌹𐌺𐌹> feature a blend of phonographic and logographic (= morphographic) elements. In simple terms, the pronunciation of these graph sequences is not simply the ‘sum’ of the pronunciations of individual graphs therein (see Fischer-Baum and Englebretson, 2016). However, there is as yet no reliable or widely accepted method for measuring the relative proportion of phonography and logography within a given WS.

(ta-Taml) are typological category-mates with the abugidic Hindi-in-Braille (hi-Brai) and Tamil-in-Braille (ta-Brai) (Iyengar, 2023).

Notwithstanding these examples, there exist numerous instances of Braille-based WSs diverging from their inkprint parallels. For all its congruence with cmn-Bopo, the semisyllabic cmn-Brai remains typologically distinct from its other homoglottal systems—namely the archetypally logographic Mandarin-in-Han characters and the phonographic Mandarin-in-Latin (§4.3). Whereas hi-Brai and ta-Brai share abugidic properties with hi-Deva and ta-Taml, the pairs also differ in noteworthy ways. Among these abugidic WSs, the inkprint ones also qualify as alphasyllabic thanks to their use of bound vowel graphs in specific environments. In contrast, the Braille-based abugidas employ free vowel graphs in all contexts and, therefore, count as alphabetic. For a detailed analysis, consolidation and taxonomy of abugidic, alphasyllabic and alphabetic WSs, including Braille-based systems, see Iyengar (*ibid.*).

The list of Braille-based WSs notable for their typological features is by no means restricted to the above examples. Indeed, a cursory overview reveals the potential they hold for advancing our awareness of graphematic possibilities. The aforementioned six-dot *tenji* variant of Japanese-in-Braille (ja-Brai-x-tenji; §4.2) appears to be a syllabary at first glance, much like its kana-based inkprint parallels. However, a closer investigation reveals that specific dots within an individual Braille cell are earmarked for vowel and consonant sounds. Dots 1, 2 and 4 in ja-Brai-x-tenji are almost exclusively used to denote vowel sounds, whereas Dots 3, 5 and 6 are typically used for consonant sounds. A comparison of consonant-vowel graphs and vowel-only graphs in ja-Brai-x-tenji is shown in (3).

(3)

[ka]	[ki]	[ku]	[ke]	[ko]
⠠	⠠	⠠	⠠	⠠
[a]	[i]	[u]	[e]	[o]
⠠	⠠	⠠	⠠	⠠

Englebretson, Holbrook, and Fischer-Baum (2023, p. 405) categorize ja-Brai as an abugida, specifying that an individual cell typically represents a mora. While the moraic nature of an individual ja-Brai cell seems self-evident, the abugidic label is at odds with the taxonomy and characterization of abugidas of Iyengar (2023). In addition, ja-Brai's discrete representation of vowel and consonant sounds within a Braille cell, along with the ability of vowel-specific dots to occur independently of consonant-specific dots (see (3)), come across as quintessentially alphabetic properties. The *tenji* variant of Japanese-in-Braille, therefore, appears to exhibit syllabic-moraic properties at the individual graph level, while operating alphabetically at the sub-graphical level. In this regard,

ja-Brai-x-tenji may have much in common with Korean-in-Hangeul (ko-Hang). While the matter requires further scrutiny and extensive examination that is beyond the scope of this paper, it is no doubt a worthwhile and promising endeavor. Yet again, the value of including Braille-based WSs in grapholinguistic explorations is plainly evident.

6. Biscrptality

The preceding sections have revealed the overwhelming evidence that exists in favour of Braille as a full-fledged script in every sense of the term. By extension, transcriptions of spoken human languages in Braille are essentially writing systems, equivalent and comparable to any inkprint WS. In addition to their role in expanding graphematic horizons, the Braille script and its associated WSs also contribute towards refining prevailing sociolinguistic concepts.

As alluded to in Section 2, Braille has been used to graphize between 100 and 130 languages globally, including nearly every major global language (Perkins et al., 2013; ScriptSource, 2025). Notably, every language graphized in Braille also has an inkprint form. There appears to be no evidence of a human language that has only ever been transcribed in Braille but never in an inkprint script. As a result, every language with a Braille-based WS emerges as BISCRIPITAL (Bunčić, 2016b). It follows that over a hundred languages worldwide, including the major ones, are biscriptal in an inkprint script and in Braille (see for example Figure 2). This reality puts paid to the stereotype that biscriptality—namely a language being contemporaneously written down in more than one script, orthography or typographic style (*ibid.*, p. 51)—is somehow unusual or anomalous. If anything, the existence of Braille-based WSs demonstrate the ubiquity of biscriptality, and should prompt a thorough revisiting and reshaping of the prevalent narrative around this sociolinguistic phenomenon.¹⁰

Along similar lines, the existence of distinct regional orthographies and contraction grades within a given Braille-based WS (§4.1 & 4.2) affirms the concepts of orthographic pluricentricity and biorthographism (*ibid.*, p. 67), wherein specific WS-internal orthographies may be adopted based on user group or context.

10. The fact that every major world language is effectively biscriptal ironically renders the phenomenon of biscriptality rather unremarkable. In a foundational work on the phenomenon, Bunčić, Lippert, and Rabus (2016, p. 51) tacitly alludes to the ‘mundanifying’ effect of Braille in labelling it a “script” that is also “too universal” for a focused sociolinguistic analysis of biscriptality. Consequently, Bunčić restricts his analysis to inkprint scripts, while acknowledging Braille as a “special-purpose” tactile script.



(fr-Brai-FR) and German-Braille as used in Germany (de-Brai-DE). The coupling of the script subtag Brai with various language and country subtags further validate Braille's role as a script for a host of world languages, and affirm the existence of country-specific orthographies within Braille-based WSs. Aside from their graphematic significance, these findings prompt some pertinent sociolinguistic questions.

Based on the prevalent—if mistaken—normalization of monoscriptality, governments around the world rarely recognize multiple scripts for a particular language at the official level. Considering that nearly every major language in the world is biscriptal in an inkprint script and in Braille, is there an argument for governments worldwide to formally recognize the Braille-based WSs of their official languages, alongside inkprint WSs? Can the government of a region or nation-state legitimately withhold official recognition from the Braille manifestations of its official languages and still remain compliant with applicable laws? Are there tenable arguments against according official recognition to a language written in Braille while justifying similar recognition to the same language written in an inkprint script? Individualized and comparative evaluations on these matters would prove immensely revealing from a sociolegal perspective. But even in the absence of these insights, it is quite obvious that global legal recognition for Braille-based WSs trails that of signed languages. Whereas a handful of governments like those of New Zealand and Zimbabwe officially recognize signed languages on par with certain spoken languages in their respective territories (Constitution of Zimbabwe, Section 6; New Zealand Sign Language Act, 2006), evidence is scant for governmental recognition of a Braille-based WS on par with inkprint ones. The inconsistency in legal recognition for the signed and tactile-graphical modes of human language aligns with observations of Klein and Spitzmüller (2022) on how society perceives the two modes (§1).

The lack of legal recognition for Braille-based WSs is especially palpable in the European context. As a script created in Europe, Braille is arguably on an equal footing with the Latin, Greek and Cyrillic scripts. More importantly, while most European languages today are typically written in only one of the three aforementioned inkprint scripts, every one of these languages is biscriptally written in Braille. As the only script common to all European languages, the sociolegal inconspicuousness of Braille compared to its inkprint counterparts is striking. For instance, the absence of the Braille-script text <€> from euro currency notes (Figure 2) contrasts with the planned and systematic inclusion of the Cyrillic-script text <EBPO> following the entry of Bulgaria as a European Union (EU) member in 2007 (European Central Bank, 2025a).



FIG. 3. Section of 5 euro banknote (2013 series) featuring Latn <EURO>, Grek <ΕΥΡΩ> and Cyril <ЕВРО>. Source: Wikimedia Commons. Copyright European Central Bank (ECB). Used under decisions ECB/2003/4 and ECB/2003/5

To be clear, the question is not about tactile or related accessibility features on euro banknotes for the benefit of BVI users.¹¹ Rather, the question is of recognizing Braille as a script capable of representing languages in writing, on par with any inkprint script. Considering how contentious issues of language and script recognition can be for sighted users, the information void on the sociolegal status of Braille and the opinions of lay and expert BVI users on these matters is telling. This is the case not just in the EU but across the world.

The year 2025 marks the bicentennial of Louis Braille's prototype of his tactile symbol inventory (§2). As such, it is an apt occasion for Blind and sighted researchers alike to renew our focus on the remarkable script that bears Braille's name, and work together to harness its full potential within grapholinguistics and beyond.

8. Acknowledgements

I thank Yannis Haralambous and Sveva Elti di Rodeano for the opportunity to present this work in its initial form at the /gɾafematik/ 2024 conference, and the three anonymous reviewers of my submission for their feedback. I'm also grateful to Jodie Lea Martire for some enlightening discussions on Braille's role within the Australian BVI community and the diversity of opinion among its users. Special thanks go out to my linguistics student Heidi Lewington-Arblaster for her invaluable in-

11. The European Central Bank's website states that it has regularly consulted with the European Blind Union on euro banknote design since the 1990s (European Central Bank, 2025b).

sights from a Braille user's perspective, all provided with her characteristic patience and goodwill.

References

- American Foundation for the Blind (2024a). *Books in Braille*. URL: web.archive.org/https://www.afb.org/about-afb/history/online-museums/life-and-legacy-louis-braille/braille-nvents-his-code/books.
- (2024b). *Louis becomes a teacher*. URL: web.archive.org/https://www.afb.org/about-afb/history/online-museums/life-and-legacy-louis-braille/braille-nvents-his-code/teacher.
- Australian Braille Authority (2024a). *International Braille Honour Roll*. URL: web.archive.org/https://brailleaustralia.org/about-braille/international-honour/.
- (2024b). *Unified English Braille*. URL: <https://brailleaustralia.org/unified-english-braille/>.
- Barbier, Charles (1809). *Principes d'Expéditive française pour écrire aussi vite que la parole [Principles of French shorthand for writing as quickly as speaking]*. 2nd ed. Paris. URL: https://books.google.com/books?id=FgVJ55_veyWC.
- (1815). *Essai sur divers procédés d'expéditive française [Essay on various French shorthand techniques]*. Paris. URL: <https://books.google.com/books?id=lkVzrU1RvEC>.
- Bauer, Thomas (1996). "Arabic writing". In: *The World's Writing Systems*. New York: Oxford University Press, pp. 559–564.
- Bogart, Darleen and Alan J. Koenig (2005). "Selected Findings from the First International Evaluation of the Proposed Unified English Braille Code". In: 99.4. URL: <https://files.eric.ed.gov/fulltext/EJ683581.pdf>.
- Braille, Louis (1829). *Procédé pour écrire les paroles, la musique et le plain-chant au moyen de points [Procedure for writing words, music and plain-song using dots]*. Paris. URL: <https://archive.org/details/procdpourcirele00loui/>.
- Bright, William (1999). "A matter of typology: Alphasyllabaries and abugidas". In: *Written Language & Literacy* 2.1, pp. 45–55. DOI: 10.1075/wll.2.1.03bri.
- Bunčić, Daniel (2016a). "A heuristic model for typology". In: *Biscriptality: A sociolinguistic typology*. Heidelberg: Universitätsverlag Winter, pp. 51–72.
- (2016b). "Other cases of digraphia". In: *Biscriptality: A sociolinguistic typology*. Heidelberg: Universitätsverlag Winter, pp. 96–101.
- Bunčić, Daniel, Sandra L. Lippert, and Achim Rabus, eds. (2016). *Biscriptality: A sociolinguistic typology*. Heidelberg: Universitätsverlag Winter.
- Campsie, Philippa (2021). "Charles Barbier: A hidden story". In: *Disability Studies Quarterly* 41.2. DOI: 10.18061/dsq.v41i2.7499. URL: web.archive.org/https://dsq-sds.org/index.php/dsq/article/view/7499/5947.

- Cranmer, Tim V. and Abraham Nemeth (1991). *A uniform Braille code*. URL: <https://iceb.org/cranem.html>.
- Daniels, Peter T. (1996a). "Analog and digital writing". In: *The world's writing systems*. Ed. by Peter T. Daniels and William Bright. New York: Oxford University Press, pp. 883–892.
- (1996b). "Shorthand". In: *The world's writing systems*. Ed. by Peter T. Daniels and William Bright. New York: Oxford University Press, pp. 807–820.
- Daniels, Peter T. and William Bright (1996). "Abbreviations, conventions, and definitions". In: *The world's writing systems*. Ed. by Peter T. Daniels and William Bright. New York: Oxford University Press, pp. xxxix–xlv.
- Dasgupta, Kalyan (2002). "Brailled Kanji: The Hasegawa approach". In: *Journal of Visual Impairment & Blindness* 96.10, pp. 743–746. DOI: 10.1177/0145482X0209601007.
- Dixon, Judy (2007). *Eight-dot Braille*. URL: <https://www.brailleauthority.org/eightdot/eightdot.html>.
- eBraille Working Group (2025). *eBraille 1.0*. URL: <https://daisy.github.io/ebraille/published/1.0/CR-ebraille-20250303/#dc:language>.
- Englebretson, Robert, ed. (2008). *IPA Braille: An updated tactile representation of the International Phonetic Alphabet*. URL: https://www.iceb.org/IPA-braille_print-ed_final.pdf.
- (2009). "An overview of IPA Braille: An updated tactile representation of the International Phonetic Alphabet". In: *Journal of the International Phonetic Association* 39, pp. 67–86. DOI: 10.1017/S0025100308003691.
- Englebretson, Robert, M. Cay Holbrook, and Simon Fischer-Baum (2023). "A position paper on researching braille in the cognitive sciences: decentering the sighted norm". In: *Applied Psycholinguistics* 44, pp. 400–415. DOI: 10.1017/S0142716423000061.
- European Central Bank (2025a). *Current banknotes > Denominations*. URL: <https://www.ecb.europa.eu/euro/banknotes/current/denominations/html/index.en.html#es2-100>.
- (2025b). *The euro > Visually impaired people*. URL: <https://www.ecb.europa.eu/euro/visually/html/index.en.html>.
- Fetnaci, Naval, Yannis Haralambous, and Marie Varin (2022). *On Arabic braille*. Conference poster. Paris. URL: <http://www.fluxus-editions.fr/grafematik2022-files/FETNACI-poster.pdf>.
- Fischer-Baum, Simon and Robert Englebretson (2016). "Orthographic units in the absence of visual processing: Evidence from sublexical structure in braille". In: *Cognition* 153, pp. 161–174. DOI: 10.1016/j.cognition.2016.03.021.
- Franklin, Simon (2011). "Mapping the graphosphere: Cultures of writing in early 19th-century Russia (and before)". In: *Kritika: Explorations in*

- Russian and Eurasian History* 12, pp. 531–560. DOI: 10.1353/kri.2011.0036.
- Gelb, Ignace J. (1963). *A study of writing*. 2nd ed. Chicago: University of Chicago Press.
- Gnanadesikan, Amalia E. (2009). *The writing revolution: Cuneiform to the internet*. Malden, MA: Wiley-Blackwell.
- (2017). “Towards a typology of phonemic scripts”. In: *Writing Systems Research* 9.1, pp. 14–35. DOI: 10.1080/17586801.2017.1308239. URL: <http://dx.doi.org/10.1080/17586801.2017.1308239>.
- Hodge, Gabrielle and Della Goswell (2023). “Deaf signing diversity and signed language translations”. In: *Applied Linguistics Review* 14.5, pp. 1045–1083. DOI: 10.1515/applirev-2020-0034.
- Honda, Keisuke (2021). “A modular theoretic approach to the Japanese writing system: Possibilities and challenges”. In: *Grapholinguistics in the 21st Century 2020. Proceedings*. Ed. by Yannis Haralambous. Grapholinguistics and Its Applications, Vol. 5. Brest: Fluxus Editions, pp. 621–643. DOI: 10.36824/2020-graf-hond.
- Hoskin, Elizabeth R. et al. (2024). “Effectiveness of technology for braille literacy education for children: a systematic review”. In: *Disability and rehabilitation: Assistive technology* 19.1, pp. 120–130. DOI: 10.1080/17483107.2022.2070676.
- IIT Madras (2020). *Introduction to Bharati Braille*. URL: https://web.archive.org/web/20200727032543/http://www.acharya.gen.in:8080/disabilities/bh_brl.php.
- International Council on English Braille (2012). *Unified English Braille Code (UEBC) Research Project*. URL: <https://iceb.org/UEB-history.html>.
- Internet Assigned Numbers Authority (2025). *Language Subtag Registry*. URL: <https://www.iana.org/assignments/language-subtag-registry/language-subtag-registry>.
- Iyengar, Arvind V. (2023). “More matters of typology: Alphasyllabaries, abugidas and related vowelised segmentaries”. In: *Written Language & Literacy* 26.1, pp. 30–56. DOI: 10.1075/wll.00072.iye.
- (2024). “The akshara as a graphematic unit”. In: *Grapholinguistics in the 21st Century 2022. Proceedings*. Grapholinguistics and Its Applications, Vol. 10. Brest: Fluxus Editions, pp. 419–436. DOI: 10.36824/2022-graf-iyen.
- (in press). *Writing systems of Sindhi: Scripts, orthographies, sociolinguistics*. Ed. by Yannis Haralambous. Grapholinguistics and Its Applications. Brest: Fluxus Editions. In press.
- Joyce, Terry and Hisashi Masuda (2019). “On the notions of graphematic representation and orthography from the perspective of the Japanese writing system”. In: *Written Language & Literacy* 22.2, pp. 247–279. DOI: 10.1075/wll.00028.joy.

- Kaye, Alan S. (1996). "Adaptations of Arabic script". In: *The world's writing systems*. Ed. by Peter T. Daniels and William Bright. New York: Oxford University Press, pp. 743–762.
- Kearney, Tamara Johnson (2012). *Inuktitut syllabary Braille code*. URL: <https://web.archive.org/http://cibtbc.org/braille/inuktitut/>.
- (2014). *Cherokee syllabary Braille code*. URL: <https://web.archive.org/http://cibtbc.org/braille/cherokee/>.
- (2019). *Klingon Braille code*. URL: <https://web.archive.org/http://cibtbc.org/braille/klingon/>.
- Klein, David and Jürgen Spitzmüller (2022). *Blind spots: On the discursive (in-)visibility of Braille as opposed to sign language*. Conference presentation. Paris. URL: <https://youtu.be/bd3aD2juNoQ>.
- Mackenzie, Clutha Nantes (1954). *World Braille Usage: A survey of efforts towards uniformity of Braille notation*. 1st ed. Paris: UNESCO.
- Martiniello, Natalina and Walter Wittich (2022). "The association between tactile, motor and cognitive capacities and braille reading performance: a scoping review of primary evidence to advance research on braille and aging". In: *Disability and rehabilitation* 44.11, pp. 2515–2536. DOI: 10.1080/09638288.2020.1839972.
- Meletis, Dimitrios (2020). *The nature of writing: A theory of grapholinguistics*. Grapholinguistics and Its Applications, Vol. 3. Brest: Fluxus Editions. URL: <http://www.fluxus-editions.fr/meletis-the-nature-of-writing-2020.pdf>.
- Mellor, C. Michael (2006). *Louis Braille: A touch of genius*. Boston: National Braille Press. URL: <https://tinyurl.com/4aw69drr>.
- Nagoya Braille Network (2006). 漢点字入門 [*Introduction to Kantenji*]. URL: <https://tinyurl.com/4rcy336b>.
- National Federation of the Blind (n.d.). *The first publication of the Braille code*. URL: <https://tinyurl.com/yut569ab>.
- Neef, Martin (2015). "Writing systems as modular objects: Proposals for theory design in grapholinguistics". In: *Open Linguistics* 1.1, pp. 708–721. DOI: 10.1515/opli-2015-0026.
- Nemeth, Abraham (1973). *The Nemeth Braille code for mathematics and science notation: 1972 revision*. Tech. rep. Louisville, Kentucky: Adopted January 20, 1972 by the AAWB-AEVH-NBA Advisory council to the Braille Authority. URL: <https://archive.org/details/nemethbraillecod00comp/>.
- New Zealand Sign Language Act* (2006). URL: <https://www.legislation.govt.nz/act/public/2006/0018/latest/versions.aspx>.
- Perkins, International Council on English Braille, and National Library Service (2013). *World Braille Usage*. 3rd ed. Washington, D.C.: UNESCO.
- Phillips, Addison and Mark Baker (2009). *Tags for Identifying Languages*. BCP 47, RFC 5646. DOI: 10.17487/RFC5646.

- Raymond, Martin (2020). *Presenting writing system information*. URL: https://scriptsource.org/cms/scripts/page.php?item_id=entry_detail&uid=r7jbnbjkfw.
- Sampson, Geoffrey (2015). *Writing systems*. 2nd ed. Sheffield: Equinox.
- ScriptSource (2025). *Braille*. URL: <https://scriptsource.org/scr/Brai>.
- Sheffield, Rebecca M. et al. (2022). "How many braille readers? Policy, politics, and perception". In: *Journal of Visual Impairment & Blindness* 116.1, pp. 14–25. DOI: 10.1177/0145482X211071125.
- Simpson, Christine and Matthew Horspool, eds. (2024). *The rules of Unified English Braille*. 3rd ed. International Council on English Braille. URL: <https://iceb.org/Rules%20of%20Unified%20English%20Braille%202024.pdf>.
- Tomic, Nenad (2025). *Deux siècles de braille, une écriture universelle en relief pour les non-voyants et malvoyants [Two centuries of Braille, a universal system of embossed writing for BVI people]*. URL: <https://www.rfi.fr/fr/connaissances/20250117-deux-si%C3%A8cles-de-braille-une-%C3%A9criture-universelle-en-relief-pour-les-non-voyants-et-malvoyants>.
- Weingarten, Rüdiger (2013). "Comparative graphematics". In: *Typology of writing systems*. Ed. by Susanne R. Borgwaldt and Terry Joyce. Amsterdam: John Benjamins, pp. 13–39.

AZVD as a Sign Language Writing System Proxy, and the Potential Evolution

Michael Filhol

Abstract. This paper presents AZVD, a proposed graphical form of Sign Language representation. It explains the method used to design it, and its goals of adoptability and synthesizability. The system is built on two prior foundations: a study of the regularities observed in spontaneous diagrams produced by signers, and the formal representation model AZee. Since AZVD can be scripted, whether through pen and paper or through recently developed editing software, and read non ambiguously to the point of being synthesisable by avatar, we submit it can serve as a proxy for writing, and give potential evolution points that would make it an even better substitute for the currently lacking Sign Language writing system.

1. Introduction

Written languages are generally easy to equip with software editors, and often other processing tools consequently. It is however not the case for Sign languages (SLs), which have no written form. Video is sometimes used as a substitute, but with multiple drawbacks: its relative size makes storage a problem, editing is not possible with mouse and keyboard, indexing and querying is not possible with the current state of technology... Video in fact better compares to audio recording than it does to written text, because it is tied to the real time of its contents, whereas scriptural notations allow independent timing for writing and reading. Worse even, anonymity is not possible, which has considerable consequences on the circulation of information and perception of ideas, e.g., on the internet. Written ideas can emancipate.

In the absence of a written standard, this work focuses on graphical representation for SL—in this instance French Sign Language (LSF)—allowing implementation in editing software environments. We first present systems designed for SLs, and contrast them with a non-systematic yet actual practice of spontaneous diagramming. We then

Michael Filhol  0000-0002-3389-0412
LISN, CNRS, Université Paris-Saclay, Paris, France
E-mail: michael.filhol@cnrs.fr

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 689–708. <https://doi.org/10.36824/2024-graf-filh>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1



FIG. 1. Graphical representations systems designed for SL

present the AZVD graphical proposal, which bridges the regularities of the diagrams and a formal representation model for SL statements, insisting on the method used to build it and its goals of maximising adoptability and synthesiability. Final sections address the potential evolution of the system, both in terms of engaging the community to conventionalise appropriate graphics and to facilitate using it as a writing system proxy.

2. SL Representation, Systematic or Spontaneous

A few representation systems have been proposed for SL, with varying objectives. Some of them were intended more as notation systems for theoretical description of signed forms, in other words more destined for use in linguistics, for example the early Stokoe notation (Stokoe, Castlerline, and Croneberg, 1965). Others were designed with language users in mind, sometimes with claims of qualifying as a writing system, e.g., SignWriting (Sutton, 2014). Some were used in, if not tailored for, more or less specific software applications. For example, HamNoSys (Hanke, 2004; Prillwitz et al., 1989) was used as the primary input encoding for the JASigning avatar (Ebling and Glauert, 2013). Figure 1 gives an example of each system mentioned above.

They exhibit differences in their appearance, their minimal graphical units and the way in which they combine. But all of them invariably break down the signed production in a sequence of units (“signs”) analogous to that of words in a sentence. Incidentally, each of these units is itself invariably represented through “manual parameters” (Stokoe, 1960), accompanied in some cases by non-manual features.

All of those scripts are designed *systems*, i.e., envisioned as consistent sets of rules ensuring that identical scripted productions yield identical representations and vice-versa. This means that scripted representations determine the signed forms to articulate to restore the corresponding signed production. This is an expected property to qualify as a writing system, true for every one adopted for non-signed languages.

However, none of the above systems can be considered adopted and practised by wide communities of users, despite in some cases, notable

fore being discarded. Consequently, reading here is not deterministic: they do not determine the forms to articulate in a systematic way. It is therefore difficult to develop software assistance for VD, and impossible to automatically generate (synthesise) the represented signed contents with an avatar.

However, regularities have been observed in spontaneous VD instances, both across VDs from the same author and between VDs of different authors. This was published after the collection and study of a first VD corpus (Filhol, 2020b). For example, there is a clear tendency for VD symbols and layouts to represent the *meaning* to interpret from them, over the *form* to articulate to read them out. For example to denote the sun, all VDs draw a pictogram (see figure 3), except when the French word “soleil” was occasionally used instead (which still does not capture the signed form). None of them contain any reference to the position (near the temple) or shape (5 fingers spread and bent to depict a half-sphere) required of the active hand in the sign meaning “sun”.

It is yet to note that, although in a minor proportion, articulated form still happens to be favoured consistently in some rarer cases. We also highlight that the meaning vs. form, while viewed as a major division in writing systems (logo-/morphography vs. phonography), can sometimes be less of a dichotomy in the case of SL. SLs are indeed known to make a ubiquitous use of iconicity, i.e., produce forms that resemble what they mean. For example, one might place objects near each other in the signing space (form) to express (mean) that they are spatially close. The graphical choice of drawing two symbols near each other then captures both facets without being objectively separable. But the disproportion outside of such cases is strong enough to establish a clear preference to capturing meaning instead of form, without ever being total.

This much contrasts with the systems proposed for SL representation up to this day, which all follow a fully phonographic design. On the contrary, a strongly imbalanced mix of phonographic and logographic features is essentially the norm in established writing systems, which coincides with VD observations. We therefore hypothesise that the exclusively phonographic design is a factor in the lack of adoption of prior SL representation systems, and that a mostly logographic system would make a better candidate for adoption.

Also found in the collected VDs are a number of recurring graphical choices, carrying an identifiable meaning and often signed in the same way, to the point where we can speak of an “associated reading”. These are sometimes conventional pictograms or icons/symbols representing fixed signs, like the examples shown in figure 3.

In other cases, they are more complex layouts, combining several parts of the drawing. For example, an equal sign (“=”) separating a left part *L* from a right part *R* generally means that *R* provides information

Observed VD symbols	Consistent form	Associated meaning
		sun

FIG. 3. Examples of spontaneous graphical representations



FIG. 4. Excerpts from VD containing an “equal” sign

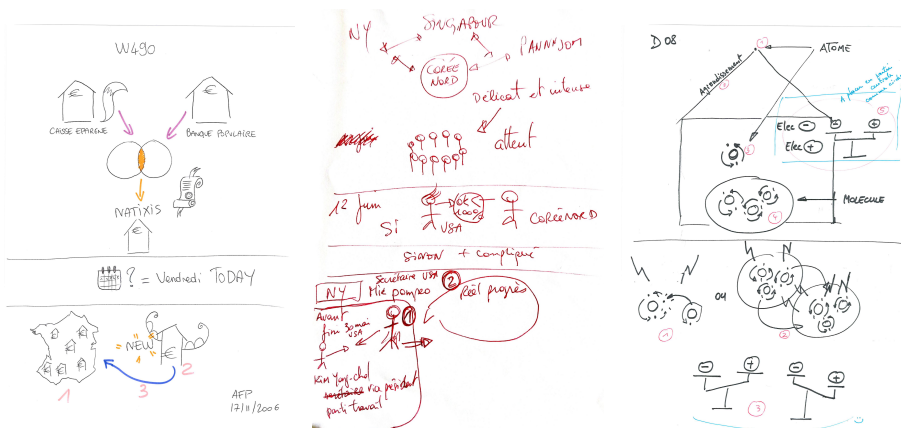


FIG. 5. VD pages with context bars

about L . Collected excerpts are shown in figure 4, and their interpretations in context are:

1. Fidel Castro's health is good.
2. The lion is kind.
3. What is cancer? ("Cancer is what?")

Another example is a straight bar separating a top part T from a bottom part B is always interpreted as providing a context T for B . This includes cases of temporal sequences, where B essentially occurs in the context of T having ended before B . Examples are given in figure 5.



FIG. 6. Excerpts of VD containing “lightning” symbols

Third example, the separation of two entities by a lightning bolt to express opposition between them, signed by placing each on either side of the signing space. Examples are shown in figure 6.

Clearly, regularities emerge despite the absence of an a priori system. As a practice adopted by some, and by nature suited for SL but evolving outside any system, VD appears as an intermediary between:

- regular systems adopted but not for SL, e.g., written German;
- and regular systems designed for SL but not adopted, e.g., SignWriting.

By positioning them this way, a path appeared to create a system that is both regular, adapted to SL, and adoptable by signers: standardising VD into a system.

3. Standardisation of VD

For us, standardising VD meant creating a regular and consistent graphical system, of which each instance determines its reading unambiguously. And a good test of this ability is whether generating a video, for example rendered through a signing avatar, is possible automatically from any input.

The problem is that each constraint applied to VD to increase its regularity may come with a loss of adaptability. Indeed, the current practice likely depends partly on the freedom felt by the authors. But the presence of spontaneous regularities already observed leads us also to suppose that such constraints are not necessarily a cause for rejection. Thus, we proposed to standardise (Filhol, 2020a) by adopting the spontaneously observed patterns in VD whenever possible. According to this proposal, the list of regular layouts presented in the previous section

should be part of the standard, each imposing an associated reading. The underlying assumption is that the more the system is inspired by familiar practices, the more adoptable it is.

That said, their number remains limited, and it is understood that if alone, this approach inevitably faces the problem of not covering the language enough by any metric. To reach coverage, the graphical system had to be complemented with additional graphics. A valuable source for this extension to the regular set could have come from research like that which examined the parallels between pedagogical/explanatory diagrams and the organisation of signing space in LSF (Guitteny, 2007). The problem is that no such study has yet claimed to cover all language phenomena, let alone be prescriptive in the sense that the reading be determined by the diagrams.

On the contrary, the formal SL discourse representation system *AZee* was designed for synthesis in the sense that it determines output SL from every input expression (Challant and Filhol, 2022; Filhol, Hadjadj, and Choisier, 2014). It also recently demonstrated a good covering capacity for LSF (Challant and Filhol, 2024). Besides, a semantic proximity was noted between several VD regularities and rules established in *AZee*, which eased bridging *AZee* and a VD-compatible set of graphics. *AZee* therefore played a central role in allowing to complement the set above for coverage. We thus provide a quick summary of *AZee*, before explaining the method followed to build AZVD.

4. *AZee*

AZee is a formal approach to representing signed utterances based on systematic correspondences between meaning (interpreted) and form (articulated) in the considered SL. Without assuming the existence or distinction of levels (morphology, lexicon, syntax...) nor any syntactic categorisation (verb, noun, adjective...), *AZee* allows to define *production rules*, each associating an identified meaning (which it is generally named after) with a specified form to express it. Rules are identified in a prior stage through a corpus search methodology (Hadjadj, Filhol, and Braffort, 2018) to ensure reproducibility and empirical validity. Thus, although the approach can in principle be applied to any SL, the set of all production rules found (namely the *production set*) is SL-dependent.

The formal specification of a production rule is done using the native *AZee* language, not detailed here. It allows to specify and synchronise the various articulations involved (finger orientations, hand position...) in a value of type SCORE, which essentially encompasses signed productions. For example, in LSF, the rule *gentil* (French for “nice, kind”) is defined as carrying the eponymous meaning and producing the fixed, conventional, stable signed form shown in figure 7.



FIG. 7. Form of gentil in LSF

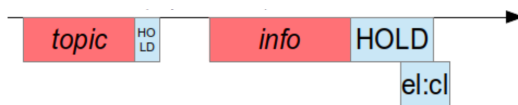
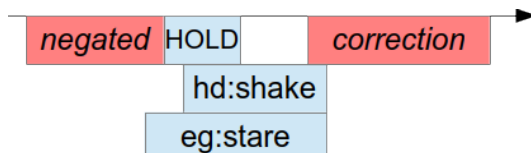
These rules can be parametrised when a variation in form is semantically interpretable. For instance, regardless of the signed production *sig*, a lip pout gesture synchronised just ahead of *sig* systematically means that *sig* is consensual, that “everybody rather agrees on/that *sig*”. This justifies the rule inter-subjectivity, with argument *sig* of type SCORE, conveying this meaning and producing the synchronised lip pout gesture. Both meaning and form jointly depend on those of *sig*.

By combining production rules, one can build *AZee discourse expressions* to represent utterances and discourses of increasing complexity. For instance, the expression below captures the constructed meaning “generally considered nice”, and mechanically (recursively) produces the appropriate signed forms.

```
:inter-subjectivity
  'sig
  :gentil
```

Similarly, *info-about(topic, info)* produces the temporal arrangement of figure 8 and means “*info*, given about *topic*”. Or, *not-but(negated, correction)* produces that of figure 9 and means “*correction*, and not *negated*”. With these rules, plus assuming the two simple eponymous rules *lion* (transparent French term) and *méchant* (French for “bad, nasty”), we can construct the expression below meaning “the lion is not bad but kind” able to generate the appropriate utterance in LSF.

```
:info-about
  'topic
  :lion
  'info
  :not-but
    'negated
    :méchant
    'correction
    :gentil
```


FIG. 8. Temporal arrangement for info-about(*topic*, *info*)FIG. 9. Temporal arrangement for not-but(*negated*, *correction*)

Thusly, increasingly elaborate discourse expressions can be constructed. An important point is that these expressions allow for an almost direct reading of the overall meaning they represent while entirely determining the output forms.

AZee has gradually developed over more than a decade and the practical work continues to refine the LSF production set by confronting it to new data, as well as theoretical studies to position and compare the approach with formal grammars proposed in the field of Sign processing or even natural language processing at large. But it has already proven effective in terms of LSF coverage, as a corpus of AZee expressions was produced covering 97% of the 1 hour total of news discourse (Challant and Filhol, 2022), namely the 120 utterances of the *40 brèves* corpus, available for download online³. What is more, the model has also proven effective in terms of avatar synthesis, as it already enabled automatic animation of the Paula avatar (McDonald et al., 2015; Wolfe, McDonald, and Schnepf, 2011), notably even for several linguistic phenomena that were previously inaccessible such as geometric constructions in continuous signing space (McDonald and Filhol, 2021).

5. AZVD

AZee is a computer-oriented approach, and is not human-friendly to parse. An AZee expression resembles more computer code than a graphically organised diagram. However, its advantage for designing a graphical representation system is two-fold:

3. <https://www.ortolang.fr/market/corpora/40-brevs>

- it is a formal, regular, and synthesisable system, which was a goal set for our graphical standard, so it was chosen to formally specify the forms to read from input graphics;
- it has demonstrated a capacity to cover LSF, precisely what seemed unattainable by building only from the VD regularities, so it was leveraged to complement the set of graphics and reach language coverage.

From this, regardless of the actual graphical choices in the beginning, the graphical system AZVD was built following the two goals below:

- every graphical icon or layout created should come with a unique AZee expression counterpart so that it is necessarily synthesisable—in formal terms, this amounts to defining a *function* from the graphical set to the set of possible AZee expressions;
- every AZee expression should be able to find at least one graphical antecedent through that function so that the graphical standard itself be as covering as AZee—in formal terms, we aimed for the function to be *surjective*.

First, consider a regular graphical icon or layout observed in VD, with an identified meaning and a determined SL output form. Assuming an effectively covering AZee production set, we can write an AZee expression, possibly parametrised by sub-elements of the drawing, which represents the SL to generate. We therefore specify a graphical *AZVD layout* identical to the VD pattern, together with an associated *AZee template*. Such a layout can use icons, specify alignment constraints or relative positions between them, as well as apply any transformation such as scaling or rotation. The AZee template can make use of elements embedded in the layout to instantiate the arguments.

The trivial case is that of the atomic symbol to which we directly associate a fixed AZee expression, with no variable arguments. For example, following the regularity presented in figure 3, we can associate the symbol “☀” with the AZee expression:

:soleil

Regularities involving variable parts can be encoded graphically with the same recursion for their content. For example, the contextualising bars observed in figure 5 suggest defining the layout in figure 10.a, containing two variable parts *ctxt* and *proc*, respectively above and below the horizontal bar, and associating it with the systematic reading provided by the template below, where the parts between brackets directly correspond to the sub-parts of the same name in the layout:

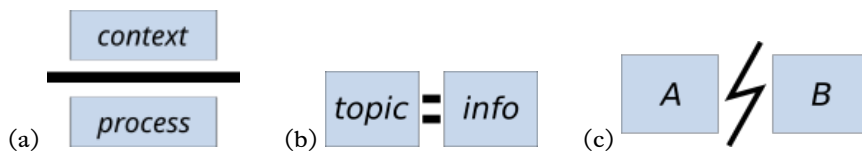


FIG. 10. AZVD layouts inspired by VD regularities

```
:context
  'ctxt
  [ctxt]
  'proc
  [proc]
```

Similarly, following the regularity shown in figure 4, the AZVD layout in figure 10.b directly corresponds to the info-about rule and its arguments *topic* and *info*.

Sometimes, more complex AZee templates are needed, but the principle remains the same. For example, the layout in figure 10.c, inspired by the regularity shown in figure 6, generates the following template, where the resulting form is the successive placement of *A* on one side and *B* on the other, with a hold and a blink of the eyes after each (this is generated by the each-of rule), a way in LSF to set up an opposition between the two:

```
:each-of
  'items
  list
    :about-point
      'pt
      ^Lssp
      'locsig
      [A]
    :about-point
      'pt
      ^Rssp
      'locsig
      [B]
```

Note that sometimes, different regular VD layouts were found to produce the same SL forms. For example, context bars were observed with either a horizontal or vertical layout. This is not a problem; several layout *variants* can be defined for a single AZee correspondence.

So far we have ensured that the spontaneously regular VD layouts were included in AZVD, with both a regular reading and a regular drawing. But as we mentioned, these alone will not be enough to constitute

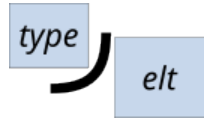


FIG. 11. Layout defined for $\text{instance-of}(\text{type}, \text{elt})$

the surjection required to cover the entire set of possible AZee expressions, as most remain without a graphical antecedent. A trivial way to ensure the surjective function objective is to increase the inventory of available layouts by creating one (at least one, as variants should also be allowed) for each production rule that does not already have a direct antecedent from the previous method. For example, the production rule *instance-of* can be assigned the layout shown in figure 11, where the parts labeled *type* and *elt* correspond to the two arguments of the rule.

In this complementing stage of the method, the layouts created are a lot more detached from anything observed in regular practices, and sometimes even just the result of arbitrary choices, which may not have as good a leverage towards ease of adoptability as the prior stage. Another problem is that the production rules that are graphically encoded may be more or less known or understood by speakers. That said, they represent empirically found operations of the language and each have an interpretable meaning. So we know that they are somehow relevant to SL structure and thought, and can hope that whether consciously or not, they are internalised by the speakers to an extent significant enough to keep the encoded concepts and relationships apprehensible.

To maximise the practical adoptability of our script, we further proposed that each layout defined also:

- be easy to remember, making it iconic of what it represents when possible;
- preferably represent meaning, unless the ease of representing meaning over simplicity/salience of form ratio is too weak—this occasional phonographic switch has indeed been observed in spontaneous practices (Filhol, 2020a);
- have at least one variant that is easy to draw with a pencil, i.e., be monochrome, and have a low number of strokes with no filled area.

Figure 12 illustrates this proposition with proposed layouts for the main AZee production rules.

These two methods jointly guarantee a surjective function onto the set of possible AZee expressions, whose domain (the set of graphical layouts and icons) is made of elements maximising their adoptability. The set of layouts thus formed, and the ability to combine them to construct arbitrarily complex planar (2D) diagrams, is what we call the “AZee verbalizing diagram” script, or *AZVD* in short. Figure 13 is an example

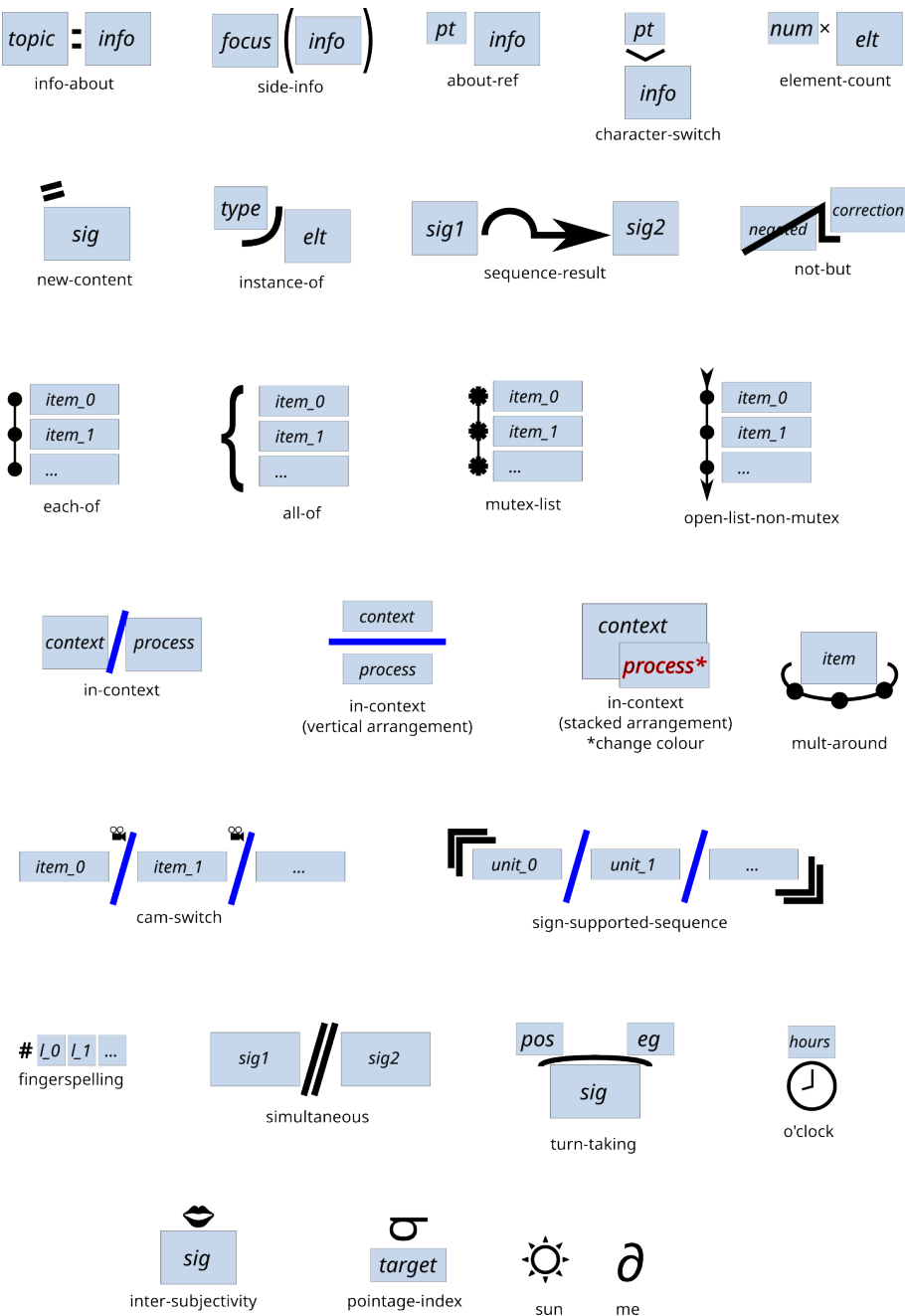


FIG. 12. AZVD layout sheet for the major AZee production rules

of a complete AZVD diagram representing the entry “2B-JP” from the *40 brèves* corpus cited earlier, whose production in LSF lasts 27 seconds.

6. Testing AZVD and Converging on Graphics

The method proposed above to build a standard graphical script is mostly built on theoretical grounds, and some of it can in principle be questioned. For example, it relies on the assumption that including spontaneous regularities is a means to maximise adoptability of the final system. Moreover, it sets an arbitrary goal of complete synthesizability, posed as a desirable feature to ensure by design. While we do hold these two features to be valuable, some empirical evidence of the advantage for users and greater adoptability of such a scheme, compared to others, is needed.

Another major, less theoretical aspect requiring engagement of the signing community is the choice of the graphical layouts themselves when no spontaneous regularity is observed. We proposed a set of icons and layouts (see figures 12 and 13), but that set is admittedly only tentative. The point was to enable first illustrations and a first implementation with usable graphics, only to kick-start the necessary debate on what would actually be preferred, this time with an actual system in the hands of the signers.

To this end, we developed an editing software program (Filhol and Ascheberg, 2024). It has so far only been tried as an AZee editor by experts of that model, and it still requires some development on icon coverage and user interface to become a fully functional AZVD environment. A demonstration video is available online⁴, including a final synthesis step but only providing a limited set of graphics.

With an editor, the natural next step is to engage signers of different profiles, whether VD users or not, in an iterative process for developing the script, to evolve it, for example by integrating new desired layouts, abandoning unnecessary variants, etc. This will have to be accompanied by workshops, and a form of assistance with graphics proposal, e.g., incorporating a community-wide upload and up-/downvoting system.

7. Further Script Design and Writing Prospects

While not designed as a writing system, AZVD is usable to render signed output through avatars from editable and lightweight graphics. It therefore allows to encode language productions in a standard 2D format and determines an LSF production for every such encoding, i.e., it is both

4. <https://zenodo.org/records/10890951>

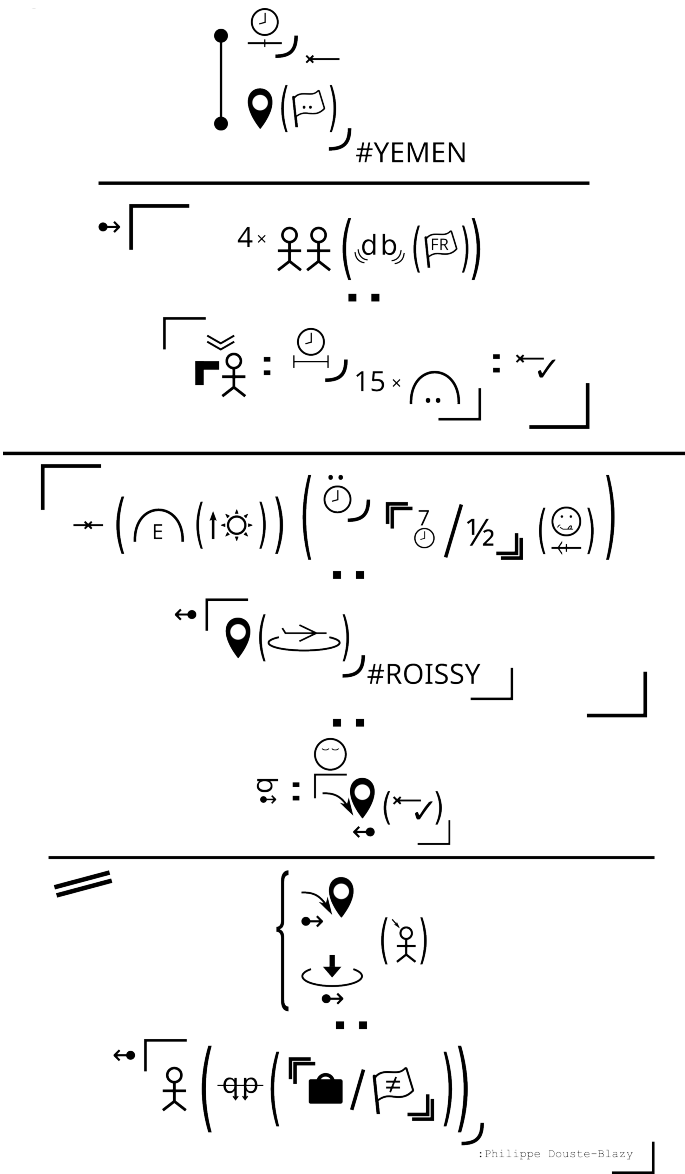


FIG. 13. AZVD for complete news item “2B-JP” of the 40 brèves

scriptable and readable. To an extent, this already makes it a possible proxy for writing LSF, and we wish to explore this opportunity.

As early as the first mention of a VD–AZee bridge (Filhol, 2020a), we discussed some of the properties that such a script would exhibit. We suggested a strong logo-/phonographic imbalance towards logography, discussed iconicity of the symbols... In the context of using AZVD as a substitute for writing, this section proposes to explore two aspects of it that likely contrast with properties of familiar language scripts, and mentions the potential avenues of evolution towards shaping into an even more appropriate system for this task.

7.1. Serialisation

In the early work cited above, we highlighted that the planar and recursive nature was radically distinct from the linearity of general writing systems, but similar to the mathematical script so not entirely outside of the realm of scripting. Also, this composition is frequent in VD, so it does not inherently impede the adoptability of the script.

But as the discourse grows, the AZVD diagram representing it is bound to extend over an arbitrarily large surface by recursively nesting the layouts that make it up. Scripting long discourses therefore presents a practical problem. Given the necessary limits posed by any supporting medium (screen or paper), some serialisation is required.

An interesting example of application for the script, well suited to address this issue, is video subtitling. Written subtitles break the text into units of limited duration, and their display time is determined by the real time of the corresponding video content. Similarly, a large AZVD instance could be broken into smaller units, each displayed separately in sequence, in an order imposed by the video.

After initial tests inspired by pauses between units of traditional written subtitles, our conjecture is that a most natural segmentation falls within the time interval separating the *context* and *process* of an in-context rule. Applied to figure 13, this would break the diagram at the horizontal bars into four smaller pieces, say A through D from the top down. A side effect is that we also lose the information on the hierarchy between them, namely the original $((A, B), (C, D))$ structure, as opposed to $((A, (B, C)), D)$ for example.

The question is whether it is acceptable to loose this information on the original discourse structure. A favourable case could be made here since the form of in-context is almost just about concatenating with a given separation time, thus the resulting forms are close enough regardless of the nesting structure, and the meaning seems mostly possible to infer from the context.

That said, it is possible that some applications of in-context will not lend themselves to splitting their content into two successive diagrams, for example when they are nested in certain rules that require a simultaneous view of their arguments. It also raises the converse question of whether the chunks after splitting are always of acceptable size as units of our sequence, or if they may require breaking down further.

More research is needed to answer those questions, but the prospect of linearizing the script to make it usable on long discourses while remaining readable and interpretable is very motivating. In a long term, striking this balance can bring a serialised AZVD quite close to a candidate writing system for LSF.

7.2. From Surjection to Injection

In this work, we built AZVD as a surjective function to ensure no loss in the coverage offered by AZee expressions. That said, it is entirely possible that this set is oversized, and that not all theoretically possible AZee expressions are necessary to cover LSF. Research on the constraints that apply to AZee expressions, and on the definition of formal grammars for LSF based on those constraints, is currently under way.

But unless we want to hypothesise LSF might escape any kind of grammatical constraint, it must be considered likely that certain AZee expressions are unacceptable. For example, certain rules might never apply outside of specific expression patterns. In such cases, it could be justified to leave the unattested AZee combinations without a possible graphical antecedent, in other words abandon the surjective property of AZVD (onto AZee), which was initially set as a methodological goal.

Conversely, we can note that the function was not constructed to be an injection, i.e., there can be more than one antecedent for some given results. Indeed, variants may have the same output AZee expression, and complex templates can be expanded into the the layouts of the rules they are defined with, producing the same result. This means that several graphical antecedents in AZVD can have the same AZee output, and therefore ultimately produce the same signed form.

In the long run though, we may question the concurring existence of multiple options to represent the same reading, and ask whether it would on the contrary be preferable to constrain, even standardise the choices of antecedents. If never more than one way of writing a given output is allowed, we will have turned our defining function into an injection, which we did not impose from the start.

Parallels can be drawn with existing scripts, such as orthographic variants that are at the writer's discretion and have no impact on the reading or meaning. For example in French: *clé/clef* (key), *cuillère/cuiller* (spoon)... yet this is a rather rare phenomenon. We could also mention

typographic variants (a/ɑ, g/g...), case variations (uppercase/lowercase) for letters... Some choices are constrained by grammar, others are aesthetic, whether set for the whole text or free to change. To what extent can we recognise those notions and properties in a script like AZVD, and will the community push towards the same level of normalisation?

8. Conclusion

We have presented the grounds and purpose of AZVD, a graphical system to encode a SL discourse, initially for software editing of signed content. The approach aims to ensure language coverage, make the system fully readable, even synthesisable, and maximise its adoptability, notably by reflecting the regularities observed in spontaneous diagramming practices (VD). As a 2D scriptable and readable representation, we suggested it could be used as a proxy for writing, given the lack of a prior adopted system. We also suggested future work evolutions to pursue: organise community engagement to incorporate their consensus, and work towards two major features generally expected from adopted writing systems and still absent from AZVD, namely serialisation and normalisation. We do hope to open the exciting prospect of AZVD reuse by users, pencil in hand outside the editor's framework and the only goal of synthesising 3D animation content. And then again, the ways in which they will deviate from the specifications will provide new insights to evolve ever more towards an easily adoptable script.

References

- Challant, Camille and Michael Filhol (2022). "A First Corpus of AZee Discourse Expressions". In: *Proceedings of the Language Resources and Evaluation Conference (LREC)*. Marseille, France.
- (2024). "Extending AZee with Non-manual Gesture Rules for French Sign Language". In: *Proceedings of the Language Resources and Evaluation Conference (LREC)*. Torino, Italy.
- Ebling, S. and J. Glauert (Oct. 2013). "Exploiting the full potential of JASigning to build an avatar signing train announcements". In: *Third International Symposium on Sign Language Translation and Avatar Technology*. Chicago, IL, USA.
- Elliott, Ralph et al. (2008). "Linguistic modelling and language processing technologies for avatar-based Sign Language presentation". In: *Universal access in the information society (UAIS)* 6.4, pp. 375–391. DOI: 10.1007/s10209-007-0102-z.

- Filhol, Michael (2020a). "A human-editable Sign Language representation inspired by spontaneous productions... and a writing system?" In: *Sign Language Studies* 21.1.
- (2020b). "Elicitation and Corpus of Spontaneous Sign Language Discourse Representation Diagrams". In: *Proceedings of the 9th workshop on the representation and processing of sign languages*.
- Filhol, Michael and Thomas von Ascheberg (May 2024). "A software editor for the AZVD graphical Sign Language representation system". In: *Workshop on the representation and processing Sign Language*. Turin, Italy. URL: <https://hal.science/hal-04712674>.
- Filhol, Michael, Mohamed Nassime Hadjadj, and Annick Choisier (2014). "Non-manual features: the right to indifference". In: *Proceedings of the workshop on Representation and Processing of Sign Languages*. Reykjavik, Iceland.
- Guitteny, P. (2007). "Langue des signes et schémas". In: *Traitement automatique de la langue (TAL)* 48.
- Hadjadj, Mohamed, Michael Filhol, and Annelies Braffort (May 2018). "Modeling French Sign Language: a proposal for a semantically compositional system". In: *International Conference on Language Resources and Evaluation*. Ed. by ELRA. ELRA. Miyazaki, Japan. URL: <https://hal.archives-ouvertes.fr/hal-01848986>.
- Hanke, Thomas (2004). "HamNoSys—representing Sign Language data in language resources and language processing contexts". In: *Proceedings of the workshop on the Representation and Processing of Sign Languages*. Ed. by O. Streiter & C. Vettori. European Language Resources Association (ELRA), pp. 1–6.
- IVT (1997). *La langue des signes, dictionnaire bilingue LSF-français*. Vol. 2, 3. Paris: IVT editions.
- Mcdonald, John and Michael Filhol (Sept. 2021). "Natural Synthesis of Productive Forms from Structured Descriptions of Sign Language". In: *Machine Translation*. DOI: 10.1007/s10590-021-09272-2. URL: <https://hal.archives-ouvertes.fr/hal-03721229>.
- McDonald, John et al. (2015). "An automated technique for real-time production of lifelike animations of American Sign Language". In: *Universal Access in the Information Society*, pp. 1–16.
- Prillwitz, S. et al. (1989). "HamNoSys version 2.0, Hamburg notation system for sign languages, an introductory guide". In: *International studies on Sign Language communication of the Deaf* 5. Signum press, Hamburg.
- Stokoe, William (1960). "Sign Language structure: an outline of the visual communication system of the American Deaf". In: *Studies in linguistics, occasional papers* 8. Ed. by University of Buffalo.
- Stokoe, William C., Dorothy C. Casterline, and Carl G. Croneberg (1965). *A Dictionary of American Sign Language on Linguistic Principles*. Washington, DC: Gallaudet College Press.

- Sutton, Valerie (2014). *Lessons in SignWriting*. 4th. The SignWriting Press.
- Wolfe, Rosalee, John McDonald, and Jerry Schnepp (Jan. 2011). "An Avatar to Depict Sign Language: Building from Reusable Hand Animation". In: *Workshop on Sign Language Translation and Avatar Technology (SLTAT)*. Berlin, Germany.

Adjusting Typography for Low Vision Readers

A Case Study on Distance Reading Performance

Héctor Mangas

Abstract. This research delves into a case study of applied research on typographic design, regarding the redesign of the wayfinding of France's ophthalmology hospital's. An experimental design was developed and run on a sample of patients from the hospital with diverse visual conditions. These fell into three groups: blurry vision ($N = 15$), central vision loss ($N = 11$), and peripheral vision loss ($N = 15$), as well as a control group ($N = 14$). The experiment tested six typeface variations, optimised for legibility with a pilot group. These varied in width and weight. The results demonstrate that larger letter widths have varying effects across different groups. These findings align with existing literature, which underscores the effects of typographic variables on readability.

1. Context

This experimental research explores typographic adjustments, specifically letter width, and their impact in patients with low vision. A psychophysics experiment was designed and run on 55 participants to explore these effects. Participants of the experiment were patients with various underlying visual conditions representing three groups of interests: severe blurry vision ($N = 15$), central vision loss ($N = 11$) and peripheral vision loss ($N = 15$), along with a control group of normal vision participants ($N = 14$). The experiment was conducted at Quinze-Vingts Hospital, France's national public ophthalmology hospital, between September and October of 2023.

2. Methods

In the experiment, which measured reading acuity, six variations of a new bespoke typeface were tested. Participants were asked to fixate on

Héctor Mangas  0009-0003-1181-945X
Álvarez de Lugo 7, Santa Cruz de Tenerife, Spain
E-mail: hector@typotheque.com

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 709–712. <https://doi.org/10.36824/2024-graf-mang>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

the center of the display. Starting with a point size of 0, a string of letters would grow at a constant rate from that central point of the screen, reaching a maximum size of 250pt after 15 seconds. The task consisted in pressing one of the buttons of the keypad as soon as reading the string of letters was possible. Two alternating noise masks would then appear for 0.5 seconds each, before the participant had to correctly choose the string they had just read among three different but similar-looking options, using the remaining buttons of the keypad. The model served as a threshold acuity experiment, based on Waller (2007).

Each participant completed 120 trials of this task. The string of letters was shown in one of six typeface variations for each trial, making 20 times for each typeface variations. The order of display of these was randomised for each participant. For the text stimuli, a list of 120 non-sense 4-letter strings was prepared. Three similar looking alternatives were written for each item (e.g., for “bzix”; “bztz,” “bqix” and “bzxi” were the three similar looking alternatives). These were created manually including and permuting one or two easily mistakable letterforms per string.

Reaction times were used as a comparative measurement of reading acuity. The answers to the similar-looking alternative questions were collected and stored, but the real intention of these was to maintain attention throughout the experiment. The list of strings was shown at random, with no participant having the same stimuli order as another.

The typographic variables of each variation were broken down as continuums of letter width, boldness and inter-letter spacing. Each participant produced six average reaction times for each of the versions of the typeface studied. Every average was produced after clearing the data of outliers. Because of the repeated measures design of the experiment—where six measurements were relative to each participant—and the non-normal distribution of reaction times, a generalised linear mixed model study was chosen for the analysis of regression. Model terms were tested using the Satterthwaite method.

3. Results

When looking at all reaction times, regardless of eye disease, the regression study showed a strong effect caused by width. This did not happen with boldness and inter-letter spacing. If participants are broken down by eye disease, we see this effect repeating for all patient groups at different levels. This effect is specially significant with healthy participants, followed by participants with blurry vision. When it comes to boldness, a positive effect can be observed for patients with blurry vision.

The findings of the present study show an advantage exerted by letter width on reading acuity of lowercase latin text. This advantage was studied with a bespoke unpublished typeface, which show largest advantages

at very extended letter widths of between 140-160. This advantage was tested in four groups underlying visual conditions, each of which showed a different effect of letter width on performance. A performance plateau emerged after Version C (width 140) for central and peripheral vision loss groups and after Version D (width 160) for patients with blurry vision and healthy readers. On letter boldness, we observed a positive effect on reading acuity for patient groups with blurred vision, with bolder weight reducing reaction times. Conversely, regarding the typographical variable of inter-letter spacing, we found no significant effects on reading acuity.

To the best of our knowledge, this is the first study to investigate the effects of multiple typographical variables with the same typefaces family on low vision readers with various visual deficits. The findings demonstrate that wider letter shapes can benefit all reader groups to varying degrees, and align with recent literature, which highlights that typographic variables affect each reader differently.

This research fed the design process of Zed, which was developed alongside data collection. Additionally, Zed Text is now the typeface for Quinze-Vingts Hospital, where the experiment took place. It is currently being implemented by Integral Designers as the wayfinding and identity typeface. The font is expected to expand its language support beyond Latin, with research prepared for Thai, Arabic and Armenian.

References

- Arditi, A. (2004). "Adjustable typography: An approach to enhancing low vision text accessibility". In: *Ergonomics* 47, pp. 469–482. DOI: 10.1080/0014013031000085680.
- Arditi, A., R. Cagenello, and B. Jacobs (1995). "Letter Strokewidth, Spacing and Legibility". In: *Vision Science and Its Applications*. Vol. 1, pp. 324–327.
- Arditi, A. and J. Cho (2007). "Letter case and text legibility in normal and low vision". In: *Vision Research* 47, pp. 2499–2505. DOI: 10.1016/J.VISRES.2007.06.010.
- Beier, S. (2016). "Designing legible fonts for distance reading". In: pp. 75–89.
- (2019). *Age-Related Deficits and Their Effects on Reading*. Association Typographique Internationale. URL: <https://www.youtube.com/watch?v=dM9JsIwhEy4>.
- Beier, S. and K. Larson (2010). "Design improvements for frequently misrecognized letters". In: *Information Design Journal* 18. DOI: 10.1075/idj.18.2.03bei.

- Beier, S. et al. (2021). "Increased letter spacing and greater letter width improve reading acuity in low vision readers". In: *Information Design Journal* 26, pp. 73–88. DOI: 10.1075/idj.19033.bei.
- Bernard, J. B. et al. (2013). "The effect of letter-stroke boldness on reading speed in central and peripheral vision". In: *Vision Research* 84, pp. 33–42. DOI: 10.1016/j.visres.2013.03.005.
- Bernard, J.-B., C. Aguilar, and E. Castet (2016). "A New Font, Specifically Designed for Peripheral Vision, Improves Peripheral Letter and Word Recognition, but Not Eye-Mediated Reading Performance". In: DOI: 10.1371/journal.pone.0152506.
- Chung, S. T. L. and J. B. Bernard (2018). "Bolder print does not increase reading speed in people with central vision loss". In: *Vision Research* 153, pp. 98–104. DOI: 10.1016/j.visres.2018.10.012.
- Garg, A. and S. H. Tsang (2023). "Retinal Dystrophies". In: *Microperimetry and Multimodal Retinal Imaging*, pp. 137–142. DOI: 10.1007/978-3-642-40300-2_14.
- Gary, G. E. L. et al. (1984). "Psychophysics of Reading — II. Low Vision". In.
- Geyer, L. R. (1977). "Recognition and confusion of the lowercase alphabet". In: *Perception & Psychophysics* 22, pp. 487–490.
- Kwon, M. Y. et al. (2017). "Slow Reading in Glaucoma: Is it due to the Shrinking Visual Span in Central Vision?" In: *Investigative Ophthalmology & Visual Science* 58, p. 5810. DOI: 10.1167/I0VS.17-22560.
- McLeish, E. (2007). "A study of the effect of letter spacing on the reading speed of young readers with low vision". In: *British Journal of Visual Impairment* 25, pp. 133–143. DOI: 10.1177/0264619607075995.
- Minakata, K. and S. Beier (2021). "The effect of font width on eye movements during reading". In: *Applied Ergonomics* 97. DOI: 10.1016/j.apergo.2021.103523.
- Oderkerk, C. A. T. and S. Beier (2022). "Fonts of wider letter shapes improve letter recognition in parafovea and periphery". In: *Ergonomics* 65, pp. 753–761. DOI: 10.1080/00140139.2021.1991001.
- Sheppard, S. M. et al. (2023). "One Font Doesn't Fit All: The Influence of Digital Text Personalization on Comprehension in Child and Adolescent Readers". In: *Education Sciences* 13. DOI: 10.3390/educsci13090864.
- Waller, R. (2007). "Comparing typefaces for airport signs". In: *Information Design Journal* 15, pp. 1–15.

Making Primæ: An Innovative Type for Learning to Read and Write

Titus Nemeth & Martin Tiefenthaler

Abstract. This paper is as much a history of Austrian handwriting models as an account of the making of Primæ, an innovative new type designed for learning to read and write. It situates the narrative of this contemporary applied design project against an historical overview of writing instruction in Austria, identifying key factors in the evolution of a national handwriting model. It demonstrates the pronounced formal continuities that span the last 100 years of teaching writing in primary school, and lays out rationale, approach, and outcomes of the last handwriting instruction reform—effected between 1984 and 1995—that was sanctioned by the Ministry of Education. It casts a critical light on the implementation of the resulting national handwriting model ‘Österreichische Schulschrift 1995’ and highlights its strategic shortcomings.

The paper then presents the making of Primæ, summarising conceptual approach, resulting design principles, and technical implementation. In this account, recurring arguments of academic discourse about methodological differences are cross referenced with the formal solutions proposed in Primæ. The paper demonstrates how the relationship of disconnected writing and connected writing was achieved and how it facilitates the incremental learning of writing styles. It emphasises the importance of design and technical skills for the making of a handwriting model used in education and shows solutions to the redundant problems found in inadequately made fonts. It argues for a comprehensive characterset for the sake of linguistic inclusion in the classroom, a systematically neglected aspect in national handwriting fonts. In conclusion, the paper argues for increased sensitivity to form and craftsmanship in handwriting education, as the acute attention children give to examples merits nothing less than our very best design efforts.

Titus Nemeth  0000-0003-3871-5792
Stanislausgasse 8/3, 1030 Vienna, Austria
E-mail: info@wienerschriften.at

Martin Tiefenthaler  0009-0009-9961-5753
Akademie der bildenden Künste Wien, Austria
E-mail: mt@ididiididesign.at

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 713–756. <https://doi.org/10.36824/2024-graf-neme>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

Beginnings of Handwriting Instruction in Austria

When in the late sixteenth century formal regulations began to be articulated, the sparse evidence suggests that a standardised handwriting instruction did not exist yet. For example, the school regulation of Tyrol from 1586 refers to so-called ‘Namenbüchlein’—spelling or Abc primers—and to the sample alphabets that they contained.¹ According to Alois Legrün, these booklets appear to have been manufactured by the respective schoolmasters and were likely to reflect their writing styles. This practice continued for some 200 years, as illustrated by the regulations of Kremsmünster of 1732, which formally prescribed the teacher’s hand as the only permissible model to be taught.² The first extant spelling primers that were printed in Austria date from the same time, indicating the gradual move towards greater uniformity in children’s instruction.³ They found a prescriptive expression in the first national school regulation that was initiated by Empress Maria Theresia (1717–1780) and came into force on 6 December 1774.

The Austrian school regulation was conceived by the Prussian Johann Ignaz von Felbiger (1724–1788), who could build on his prior experience conceiving school regulations for Catholics in Silesia.⁴ The *Allgemeine Schulordnung für die deutschen Normal-, Haupt- und Trivialschulen* stipulated that all children aged six to twelve had to be taught and its provisions extended to the training of teachers and the contents of textbooks.⁵ In 1775, the *Methodenbuch für Lehrer der deutschen Schulen in den kaiserlich-königlichen Erbländern* offered guidance for teachers in more than 500 pages that extended, amongst other subjects, to the merits of teaching in a group, the qualities teachers ought to have, and subject-specific considerations.⁶ In conjunction with the *Methodenbuch*, Felbiger also published the reading primer *Abc- oder Namenbüchlein*. On its first spread a chart shows the alphabet in four styles of type—Fraktur, Kurrent, roman, and italic—that children were expected to master—an illustration of the considerable de-

1. Alois Legrün, *Auf dem Wege zur naturgemäßen Schrift* (Vienna, 1924), 4.

2. Ludwig Boyer, *Elementarschulen und Elementarunterricht in Österreich: illustrierte Chronik der Schul- und Methodengeschichte von den ältesten Quellen bis zum Ende des 19. Jahrhunderts* (Graz, 2012), 73.

3. Ludwig Boyer names the primer by Johann Balthasar Antesperg of 1739 as an early example. Boyer, *Elementarschulen und Elementarunterricht in Österreich*, 73.

4. Prussia was an early pioneer of public schooling.

5. *Allgemeine Schulordnung, für die deutschen Normal-Haupt- und Trivialschulen in sämtlichen Kaiserl. Königl. Erbländern d.d. Wien, den 6ten December 1774* (Vienna, 1774).

6. Johann Ignaz von Felbiger, *Methodenbuch für Lehrer der deutschen Schulen in den kaiserlich-königlichen Erbländern* (Vienna, 1776).

mands that the biscriptualism in the German-speaking world placed on handwriting education.⁷

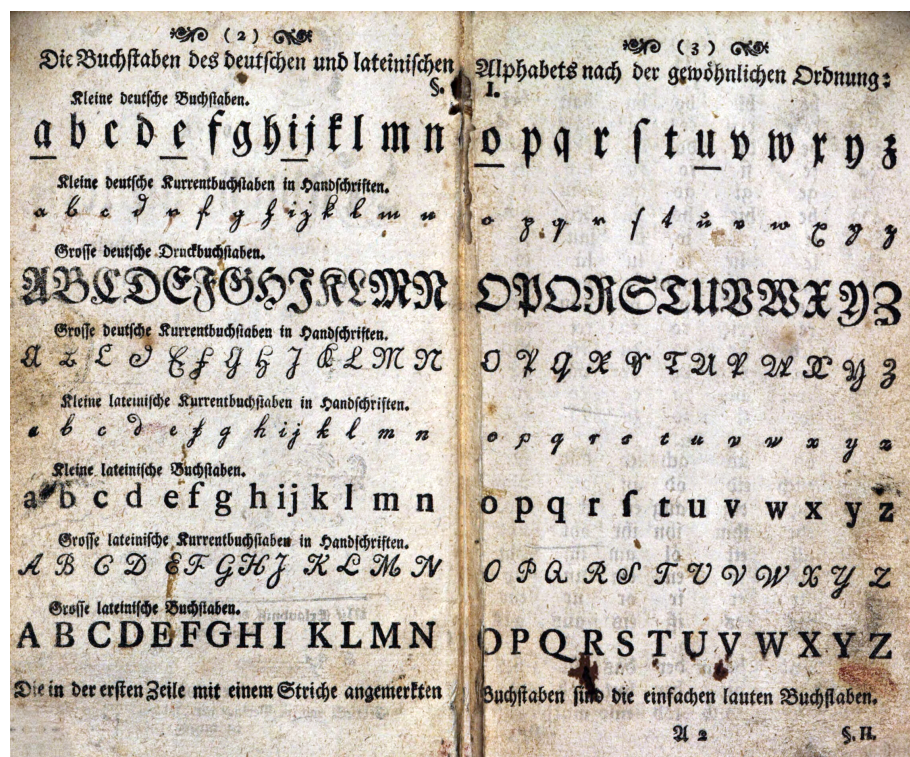


FIG. 1. Alphabet chart showing the four basic letterform styles children in the German-speaking world were expected to learn for basic literacy. From Johann Ignaz von Felbiger, *ABC oder Namenbüchlein* (Linz: Johann Michael Feichtinger sel. Wittwe, 1786) pp. 2–3. Courtesy of the Austrian National Library, <http://data.onb.ac.at/rec/AC08741604>

A writing manual, the *Anleitung zum Schönschreiben nach Regeln und Mustern, Oder Vorschriften: Zum Gebrauche der deutschen Schulen in den kaiserl. königl. Staaten*, was published in parallel and was intended to complement the *Methodenbuch* for handwriting instruction. The examples were written by the scribe of the *Normalschule zu St Stefan*—the Viennese school that

7. In the early modern period the use of blackletter letterforms subsided in most of Europe, as roman letterforms became the dominant style. However, in the German-speaking world the two variants were used in parallel, denoting German and foreign language—and specifically Latin text—respectively.

served as a standard for all schools throughout the empire—and were reproduced with copperplate etchings.

According to the author, it contained ‘all that is essential for Germans to know and learn of the most common styles of writing’,⁸ including models of the three writing styles Kurrent (German cursive), Kanzlei (German chancery), and Fraktur (blackletter), as well as a version of the so-called Latin running hand. As in most German writing manuals, the Germanic writing styles held pride of place and Latin appeared secondary, both in prominence of presentation and accomplishment. Despite this apparent order of priorities, stylistically all samples reflected the then current ideal of the English roundhand with its marked contrast between thick and thin strokes and the tendency towards decorative swashes.⁹ This adoption of features that originated in Latin writing styles was to remain characteristic for the further evolution of Germanic handwriting until the twentieth century and featured prominently in the ensuing disputes over the appropriate writing styles for the German speaking world.

Handwriting Instruction in the Nineteenth Century

Felbiger’s writing manual and his *Abc- oder Namenbüchlein* remained in use into the middle of the nineteenth century.¹⁰ Only after the revolutionary movements of 1848 and the emergence of a liberal bourgeoisie, the education system became an area of reform and modernisation. In 1868 the Church nominally lost its influential role in public education,¹¹ and with the Reichsvolksschulgesetz of 1869 the first modern school regulation of Austria was enacted.¹² It provided the legal basis for a thorough

8. ‘Die Anleitung zum Schönschreiben [...] enthält alles wesentliche, was für Deutsche von den gebräuchlichsten Schriftarten zu wissen und zu lernen nothwendig ist.’ *Anleitung zum Schönschreiben nach Regeln und Mustern, Oder Vorschriften: Zum Gebrauche der deutschen Schulen in den kais. königl. Staaten* (Wien, 1775), 2 [my translation].

9. George Bickham’s influential *The Universal Penman* had been published in 1733.

10. The literature provides various dates. Karl Dostal claims the writing manual remained the official model until 1832 without providing a source, whereas Legrün suggests that a decree of 2 February 1866 established the freedom of method and didactic material in primary schools. Legrün noted, however, that he was not able to consult the actual decree, because it had already been thrown away. Karl A. Dostal, *Methodik des Schreibunterrichts: 1.–8. Schulstufe* (Vienna, 1972), 27. Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 12.

11. Reinhard Buchberger and Nina Linke, ‘Von den Tafelkratzern des Mittelalters bis zu den Tintenpatzern des fin de siècle’, in *Tafelkratzer, Tintenpatzer: Schulgeschichten aus Wien*, ed. by Reinhard Buchberger and others (Vienna, 2015), 61.

12. ‘Imperial primary school act’ [my translation].



FIG. 2. Illustration of the first official Austrian model used for handwriting instruction, demonstrating the technical exigencies that were required. From *Anleitung zum Schönschreiben nach Regeln und Mustern, Oder Vorschriften* (Vienna: Verlag der deutschen Schulanstalt, 1775) plate 2. Courtesy of the Austrian National Library, <http://data.onb.ac.at/rec/AC09658801>

reconsideration of the role of education in the country and remained in force for nearly 100 years.¹³ Once the state monopoly on the production of didactic material was lifted, private enterprise increasingly began to compete in the emerging market. New primers and teaching materials—which still had to be approved by the school authority—proliferated and diversified the available options.¹⁴

The emerging calligraphic handbooks for writing instruction offered various takes on the established hands Kurrent, Fraktur, and Latin.¹⁵ Whereas they were of varying quality and some espoused specific concepts, stylistically they tended to be heavily influenced by the English roundhand. Ironically, this also applied to the Germanic styles, contra-

13. Boyer, *Elementarschulen und Elementarunterricht in Österreich*, 286.

14. Buchberger and Linke, 'Von den Tafelkratzern des Mittelalters bis zu den Tintenpatzern des fin de siècle', 63.

15. The Kanzlei style, still in use in the early nineteenth century, gradually disappeared from use. According to Georg Land, its demise was fastened by its incompatibility with pointed steel pens, which came to dominate penmanship in the nineteenth century. Georg Lang, *Die Technik der Feder: Der Weg der Schreiblehrkunst, sachlich begründet und methodisch erläutert. Ein Vortrag mit ergänzenden Abhandlungen zur Federtechnik, Schriftästhetik und Schreibmethodik*, Reprint of first edition from 1905 (Berlin, Boston, 2019), 65 <https://doi.org/10.1515/9783486732672> [accessed 20 January 2025].

dicting their different origins and their apparent priority in handwriting instruction. Some issues that featured prominently in discussions about the deterioration of children's writing arose from the introduction of traits borrowed from Latin styles. For example, traditionally Kurrent letterforms had various inclinations, a feature that was considered characteristic for the style.¹⁶ But as the nineteenth century advanced, the angles of letterforms were gradually normalised, matching the consistent inclination of English roundhand, a development that Legrün and other scholars opposed. According to them, it forced the hand into an unnatural position that was difficult to acquire, and which contradicted the style's internal logic. In his sketch of the historical evolution of handwriting, Legrün even speaks of the 'corruption of our handwriting' that happened when, in the first decades of the nineteenth century, writing masters in Germany adopted the pointed metal pen.¹⁷

Other criticisms of the overly mannered and rigid ideals of nineteenth-century fashion in penmanship related to the excessively strong inclination, the extreme proportions of letterforms with a small x-height and exuberant extenders, the technical difficulty of execution, as well as the general tendency to exaggerated ornamentation.¹⁸ Scholars invested in handwriting instruction lamented that beautification overruled more pragmatic concerns for teaching, legibility, and ergonomics. In reaction to the dominant style, alternative proposals such as upright cursive writing emerged. This wide-spread discontent with handwriting instruction was underpinned by a fierce dispute about the respective merits of Ger-

16. The Kurrent hand used two distinct writing techniques for various letterforms: key minuscules such as e, m, n, u were written only with movements of the fingers, whereas letters with extenders and capitals were shaped with a gesture that involved hand and wrist, leading to various writing angles. Dostal, *Methodik des Schreibunterrichts*, 27, and Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 6–7.

17. My translation of 'die Verfälschung unferer Schreibschrift', Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 11. Legrün identifies the calligrapher Johann Heinrigs from Krefeld (1781–1861) as the likely originator of the practice when, in 1813, he sought to 'redesign' handwriting after the model of the English roundhand 'by showing writing [...] in such a way as may be engraved in a copperplate, but cannot be performed with the pens commonly used in schools'. My translation of 'indem er [...] die Schrift so darstellte, wie sie wohl in die Kupferplatte eingraviert werden konnte, wie sie aber mit den in den Schulen verwendeten Schreibfedern unausführbar ist', Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 13, and Theodor Loew, *Gebrechen unseres Schulschreibsystems und ihre Herkunft mit Vorschlägen zur Abhilfe* (München, 1913).

18. Whilst elements of the critique appear reasonable from a contemporary perspective, the manner in which it was advanced, often was not. Frequently authors who favoured more conservative Germanic writing styles evoked notions of national identity, suggested innate 'natural' advantages, and dismissed the characteristics of English roundhand as weak, soft, and effeminate. See for example Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 13, and Theodor Loew, *Gebrechen unseres Schulschreibsystems und ihre Herkunft mit Vorschlägen zur Abhilfe* (München, 1913).

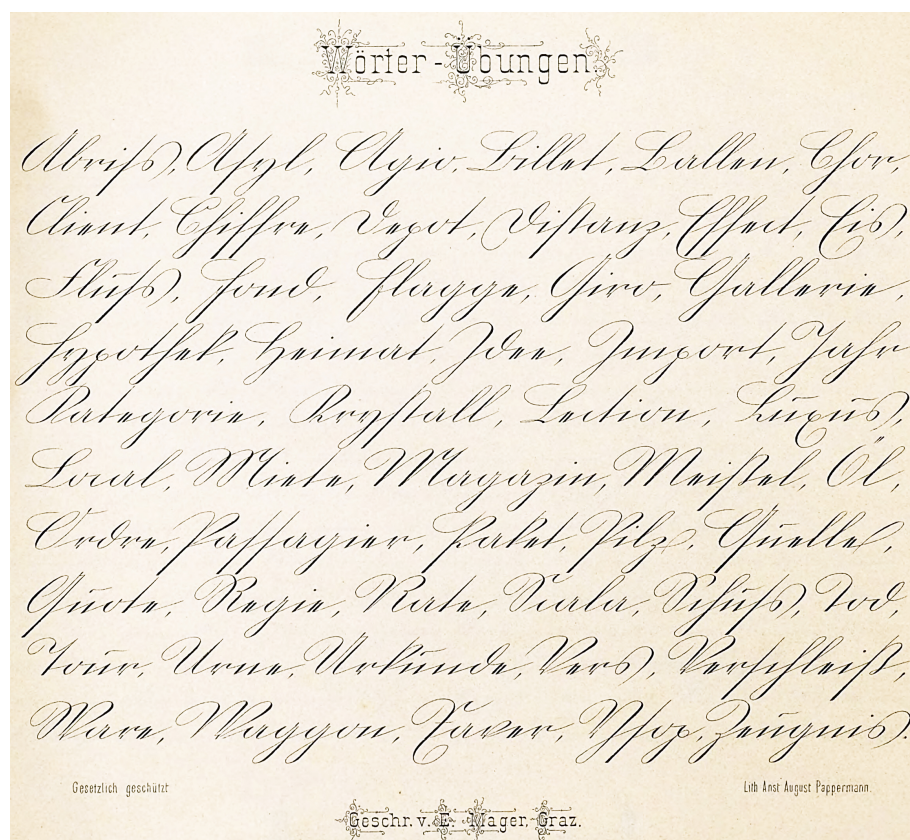


FIG. 3. An example of the overly mannered, technically challenging, and poorly readable Kurrent style that was fashionable in nineteenth century Austria. From Emil Mager, *Moderne und neueste Current-Schrift für das kaufmännische Schnellschreiben* (Vienna: Perles, 1892) plate 11. Courtesy of the Austrian National Library, <http://data.onb.ac.at/rec/AC10091818>

manic and Latin writing styles that engaged the German speaking world at the time. The so-called 'Schriftstreit' (script controversy) principally played out through publications and extended from the 1880s until a decree by the German National Socialist regime brought it to an abrupt end in 1941. A discussion of the Schriftstreit goes beyond the scope of the present paper, but the controversy provided the background for the reform proposals for handwriting instruction of the early twentieth century.¹⁹

19. For studies of the subject see Silvia Hartmann, *Fraktur Oder Antiqua: Der Schriftstreit von 1881 Bis 1941*, 2nd edn (1999); Horst Heiderhoff, *Antiqua oder Fraktur?: zur*

One of the reform proposals of the 1910s was developed by the graphic artist Ludwig Sütterlin (1865–1917). He taught from 1904 at the school of arts and crafts (Unterrichtsanstalt des königlichen Kunstgewerbemuseums) in Berlin, where he developed a keen interest in type.²⁰ In 1910 Sütterlin presented a draft of a new model for handwriting instruction to the Prussian Ministry of Education and Culture (Kultusministerium),²¹ and was subsequently commissioned to develop it into a course for kindergarten and primary school teachers.²² The resulting curriculum was introduced as a field trial in two schools in Berlin and by 1914 Sütterlin was ready to publish his corresponding teaching manual, but postponed its release because of the start of the war. The book was eventually published in 1917, just months ahead of Sütterlin's premature death.

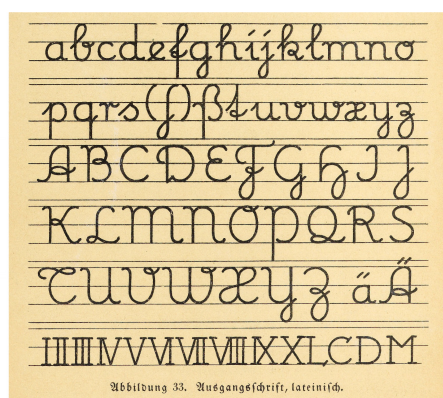
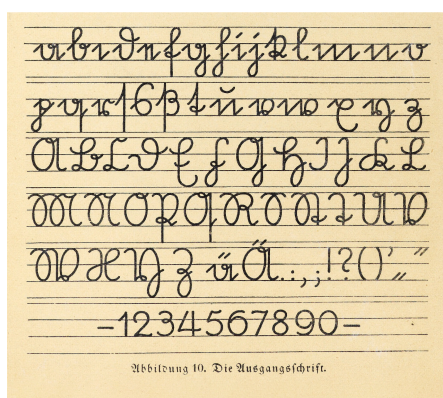


FIG. 4. The writing models of Friedrich Sütterlin strongly influenced the work of Alois Legrün. From Friedrich Sütterlin, *Neuer Leitfaden für den Schreibunterricht* (Berlin: Verlag Albrecht Dürer Haus, 1922) plates 10 and 33. Courtesy of the German National Library, <https://d-nb.info/1124005439>

Problemgeschichte eines Streits (Frankfurt am Main, 1971); August Kirschmann, *Antiqua oder Fraktur? (Lateinische oder deutsche Schrift.) Kritische Studie*, Monographien des Buchgewerbes, 1, 2nd rev. ed. (Leipzig, 1912).

20. Reinhold Zilch, 'Sütterlin, Ludwig', *Neue Deutsche Biographie* (2013), 688–89 <https://www.deutsche-biographie.de/sfz129700.html#dbcontent> [accessed 21 January 2025].

21. Zilch, 'Sütterlin, Ludwig', 688–89.

22. Ludwig Sütterlin, *Neuer Leitfaden für den Schreibunterricht* (Berlin, 1917), 1. Sütterlin described the courses which started in October 1911—three in total, each running for 24 months—as workshops with twenty-four participants in which all questions of instruction and letterforms were thoroughly discussed.

Sütterlin's two writing models for Kurrent and Latin styles were a radical departure from established norms. They jettisoned all inclination and any degree of stroke contrast, reduced the proportions of ascenders, x-height, and descenders to a manageable 1:1:1 ratio, and rendered the letterforms as wide, open shapes. Sütterlin's introduction of a flat, circular nib producing monolinear strokes was central to creating formal qualities that children could reproduce easily. They give the impression of a slow, diligent, and controlled writing movement, which corresponds well to the first steps of writing acquisition.

Sütterlin's model became highly successful and was widely adopted throughout Germany. His name and work became synonymous with his form of the Kurrent style—casually termed 'Sütterlinschrift', which in some states was taught until the 1950s. By contrast, his Latin model received considerably less interest and attention, reflecting the preeminent role Germanic writing styles still held in large parts of the German speaking world.²³ In Austria, Sütterlin's work resonated as well, and his influence was to last even longer, albeit only indirectly.

The Wiener Richtformen of 1924

Alois Legrün (1889–1970) was a teacher at the Pedagogical Institute of the city of Vienna (Pädagogisches Institut der Stadt Wien), a key institution of the school reforms that were implemented under the leadership of the social democrat Otto Glöckel (1874–1935).²⁴ In 1924 Legrün published a new model for writing instruction, which came to be known as the 'Wiener Richtformen'.

According to Legrün's account, he had developed the letterforms with his students at the Pedagogical Institute.²⁵ Subsequently, a commission composed of Viennese teachers and scholars of writing approved the design and in 1924 it was presented to all teachers for critique.²⁶ Legrün underlined that he had been known as an opponent of prescriptive writing models and that he intended his design to serve only as an aid to

23. Tellingly, having dedicated 84 pages to general considerations and the instruction of Kurrent, even Sütterlin remarked about his Latin model that 'there isn't much to say about it' [my translation]. Sütterlin, *Neuer Leitfaden für den Schreibunterricht*, 85.

24. Glöckel was first Minister for Education from 1918 to 1920 and then, after the collapse of the federal government, president of Vienna's state body for education, the Stadtschulrat. Alfred Pfoer, 'Die österreichische Schulreform', in *Tafelkratzer, Tintenpatzer: Schulgeschichten aus Wien*, ed. by Reinhard Buchberger and others (Vienna, 2015), 203.

25. Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 23.

26. According to Dostal, Vienna's Stadtschulrat recommended the 'Wiener Richtformen' for handwriting instruction in 1924. Dostal, *Methodik des Schreibunterrichts*, 31.

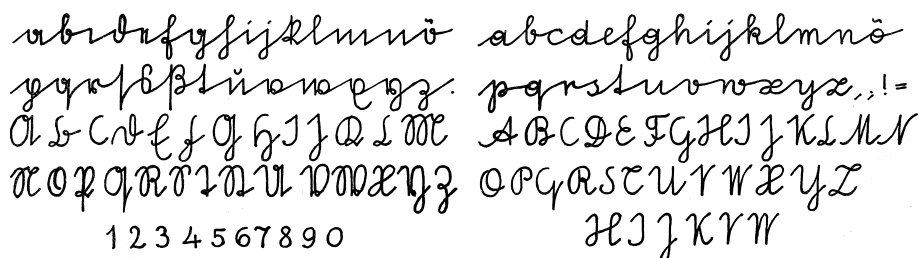


FIG. 5. Samples of the 'Wiener Richtformen' teaching alphabet, from Alois Legrün, *Auf dem Wege zur naturgemäßen Schrift*, (Vienna: Verlag für Jugend und Volk, 1924) 24–25

teachers: He had argued against their use as recently as 1922, in a publication that showed the strong influence of the German writing reformer Fritz Kuhlmann (1857–1941).²⁷ He described his proposal to have resulted from the following guiding principles: (1) neutrality of inclination, where the upright form of the model is not intended to be compulsory; (2) a minimum of ambiguity in letterforms; (3) shapes that allow for continuous single-stroke writing, both internally and in connection to surrounding letters; and (4) the representation of pared-down, archetypal letterforms.

Legrün was keenly aware of Sütterlin's work—he referenced it extensively in earlier publications—but did not mention it in the notes that accompanied his proposed design even though a comparison of the two models reveals noticeable formal similarities.²⁸

The 'Wiener Richtformen' were characterised by the same vertical proportions as found in Sütterlin's design and the use of a pen that produced monolinear strokes. In the Kurrent style, small structural differences are only found in a handful of capitals (H, K, L, M, N), all other letterforms follow the same pattern with small differences of execution. Also in the Latin style, most minuscules share qualities with Sütterlin's model, yet here Legrün introduced novel features. Following his principle of continuous single-stroke letter architectures, the letterforms for a, d, g, o, p, and q contained an internal loop, allowing them to be written and connected to adjacent letters without lifting the pen. This construction derived from the Kurrent style, and Legrün, who considered shorthand to be the future of writing, may have thought it advantageous for speed. A concern for writing pace also appears to be reflected in inter-

27. Alois Legrün, *Naturgemäßer Schreibunterricht. Grundlagen und Wege*, Lehrerbücherei 12 (Vienna, 1922). Legrün, *Auf dem Wege zur naturgemäßen Schrift*, 23.

28. Dostal notes that 'Sütterlin's influence extends into the present, in Austria primarily through the work of Alois Legrün, Vienna' [my translation], but does not elaborate how this influence manifested itself. Dostal, *Methodik des Schreibunterrichts*, 30.

letter joining strokes. Whereas Sütterlin showed his letterforms without connections, in Legrün's sample all minuscules are joined up. The distance between letters is remarkably wide, evoking a style of handwriting that was popular in the United States during this time. The 'Palmer method' had been invented by Austin Norman Palmer (1860–1927) in the 1880s and 90s, and he promoted it with great success in the first decades of the twentieth century.²⁹ Its widely spaced word images may have been known by Legrün, and Palmer's ideas of muscular movement and rigorous exercise as the foundations of penmanship reflected topical notions of the time that can also be found in the writings of contemporaries in Austria and Germany.

The capitals of the 'Wiener Richtformen' diverged further from Sütterlin's model, replacing some of its Kurrent shapes with roman letterforms. As in the minuscules, in the capitals Legrün's concern for single-stroke constructions is apparent: with the exception of F and K, all capitals can be written in one uninterrupted movement. Regarding the mixture of Kurrent and roman styles, Legrün noted that the letterforms of b, f, j, l, C, J, I, L, and X were kept identical for both styles as this was in line with current practice, but that he (following Sütterlin) also introduced the same shape for t.

Legrün's 'Wiener Richtformen' were adopted in a slightly modified form across Austria in 1926 and remained in use until 1941, when the National Socialist ban on blackletter styles came into force and spelled the end for Kurrentschrift.

For the remainder of the Third Reich, a Latin cursive type—the 'Deutsche Normalschrift'—became the new, short-lived standard.³⁰ After the war, on 22 September 1945, the Austrian authorities reverted to a 'Richtalphabet 1945' and decreed that only the Latin hand was to be taught in schools.³¹ The following year, a decree prescribed again Legrün's model, now called 'Österreichische Schulschrift', as the stan-

29. Palmer's method was published in 1894 and promoted vigorously by its inventor. Austin Norman Palmer, *Palmer's Guide to Business Writing* (Cedar Rapids, Ia, 1894). See also Tamara Plakins Thornton, *Handwriting in America: A Cultural History* (1996). For a thorough perspective on the teaching of writing in the United Kingdom in the early twentieth century see Sue Walker, 'Letterforms for Handwriting and Reading: Print Script and Sanserifs in Early Twentieth-Century England', *Typography Papers*, 7 (2007), 81–114. For a cursory overview of handwriting instruction in the Latin script in the twentieth century see Rosemary Sassoon, *Handwriting of the Twentieth Century* (Bristol, Chicago, 2007).

30. Dostal, *Methodik des Schreibunterrichts*, 32–33.

31. *Verordnungsblatt für den Dienstbereich des Bundesministeriums für Unterricht* (Vienna, 1946), 69. According to Dostal, this 'Richtalphabet' was Legrün's model.

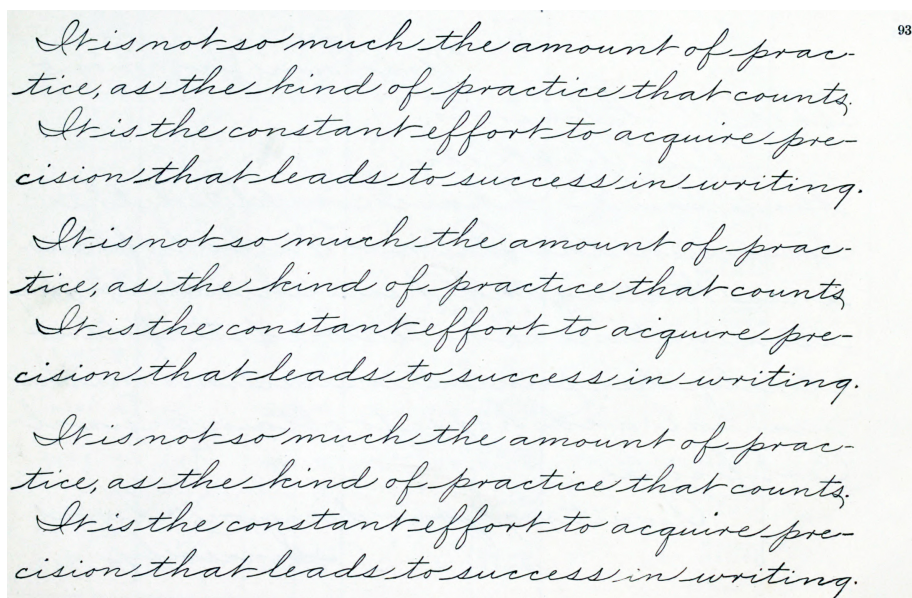


FIG. 6. A page of Palmer's handwriting manual, showing the extended joining strokes between letters. From Austin Palmer, *The Palmer method of business writing*, (New York: A.N. Palmer Company, 1915) 93. Courtesy of University of California Libraries, <https://archive.org/details/palmermethodofbu00palmrich/>

dard for handwriting instruction.³² Under this new label a couple of minor changes were introduced—the descender of the f lost its loop and the x was no longer written in one continuous movement—but overall Legrún's model was maintained.

The following decades saw few consequential changes in Austria's approach to handwriting instruction. In 1951 the Ministry, then run by Austria's conservative party, reintroduced the teaching of Kurrent into the curriculum. In 1964 the Ministry initiated a reform of the Latin model, but the proposal was rejected during the review process.³³ The following year, a slightly modified version with alterations of two letters

32. A sample of the model was published as an attachment to the Ministry's regulations, referencing the bill 32.964-IV/12, dated 3 October 1946 *Verordnungsblatt für den Dienstbereich des Bundesministeriums für Unterricht* (Vienna, 1946).

33. Dostal, *Methodik des Schreibunterrichts*, 34–35. Hadmar Lichtenwallner und Brigitta Scheiber suggest that the rejection of the reform proposal was caused by a lack of public consultation and that a perceived 'top-down' imposition of the reform fuelled the opposition amongst teachers. Hadmar Lichtenwallner and Brigitta Scheiber, 'Die Österreichische Schulschrift', in *Kommentar zum Lehrplan der Volksschule*, ed. by Dieter Antoni, 2nd rev. ed. (Vienna, 1996), 666.

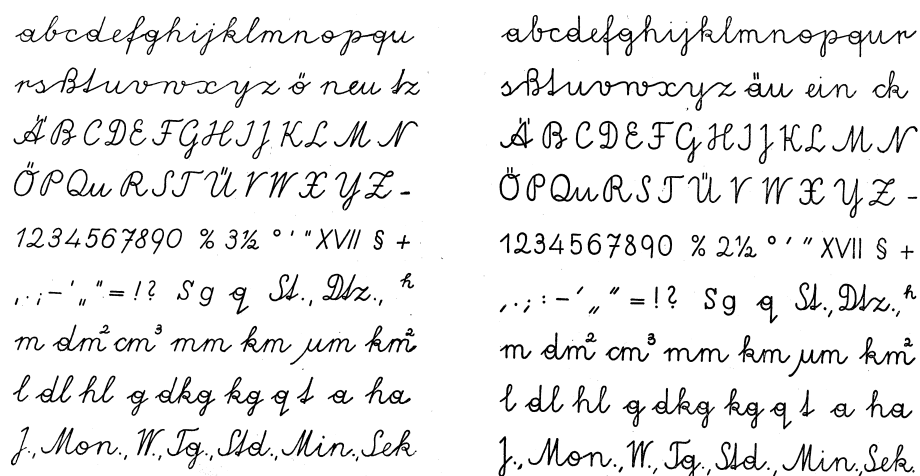


FIG. 7. Official sample of the post-war handwriting model that was principally based on Legrün's 1924 design. *Die Österreichische Schulschrift 1946*, (Vienna: Österreichischer Bundesverlag, 1946)

was introduced. The r was given the unusual form that originated in the historical French Ronde hand, a style that was rediscovered and promoted by Friederich Soenneken (1848–1919), whilst the x, previously following the shape of the Ronde, was now rendered in the more conventional crossed configuration. Overall, however, forty years after Legrün introduced his model for the first time, it was still largely unchanged.

Despite its undeniable success, some of its characteristics no longer reflected the state of the art of handwriting instruction and calls for a reform emerged. In 1972, Karl Dostal argued that a new model ought to be inclined and listed nine points of desirable improvements that he illustrated with a draft proposal. Amongst others, he suggested that the construction of individual letterforms should be streamlined, avoiding superimposed strokes and suppressing the loops in a, d, g, and q—a peculiarity introduced by Legrün—and that the arches of n, m, u etc. should be more pointed to become conducive to higher writing pace, in effect calling for a design akin to the italic hand. Dostal concluded that,

he new letterforms contain many traits that are also found in refined adult handwriting and contemporary graphic design, for why should primary school pupils learn and automatise a script that they won't later be able to write quickly?³⁴

34. 'Die neuen Formen enthalten viele Merkmale, die man auch in gepflegten Erwachsenenhandschriften und in der modernen Graphik antrifft, denn weshalb

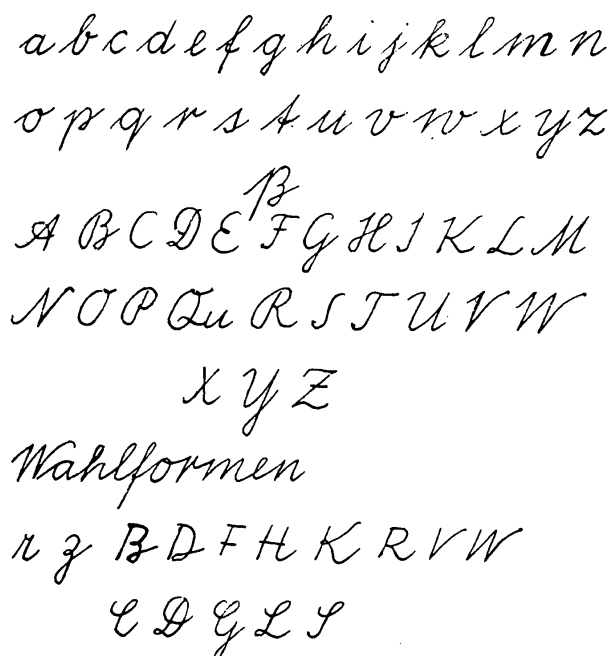


FIG. 8. Karl Dostal's draft proposal for a reformed handwriting model, from *Methodik des Schreibunterrichts: 1.–8. Schulstufe*, (Vienna: Jugend und Volk, 1972) 37

The Schulschrift of 1995

Despite the reform calls from the 1970s, only in 1984 the Ministry, then again under social democratic leadership, tasked a working group—Ludwig Boyer, Reinhold Felzmann, Hadmar Lichtenwallner, and Oskar Seber—to develop a proposal.³⁵ Its stated goals were to develop a handwriting model that was (1) specific to Austria; (2) easily learned through simplified letterforms; (3) faster to write through the removal of redun-

sollen die Volksschüler eine Schrift lernen und automatisieren, die sie später doch nicht schnell schreiben können?' Dostal, *Methodik des Schreibunterrichts*, 38–39 [my translation].

35. Ludwig Boyer, *Kommentar zur Ausgangsschrift*, ed. by Wilhelm Wolf, aps, 12, 2nd rev. ed. (Vienna, 1988), 76. Further to the four members of the initial draft, the final announcement of the new model listed fourteen (!) additional contributors, namely Dieter Antoni, Thomas Benke, Franz Gerstenbrand, Margarete Habringer, Margit Hochleitner, Beatrix Irschik, Rosemarie Müller, Richard Olechowski, Andrea Santner, Brigitta Scheiber, Nikolaus Severinski, Wilhelm Urban, Barbara Weiland, and Wilhelm Wolf. *Die Österreichische Schulschrift 1995: gut lesbar, leicht erlernbar, besser vermittelbar* (Vienna, 1994).

dant elements; (4) highly legible, offering clear and unambiguous letterforms; (5) conducive to further development into a personal hand; (6) reflecting recent scientific findings (where they did not contradict other concerns); (7) aesthetically pleasing; (8) in line with international trends such as the convergence of manuscript letterforms with printing type.³⁶ The following year, a draft that sought to fulfil these criteria was ready and put to a first, limited trial in select schools.³⁷

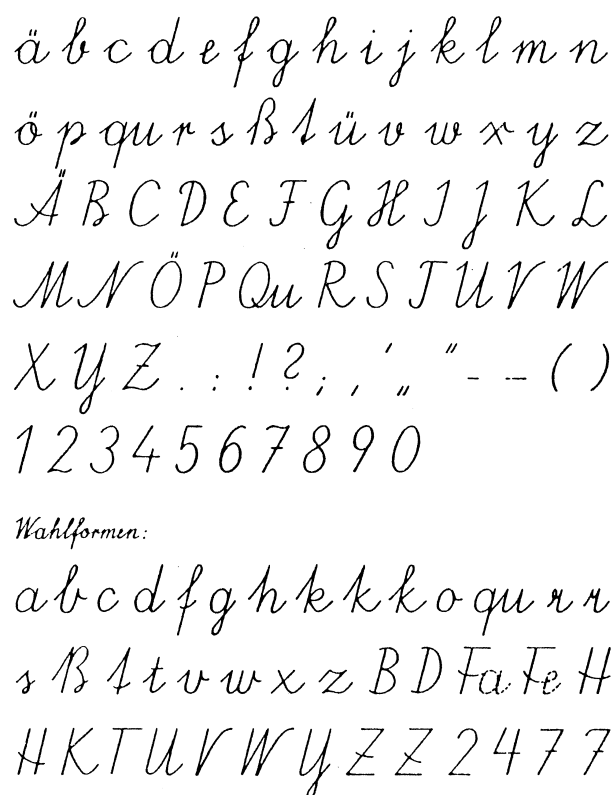


FIG. 9. Draft dated 1985 of the handwriting reform initiated in 1984, from Ludwig Boyer, *Kommentar zur Ausgangsschrift*, 2nd. ed., aps (Vienna: Bundesministerium für Unterricht, Kunst und Sport, 1988) 77

36. Boyer, *Kommentar zur Ausgangsschrift*, 79–80.

37. According to Boyer, the 1985 draft was revised in 1987 but the literature does not document any changes and no original documentation of the process has been found. Boyer, *Kommentar zur Ausgangsschrift*, 77.

After two years, the test was extended to more than 3000 classes across Austria and run from the school term 1987/88.³⁸ The trials were accompanied by teacher questionnaires in 1988—which reportedly were positive—and a quantitative evaluation in 1991 in which writing samples of 154 participating classes were compared with specimens from a control group of 300 classes. The goal of the evaluation was to compare the new proposal to the previous model using scientific methods, yet the only quantifiable criterion—correct orthography—did not yield any statistically relevant differences. All other evaluations were qualitative appraisals, wrapped in a quantitative selection of samples.³⁹ Whilst illustrating the difficulty of using objective measures in the assessment of handwriting instruction methods, it also shows that the subject was taken remarkably seriously by the authorities. In summary, although far from scientific proof, the findings of the various assessments and the feedback received from participating teachers suggested that the new draft was an improvement over the previous model.

Although these results were available by 1991, only in autumn 1994 the Ministry published the new model as ‘Österreichische Schulschrift 1995’. Despite the ten-year (!) gestation, the final version differed only slightly from the 1985 draft: a handful of letterforms were substituted by alternates which had already been conceived for the earlier version: f and t lost their loop in favour of a two stroke construction; o was now written without internal loop; and B, D, F, and H were rendered as less ornate letterforms. Perhaps, considering that the model consisted only of a handwritten alphabet, rather than a full typeface, the excessively long development may be attributable to political factors.⁴⁰

Henceforth the precursor model was called ‘Schulschrift 1969’, officially because it was the last time a change had been made, ignoring (and perhaps conveniently disguising) that its design largely dated to 1924. But also the 1995 version was not entirely new. A comparison with the 1969 model demonstrates two key changes: in the minuscules, the internal loop in a, d, g, o, and q—a glaring anachronism not found in any other Latin writing model—was removed, and in the capitals, where most changes happened, more letterforms akin to printing type were proposed. In summary, the Schulschrift 1995 achieved some of its stated goals: the reduction of redundant loops and ornamental flourishes lent the new model a more modern appearance and the simplifications of ar-

38. Lichtenwallner and Scheiber, ‘Die Österreichische Schulschrift’, 668.

39. For details of the methods see Lichtenwallner and Scheiber, ‘Die Österreichische Schulschrift’, 668–670.

40. The official handwritten alphabet chart, which constituted the main visual of the published model, contains a small note identifying Hadmar Lichtenwallner (1944–2023) as its writer. No other claims of credit or attribution to Lichtenwallner have been found.

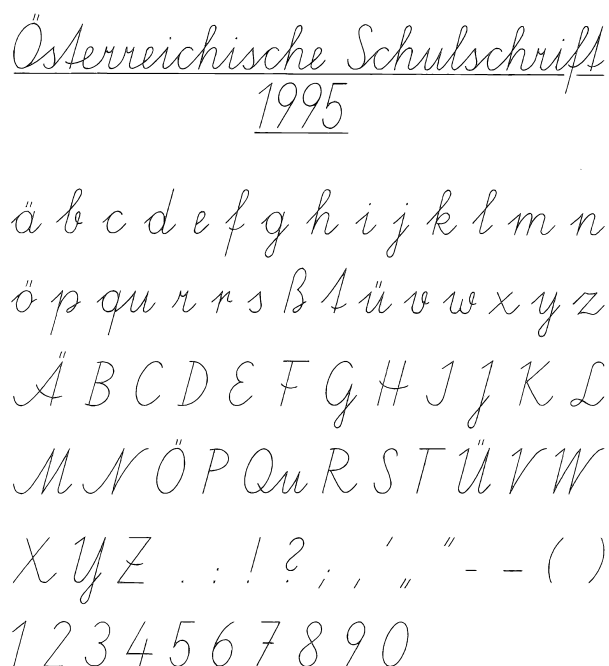


FIG. 10. Official published sample of the handwriting model unveiled in 1994, from *Die Österreichische Schulschrift 1995: gut lesbar, leicht erlernbar, besser vermittelbar*, (Vienna: Bundesministerium für Unterricht und Kunst, 1994) 7

chitecture contributed to letterforms that were easier to learn and faster to write. Importantly, a comprehensive commentary to the new model was published as a section of the *Kommentar zum Lehrplan der Volksschule*.⁴¹ It explained considerations that led to the new design and elaborated on optional decisions that were left to the teachers, adding important nuance to the widely distributed alphabet chart. For example, it suggested further simplifications where appropriate, such as the use of a roman capital E shape instead of the default cursive form if children struggled with the shape; it encouraged teachers to suppress in-strokes at the beginning of words, offered alternative constructions for letterforms, and gave recommendations for plausible connections between capitals and minuscules, as well as cases in which interruptions were recommended. In short, it provided a manual for teaching writing with the new model.

To what extent the qualifying commentary was absorbed by Austrian primary school teachers in the 1990s is not known, but current practice suggests that its detailed considerations are not generally appreciated.

41. Dieter Antoni, ed., *Kommentar Zum Lehrplan Der Volksschule* (Vienna, 1996).

Furthermore, perhaps owing to the idea that a distinctly 'Austrian' identity should be maintained, anachronistic details and idiosyncratic letterforms were carried over into the new model. Despite its move towards letterforms of the italic hand, the Ronde style r—curiously introduced in 1965—and the Kurrent form of t with a full-length ascender—hailing from Sütterlin's 1914 model—were retained. Irrespective of questionable choices for individual letterforms, the Schulschrift 1995 was hamstrung by other factors.

Conceptually, despite the considerable effort that went into the new model, it ignored the question which letterforms children learned first. In Austria reading and writing instruction typically begins with block capitals and print minuscules, but the 1995 reform offered no guidance or model for these very first letterforms that children encounter. The curriculum left it open to teachers whether to use only roman capitals (Blockschrift), mixed-case roman type (Gemischtantiqua), or the new running writing model (Schulschrift).⁴² The bulk of literacy acquisition that happens in the first grade was thus excluded from consideration in the 1995 reform, limiting its remit to running writing. Issues surrounding the ideal order in which various writing styles should be taught, including the potential difficulties that children encounter when progressing from one form to the other—an area of considerable professional debate and interest—were wholly eschewed.

Moreover, political indecisiveness, perhaps triggered by concern to cause a backlash as during the abortive 1964 reform, meant that the Ministry left it open to teachers which model to use in class. From 1995 either version could be taught, with the result that two classes of the same school could be learning different models. The curriculum emphasised that the Schulschrift 1995—as had already been the case for all its precursors since 1924—was only intended as a guideline, rather than a prescriptive norm. To avoid any form of 'dogmatism', teachers were left to decide which letterforms they considered most suitable for their writing instruction, potentially also mixing elements of both versions in their teaching.⁴³

Yet the most critical failure of strategic vision was the decision not to develop the model as a digital font for distribution. On one hand, Lichtenwallner and Scheiber presented a rationale for this inaction, arguing that it intended to avoid formal prescription and celebrate the irregular quality of handwriting.⁴⁴ On the other hand, they reasoned that

42. Ludwig Boyer, '6 Schreiben (1. und 2. Schulstufe)', in *Kommentar zum Lehrplan der Volksschule*, ed. by Dieter Antoni (Vienna, 1996), 314.

43. Lichtenwallner and Scheiber, 'Die Österreichische Schulschrift', 670–671. Although well intended, it is questionable whether primary school teachers consider it helpful to have the responsibility for such fine-grained choices of letterforms.

44. Lichtenwallner and Scheiber, 'Die Österreichische Schulschrift', 665.

a digital cursive type would have resulted in many bent lines and other compromises of shape, betraying the actual reasons for the decision: an inability to implement a digital font in the quality and complexity that was required.⁴⁵ Although the federal publishing house (Österreichischer Bundesverlag, öbv) went on to commission a digitisation of the *Schulschrift 1995*,⁴⁶ it appears to have been a strictly proprietary endeavour which remained exclusive to the company.⁴⁷ Moreover, the fonts lacked the detail, options, and subtlety that were called for in the commentary to the new model.⁴⁸

As a result, the making of handwriting primers, in the 1990s already predominantly reliant on digital workflows, lacked the means to faithfully reproduce the *Schulschrift 1995*. As the handwriting of samples was no longer a viable practice, publishing houses used digital fonts to approximate the model provided in the curriculum. But for want of an officially approved digitisation, publishers had to source suitable type for their books elsewhere. Owing to the limited choices on the market and lacking clear incentives to invest in a qualitative reproduction of the official model—the emphasis of the guidelines that a vague resemblance was good enough could be interpreted that way—free fonts began to fill the gap. The concern that a typeface could not convincingly reproduce the handwritten model—advanced by the team behind *Schulschrift 1995* to argue against the making of a font—thus materialised because the field was left vacant. Mediocre to downright substandard digital typefaces by hobbyists, distributed via freeware sharing sites without quality control, found their way into Austrian reading and writing primers. With the rise of online platforms for the exchange of teaching materials these fonts proliferated and began to be used by teachers designing their own materials with predictably poor results. The apparent lack of vision and care for the technical conditions in which didactic materials are made thus contributed to a marked deterioration of the circumstances for literacy acquisition in Austria.

Against this background, in 2018 Yuki Sakurai, then head of the Wiener Bildungsserver, an association of the city of Vienna that aims

45. 'Aus diesem Grund, wie auch wegen der eingangs erwähnten besonderen Qualität einer Handschrift, war es auch keine Zielvorstellung, eine die digitale Verarbeitung optimal ermöglichende Verbundschrift zu entwerfen; dies hätte an vielen Stellen geknickte Linien und andere den Intentionen zuwiderlaufende Formmerkmale erfordert.' Lichtenwallner and Scheiber, 'Die Österreichische Schulschrift', 665.

46. According to Lichtenwallner and Scheiber the type contained a wide and a narrow version. Lichtenwallner and Scheiber, 'Die Österreichische Schulschrift', 665.

47. Note that whilst still a publicly funded company in the 1990s, in 2002 the publisher was privatised.

48. An early use example of the font is found in Franz Jarolim, *Schreiblebrgang Österreichische Schulschrift 1995* (Vienna, 1996). The type appears to be in continued use by the publisher, the largest commercial provider of didactic material.

Buchstabenformen
primitiv ist nicht kindgerecht

Mimi weinte, die Buchstaben taten so in den Augen weh

*Buchstabenformen
primitiv ist nicht kindgerecht*

Mimi weinte, die Buchstaben taten so in den Augen weh

FIG. 11. Samples composed in the widely used free fonts 'Fibel Vienna' (above), made by a certain Peter Wiegel, and 'Schulschrift95' whose originator could not be identified. The large sizes demonstrate poor workmanship in curves and inadequate proportions, the smaller sizes show the negative effect of sub-par spacing on word formation.

to facilitate media competence amongst children,⁴⁹ approached Martin Tiefenthaler in his capacity as a founding member of the typographic association of Austria, with the suggestion to develop a new typeface for learning to read and write.

The Making of Primæ

Interested by the project, Tiefenthaler, an experienced typographer and teacher at Vienna's 'die Graphische',⁵⁰ sought a professional type designer with a demonstrated interest in handwriting instruction. Around

49. 'Home | Wiener Bildungsserver' <https://bildungsserver.wien/start/home-wiener-bildungsserver> [accessed 12 February 2025].

50. Die Graphische was founded in 1888 and is the oldest vocational school for graphic arts in Austria.

the same time Nemeth's three-year-old son developed an early fascination with writing, prompting him to explore didactic fonts and make an improved digitisation of the Schulschrift 1995 for personal use. In conversation, we recognised that our shared interest and respective competences aligned well, and decided to collaborate on the making of a new typeface for learning to read and write.⁵¹

Although initial conversations stretched back as far as 2018, the global Covid pandemic meant design work could only begin in earnest once a formal agreement with the Bildungsserver was reached, in April 2021.⁵² In the interim Tiefenthaler had researched the state of handwriting instruction in Austria, the German speaking world, and beyond. He had reviewed academic literature,⁵³ current handwriting primers,⁵⁴ contributions from typographic designers,⁵⁵ and conducted informal interviews with primary school teachers. Moreover, he had invited a group of distinguished typographic scholars and designers to form a review panel

51. A long friendship and previous professional cooperation helped in making this decision.

52. By that time the organisation's leadership had changed, it was now headed by Donat Klingesberger.

53. See for example Karin H. James and Laura Engelhardt, 'The Effects of Handwriting Experience on Functional Brain Development in Pre-Literate Children', *Trends in Neuroscience and Education*, 1/1 (2012), 32–42; Marieke Longcamp, Marie-Thérèse Zerbato-Poudou and Jean-Luc Velay, 'The Influence of Writing Practice on Letter Recognition in Preschool Children: A Comparison between Handwriting and Typing', *Acta Psychologica*, 119/1 (2005), 67–79; Danielle S. McNamara, ed., *Reading Comprehension Strategies: Theories, Interventions, and Technologies* (New York, 2007); Christian Marquardt and others, 'Learning Handwriting at School—A Teachers' Survey on Actual Problems and Future Options', *Trends in Neuroscience and Education*, Writing in the digital age, 5/3 (2016), 82–89; Pam A. Mueller and Daniel M. Oppenheimer, 'The Pen Is Mightier than the Keyboard: Advantages of Longhand over Laptop Note Taking', *Psychological Science*, 25/6 (2014), 1159–68; Audrey L. H. van der Meer and F. R. (Ruud) van der Weel, 'Only Three Fingers Write, but the Whole Brain Works†: A High-Density EEG Study Showing Advantages of Drawing Over Typing for Learning', *Frontiers in Psychology*, 8 (2017).

54. See in particular Renate Tost and Frank Ortmann, *Schreibenlernen mit der Hand bildet Formsinn und Verstand: Gestalterische Grundlagen der Schulausgangsschrift* (2021); Rosemary Sassoon and Gunnlaugur S. E. Briem, *Better Handwriting*, Teach Yourself (London, 1993).

55. Important influences were the contributions by the Swiss type designer Hans Eduard Meier, the British and American schools of italic handwriting of the twentieth century, and the Dutch writing scholar Gerrit Noordzij. Hans Eduard Meier, *Anleitung Zu Einer Zeitgemässen Schulschrift Für Alle, Die Schreiben Lernen: Ein Buch Für Die Lehrenden Und Übungsbefte Für Die Lernenden* (Glarus, 2003); Alfred Fairbank, *A Handwriting Manual*, rev. and enlarged (London, 1975); Gerrit Noordzij, *Kind und Schrift* (München, 1985); Gerrit Noordzij, *The Stroke: Theory of Writing*, trans. by Peter Enneson (London, 2005).

that we were able to consult during the design process.⁵⁶ By 2021 much of this preliminary work was done and we settled down to establish how we were to approach our task. In conversation we reviewed precursors, weighed strengths and shortcomings, and considered how best to respond to the primary challenges that were reported by teachers. Through this process, we distilled key findings that informed our five primary design principles: we wanted to achieve (1) a structural formal relationship between unconnected and joined letterforms; (2) an ergonomic architecture of letters *and* their connections in running writing; (3) even spacing achieved through formal freedom over technological constraints; (4) a model that demonstrates the freedom to interrupt running writing and to write letters in different ways; (5) a model that demonstrates the same care for letterforms of different languages for the inclusion of children of all backgrounds. The following account is drawn from our own research and design process rather than the secondary literature.

1. Disconnected—Connected

The *Schulschrift 1995*, as well as many other methods teaching running writing, ignores which letterforms children learn in their first steps of literacy acquisition. It treats disconnected and joined writing styles as unrelated sets of letterforms and relies on children learning a second formal palette. In Austria, owing to the lack of a model of first letterforms and the subsequent adoption of crude printing fonts for writing instruction, the gap between the first and the second writing style tends to be particularly wide. Many didactic publishing houses even feel compelled to have ‘transitionary’ course books in their range, as the jump from so-called ‘printed’ letterforms to running writing is perceived to be excessively demanding for children.

This lack of consideration of a central element of instruction is surprising, as the literature on methodology had engaged with the subject for a long time. In 1995 Boyer suggested that there was no consensus on which style to learn first,⁵⁷ but cited Heinrich Grünewald thus:

Es ist grundsätzlich von Nachteil, wenn Schüler nacheinander zwei Schriftalphabete schreiben müssen, die in ihrer Form und Struktur voneinander abweichen. Denn das individuelle Bewegungsverhalten verfestigt sich

56. The advisory board was formed by Ann Bessemanns, Matthew Carter, Florian Hardwig, Sami Kortemäki, Just van Rossum, and Alice Savoie.

57. Boyer, ‘6 Schreiben (1. und 2. Schulstufe)’, 314–315. Boyer suggested that an initial handwriting model that converges with the forms of printing type could alleviate the issue.



FIG. 12. Samples composed in 'Fibel Vienna' and 'Schulschrift95' show the absence of formal cohesion between first and second writing styles that exacerbate the difficulty children experience when learning running writing.

beim Schreiben verhältnismäßig früh und wird selbst dann beibehalten, wenn die äußere Form der Schrift ein anderes Gesicht bekommt.⁵⁸

Historically, this question has already occupied teachers and reformers of handwriting education for more than a hundred years. It found an early expression at the beginning of the twentieth century with the so-called 'print-script' movement in the United Kingdom. It promoted the use of a single set of simplified, skeletal letterforms for reading and writing instruction, arguing convincingly that it helped children to master initial literacy acquisition. Much like in the German speaking world, this reform movement was born from the struggle to teach children the calligraphic English roundhand, and in response it jettisoned any form of running writing altogether.⁵⁹ Fairbank, a leading proponent of the italic hand, however, criticised this approach as excessive, noting that

58. It is fundamentally disadvantageous if pupils successively have to write two writing styles which differ in form and structure. For the individual motor movement consolidates relatively early in handwriting and is retained even if the superficial form of the script changes. [my translation] Heinrich Grünewald, *Schreibenlernen: Faktoren—Analysen—methodische Verfahren*, Kamps pädagogische Taschenbücher (Bochum, 1981), 52.

59. Walker, 'Letterforms for Handwriting and Reading: Print Script and Sanserifs in Early Twentieth-Century England', 90–98.

Print-script is held by teachers of infants, who are doubtless appreciative of its simple character, to be of assistance in teaching both reading and writing, since one alphabet serves the two purposes. It has two shortcomings: there is nothing about it that gives a hint of development into a running hand and it has circular instead of elliptical movements.⁶⁰

The D'Nealian method, developed by the teacher Donald N. Thurber (1927–2020) in response to the 'print script' approach, also sought to resolve the issue of two writing styles. It proposed two strongly related sets of letterforms with an identical inclination, arguing that it removed the need to learn everything again when progressing to a running hand:

Learning is accomplished on a continuum without a break in the developmental process. Ninety percent of what the child learns in forming print letters will carry over into later cursive writing. With the addition of connecting strokes, manuscript print becomes cursive when the child is ready.⁶¹

In France, by contrast, the current model exclusively teaches connected letterforms, avoiding the issue by discarding upright minuscule letterforms entirely.⁶²

In our approach, the unconnected style is characterised by all the qualities that the 'print-script' proponents and its later successors demand for ease of learning—unadorned simplicity, monolinear strokes, skeletal forms—reflecting the letters children already encounter prior to

60. Fairbank, *A Handwriting Manual*, 26.

61. Quoted from Sassoon, *Handwriting of the Twentieth Century*, 189. The conceptual similarity between Primæ's unconnected and cursive styles and the D'Nealian method has only been brought to our attention after its publication.

62. In contrast to the Austrian authorities, in France the Ministry already recognised the need for a digitisation of its writing models in 2013: 'De nouveaux supports sont apparus et se développent encore qui introduisent le stylet numérique et renouvellent le besoin des enseignants et de leurs élèves de disposer de polices de caractères cursives de qualité, reconnues par le ministère de l'éducation nationale et mises à disposition de la communauté éducative pour l'apprentissage de l'écriture et l'édition des documents pédagogiques. En effet, les tableaux numériques interactifs (TNI) équipent progressivement les salles de cours et les tablettes ou ardoises tactiles pénètrent dans les classes elles aussi depuis deux ou trois ans en réintroduisant le stylet numérique à côté du clavier virtuel.' 'New media have appeared and are still being developed which introduce the digital pen and renew the need for teachers and their pupils to have access to quality cursive fonts, recognised by the French Ministry of Education and made available to the educational community for learning to write and for publishing educational documents. Interactive digital whiteboards are gradually being installed in classrooms, and touch-sensitive tablets and boards have also been making their way into classrooms over the last two or three years, reintroducing the digital pen alongside the virtual keyboard.' [my translation] Ministère de l'éducation nationale, *Modèles d'écriture scolaire* (Paris, 2013) <https://eduscol.education.fr/204/polices-de-caracteres-cursives-pour-l-enseignement-de-l-ecriture> [accessed 16 February 2025].

school.⁶³ At the same time its letterforms anticipate the architecture required for faster (running) writing, favoured by advocates of the italic hand. Thus, as already demanded by Dostal in 1972, in our design arched characters like h, m, n etc. have a structure that facilitates a single continuous movement, rather than an interrupted construction from two strokes. Because the unconnected style is used first to teach *writing*, we chose to design letterforms that can actually be written. Like the n-group, also the e, the most frequent character of German, has a ‘written’ architecture that sets it apart from commonly used printing type which, owing to its rigidly constructed aspect, is more suggestive of drawing.⁶⁴



FIG. 13. Samples composed in ‘Primæ’ demonstrate how—in contrast to the samples in figure 12—the formal consistency between first and second writing styles facilitates the transition from unconnected to running writing.

To facilitate the transition from first to second writing style, the most idiosyncratic and anachronistic shapes of the *Schulschrift* 1995 also re-

63. In Germany the lively discourse about the appropriate initial writing style, paired with a strong federal tradition, led to the adoption of various models in different states. One stream of thought propagates that only unconnected letterforms similar to printing type—the so-called *Grundschrift*—should be taught. Our approach shares many of its arguments, which are summarised in Horst Bartnitzky, Ulrike Hecker and Christina Mahrhofer-Bernt, eds., *Grundschrift: Damit Kinder Besser Schreiben Lernen*, Beiträge Zur Reform Der Grundschule, 132 (Frankfurt am Main, 2011).

64. It is not a coincidence that proponents of print-script talked about ‘drawing the printed letter’, a practice that is hardly conducive to teaching writing.

quired attention. The Ronde form of r and the Kurrent form of t are entirely alien to children who are growing up today. They encounter these letterforms for the first and only time when they begin to learn running writing, introducing a wholly unnecessary hurdle at an advanced stage of the learning process. With the corresponding letterforms from the humanistic minuscule—the ‘printed’ form—we can avoid this difficulty for current learners. The same principle applies to the triangular letterforms for v and w, which are now better distinguished from u and related shapes.



anachronistic
appropriate
appropriate

FIG. 14. Juxtaposition of samples composed in ‘Schul 95 normal’ by a certain Hans-Dieter Lahe (above) and ‘Primæ’ (below) illustrates the effect brought by substituting the anachronistic shapes of r and t. The third line shows the optional interruptions after r and t in ‘Primæ’.

Furthermore, even in the unconnected style we introduced a minute slant to the right. It not only indicates the writing direction but is also suggestive of the inevitable imperfections of the human hand, avoiding the impression of technical exactitude and rigidity that may unduly intimidate young learners. Finally, the modest inclination hints at the effect of a higher pace, preparing for the next phase of learning: running writing.

2. Ergonomic Letterforms *and* Connections

Whereas the commentary on the Schulschrift 1995 in theory contained certain freedoms of letterform construction and joining principles, these provisions were largely lost in practice. The principal information about the model distributed to teachers was a single handwritten alphabet sheet and the letterforms themselves provided little clarity and guidance on construction and ductus.



FIG. 15. Comparison of a word set in 'Schul 95 normal' (above) and a word set in 'Primæ' (below) illustrates the advantages of italic letterforms of a, d, g over the synthetic shapes of the Schulschrift 1995, which are bereft of handwriting qualities.

Moreover, inept digitisations reproduced the official model with a minimal characterset in which a single letterform represented every letter irrespective of context, providing a grossly misleading example. The letterforms of a, d, g, o, and q were the principal targets for the 1995 reform as the interior loop, introduced by Legrün for a continuous writing movement, was deemed outdated. However, rather than devising a new lettershape with a clear and unambiguous stroke order and directionality, the Schulschrift 1995 only purged the offending loop. The reformed model therefore proposed highly synthetic letterforms, that, paraphrasing Fairbank, have nothing about them that give a hint of running writing. Pupils and teachers are left to guess how these letterforms may or may not be written. [see figure 16 below]

In our approach, the tried and tested architecture of italic letterforms has no such issues: a, b, d, g, p, and q are distinguished by their asymmetrical, pointed counters. Tiny gaps and slight swelling of strokes indicate changes of direction, providing visual hints for the stroke order even in fully joined words. And the letterforms of o are conceived so that they

can only be written in one way, offering clear and unambiguous guidance to the learner.

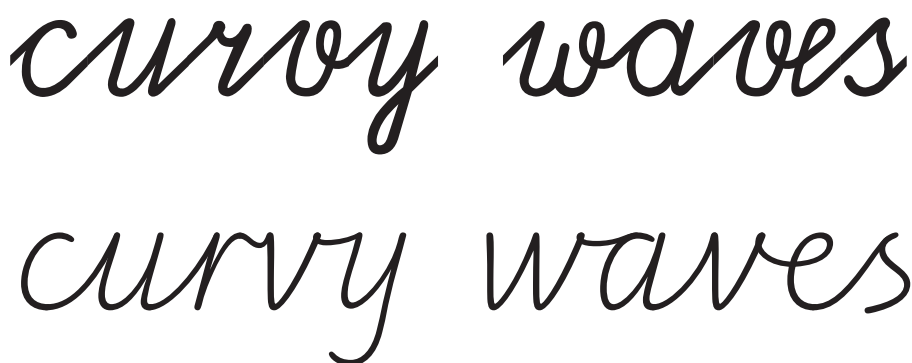


FIG. 16. Comparison of two words set in ‘Schul 95 normal’ (above) and in ‘Primæ’ (below) demonstrate the latter’s benefits: italic letterforms for *r*, *v*, and *w* provide increased clarity, the drawings are of a quality that can serve as a model, and thought-through joining strategies improve ergonomics, remove redundant strokes, reduce ambiguity, and deliver evenly spaced words.

In the *Schulschrift 1995*, the lack of documentation or a sound digital font makes the practice of connecting letters—an element of considerable import in running writing—lamentably underdeveloped. The sample in figure 10 shows that the individual letters of the alphabet cannot possibly suffice to demonstrate how letterforms may be written continuously. In our design we therefore made the joins between letters an area of heightened attention and, where appropriate, left them out entirely.

In primers that claim to follow the *Schulschrift 1995*, there are many cases of capitals joined to following minuscules where such a connection is wholly inappropriate. Whenever a *B*, *D*, *F*, *I*, *N*, *O*, *P*, *T*, *V*, *W*, or *X* is joined to any lowercase letter, an additional and redundant stroke has to be introduced, a practice that we consider unergonomic. Furthermore, for letters such as *F*, *P*, and *T*, the superfluous joining stroke that extends from the base of the stem creates considerable potential for ambiguity and confusion. In our approach a connection between a capital and a minuscule is only provided where the final stroke’s direction and trajectory suggests that it may be continued to join with the next letter.

Enabling fluid and ergonomically sound connections between minuscules is even more important and a key design consideration in the making of *Primæ*. Here, we identified a recurring shortcoming of previous handwriting models and their reproduction as digital fonts.

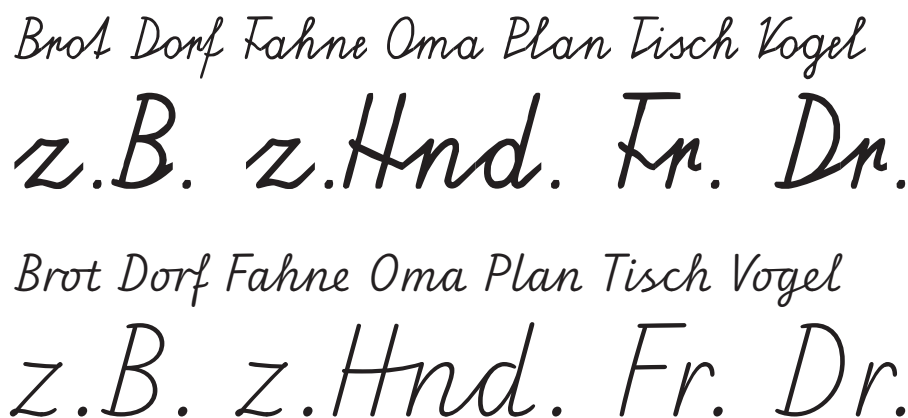


FIG. 17. Sample composed in 'Schulschrift95' (above) shows the negative effect of superfluous connections between capitals and minuscules. The sample set in 'Primæ' (below) highlights the considerable improvements in clarity brought by interruptions.

3. Formal Freedom Over Technological Constraints for Even Spacing

Designing a handwriting font primarily means conceiving of a systematic way to join disparate elements of various shape and alignment in a plausible way. Ideally, it should appear natural, so that the reader—or indeed the learner who copies the example—perceives the connections between letters as self-evident and unobtrusive to reading and writing. The joining system should be invisible.

This is not the case in digitisations of the Schulschrift 1995, where every letterform, regardless of the surrounding letters or whether standing by itself, always sports unsightly connecting lines at the same height. These elements create disfigured letterforms, with considerable potential for distraction and confusion, and it is hard to think of a context in which this could be more inappropriate than in the acquisition of reading and writing. The resulting detours and illogical stroke sequences are imposed on children, apparently ignoring the exceedingly bad example that they set. [see Fig. 17 above]

The influence of inadequate technical ability on the teaching of reading and writing can also be seen in a German model, the 'Vereinfachte Ausgangsschrift'. Here, every joining letterform has to terminate at the

x-height, imposing a modularity that is completely alien to handwriting, but directly reflects the simplification strategies of printing type.⁶⁵

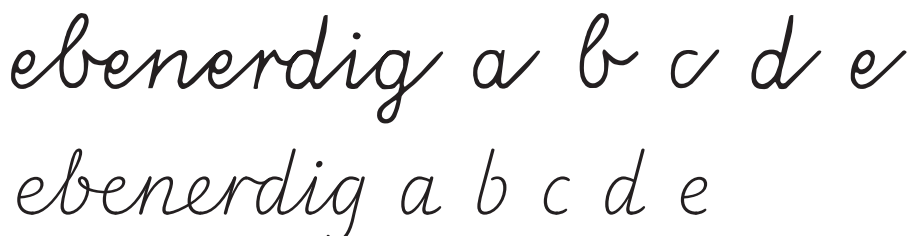


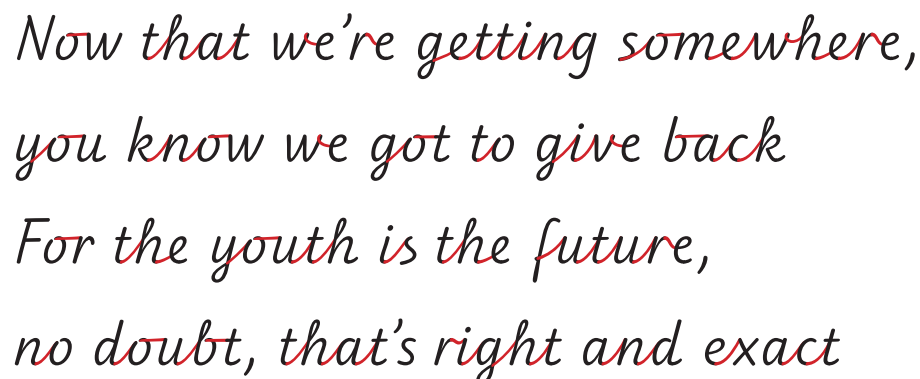
FIG. 18. Sample composed in ‘VA unliniert’ (above), a font distributed by the German Pelikan Group GmbH, shows—apart from inferior craftsmanship in type design—the nonsensical modularity of the ‘Vereinfachte Ausgangsschrift’ that imposes mechanical simplification on children’s handwriting. The sample in ‘Primæ’ below illustrates the effect of the opposite approach, wherein technical solutions were designed for fluid writing.

In our design approach, we did not want technical circumstances to prescribe how children learn to write. Instead, we strove to develop technical solutions to facilitate the task. The method that we developed was informed by my experience with the joined Arabic script, one of the most sophisticated writing cultures of humanity. In Primæ, connections between letters are conceived to enable ideal—i.e. ergonomic, direct, and fast—connections between any letter sequence. Rather than prescribing how *letterforms* must be shaped to match a modular system, as seen in the digitisations of Schulschrift 1995 and the Vereinfachte Ausgangsschrift, in Primæ *flexible joining strokes* adapt to the context. [see Figure 18 above]

With this approach, the model provides connections that reflect proven manuscript practice regardless of letter sequence. That different letterforms call for different connection strategies is an inherent characteristic of running writing: it is not ergonomically possible to join the sequence n-e in the same way as o-e. Primæ shows how various combinations are best solved, providing learners with established strategies, rather than leaving them struggling to come up with their own solutions—as advocated by some methods. The effort to learn a tried and tested system, even if it entails variation, is incomparably easier than de-

65. Criticism of the ‘Vereinfachte Ausgangsschrift’ is widespread, and some commentators suggest that it was introduced to save publishing houses the costs associated with the making of handwritten samples because it allowed for easier typographic reproduction. Ute Andresen, ‘Einführung der Grundschrift: Keine pädagogischen Interessen’, *Die Tageszeitung: taz*, 6 April 2011 <https://taz.de/Einfuehrung-der-Grundschrift/!5123334/> [accessed 27 February 2025].

vising one from scratch: we do not think that every child that learns to write has to reinvent the wheel all over again.



*Now that we're getting somewhere,
you know we got to give back
For the youth is the future,
no doubt, that's right and exact*

FIG. 19. Illustration of the joining strokes in 'Primæ'. Harnessing current digital font technology, 'Primæ' automatically inserts tailor-made joining strokes between eligible letter pairs.

Moreover, and in stark contrast to extant handwriting instruction fonts, it allowed us to optimise the spacing between every letter combination. Primæ does not need a commentary to point out that one letter sequence requires a different joining strategy or that a particular combination benefits from more generous spacing: it shows it. Writing techniques that are hidden in conventional modular fonts, are thus made explicit and transparent in Primæ. Here, pupils can learn by observation and imitation, avoiding the frustration of opaque letter connections that cannot be written by hand. Owing to this design solution, we could create a model that not only demonstrates comfortable, continuous, evenly spaced, and fluid writing, but that can also be used to show deliberate interruptions.

4. Freedom to Interrupt Running Writing and to Write Letters in Different Ways

In our conversations with teachers, we frequently heard reports about the difficulty some children have connecting all the letters in running writing. Long words, which are frequent in German, may lead to a cramped hand, and to a correspondingly unpleasant experience for the learner. This need not be the case. There is wide-spread recognition that the compulsory joining of all letters is not important, nor should it be required of children. One would probably be hard pressed to find a teacher

today who insists on the seamless connection of each and every letter, and neither curriculum nor common methods require such a feat from children. Notwithstanding this consensus, primers for running writing principally show only fully joined examples, setting a standard that is difficult or sometimes impossible to achieve. Without qualification or commentary such samples may become the root of one of the most frustrating, and thus destructive aspects of handwriting education.

In our approach, we wanted to avoid this remnant of ill-understood discipline in schooling. Because the example provided to learners plays such a central role as the implicit authoritative model, we decided that it had to allow for variation and give room to alternatives. Consequently, *Primæ* is built with the ability to demonstrate interruptions within running writing, as well as the option to select from a range of alternate letterforms in either writing style. Teachers, publishers, and designers may take advantage of this ability to facilitate various didactic approaches, and stylistic preferences. Pupils struggling with a letterform may be shown a different variant to demonstrate that it is perfectly acceptable not to connect all the letters of a word. The fonts provide designed interruptions after the *r*, that benefits in clarity from a break; before *k* and after *t*, letterforms that are written with two strokes; after the descenders of *g*, *j*, and *y*, where the looped connecting stroke may be more cumbersome; and after the umlauts *ä*, *ö* and *ü*, where the diacritic sign may encourage a mid-word interruption. The *x*, a notoriously difficult letterform for continuous writing, does not connect to the right by default. Yet, it may also be displayed without any connections or fully joined if the architecture of surrounding letters suggests continuous strokes. Further to the capitals *B*, *D*, *F*, *I*, *N*, *O*, *P*, *T*, *V*, *W*, *X* that never join a following letter, *E*, *G*, *K*, *L*, *R*, and *Q* are also available as isolated letterforms.

We realise that other break points may appear in individual hands—as for example in the case of any letters with diacriticals. The intention of the range of optional interruptions included in *Primæ* is therefore not a comprehensive inventory of possible breaks—which is not realistically possible—but to provide a tool that may be used to illustrate that the consistent joining of all letters is not compulsory.

In this spirit, *Primæ* also includes numerous variants of letterforms. As in the case of optional interruptions, they may provide alternative solutions to children struggling with the default model. In the unconnected style, there are two forms of *f* and *J*, with and without descending stem; the *k* may be shown in a continuous or a two-stroke architecture; the *q* may feature a spur, distinguishing it from *g*; the *a* can be shown in its two-storey form, akin to printed type; and the *U* may feature an outstroke or not. The cursive style contains, further to the optional interruptions, stylistic variants of the *æ*, as written in some Scandinavian countries, and of the *ß* with or without descender.

*Ella, Gianna, Karl,
León, Quentin, Rosa
crickey, roar, tricky, räksmörgås
müesli, jarringly, texts, sixteen*

FIG. 20. ‘Primæ’ contains optional interruptions in strategic positions to illustrate that the consistent joining of all letters is not compulsory.

5. Linguistic Inclusion and Typographic Utility

Comprehensive language support was an essential aspect of our approach to Primæ’s design. Whereas this is widely considered a standard of professional type making today, unfortunately a review of current digital fonts for handwriting instruction revealed that children’s educational material does not typically receive the same care and attention.

As there are no officially supported fonts in Austria, we were not surprised that the haphazardly digitised fonts of the Ministry’s model do not contain accented characters for other languages. But also in Germany, where commercial providers offer digital fonts of the various styles taught across the states, children’s names in languages like Polish or Turkish are not supported.⁶⁶ In France, one of the most multi-ethnic and multilingual countries in Europe, where official fonts were commissioned by the Ministry of Education in 2013, languages beyond those that share French accents are ignored.⁶⁷ Even the open-source Australian school fonts that were built and published with the help of Google include a minimal character set that supports only English.⁶⁸

66. ‘Schulschriften von Will Software’ <https://www.will-software.com/infos/schlsoft.htm> [accessed 23 February 2025].

67. Ministère de l’éducation nationale, *Modèles d’écriture scolaire*.

68. Mez, ‘MezMerrit/AU-School-Handwriting-Fonts’ (Australia, 2024) <https://github.com/MezMerrit/AU-School-Handwriting-Fonts> [accessed 23 February 2025]. Google’s commissioned ‘Playwrite’ types have contemporary language support but were only published in summer 2024. It is a comprehensive type system that uses parametric design options to approximate the extant handwriting models of dozens

Josefine or Jeff, Ulysses or Ursula
 bequem, kreuz und quer, kleinkariert
above all alternatives
when Lætitia met Solskjar
große Straßenbahn

FIG. 21. Further to its optional interruptions, 'Primæ' contains a number of variant letterforms that can be used to offer pupils proven alternatives or to accommodate specific didactic approaches.

In contrast to such national handwriting models that limit their didactic remit to the dominant national language and its letterforms, from the outset Primæ's design was conceived as a multilingual and inclusive writing model. Diacritics and language-specific letterforms were designed in line with design principles established above. For example, Polish ogonek and Icelandic thorn take advantage of the interruption mechanism described in Section 4, and ə alone—used in Azerbaijani and gender-neutral Italian—is rendered with twenty specialised joining strokes in Primæ Cursive. Currently its characterset supports 215 languages written in the Latin script and its design principles lend it to the further extension of linguistic support.

Moreover, all styles of Primæ feature eight sets of figures (lining, tabular, ranging, tabular ranging, superscript, numerators, denominators, subscript), allow for the dynamic composition of fractions, and contain a broad selection of punctuation signs, commonly used symbols, and a

of countries. Given its scope, it is an approach that entails inevitable formal compromises. The documentation of the project 'Primarium' was also published after our project 'Prima' and is, despite the similarity of names, entirely unrelated. TypeTogether s. r. o., 'Primarium: Handwriting Education in Primary Schools', *Primarium* <https://primarium.com/> [accessed 23 February 2025].

Now also children who speak Dënesytiné Yatié (the language of the Chipewyan in Northwest Canada) can write their names. That also includes Ludmiła and Róża from Poland, Akyıldız and Çağdaş from Turkey, Sigríður and Emília from Iceland, Ëngjëll from Albania, Kateřina and Lukáš from the Czech Republic, Åke, Ødhe and Sørina from Northern Europe and of course François, Mátyás, Jokūbas, Siân, Nuñez, too, as well as Lætitia and Gal'la, Llúcia and Llorenç from Catalonia, not to forget Aîza and Əhməd from Azerbaijan.

FIG. 22. 'Primæ' has a large character set, supporting 215 languages written in the Latin script. For the authors, linguistic inclusion in the classroom is a matter of course.

handful of printer's ornaments such as arrows, checkboxes, manicules, and emojis that may be useful for the design of teaching materials.

Publication, Reception and Further Development

In February 2023⁶⁹ Primæ (then still called Prima) was published through a dedicated microsite,⁷⁰ the website of the Wiener Bildungsserver,⁷¹ and via GitHub.⁷² The announcement of a new typeface for learning to read and write by an association of the city of Vienna led to considerable media interest in Austria.⁷³ The reactions concerning approach, design principles, and the actual typeface were consistently

69. Although the first two styles of Primæ—regular and cursive—had been finished by summer 2022, strategic considerations of the client postponed the publication.

70. 'Primæ · Eine Schrift Zum Lesen- Und Schreibenlernen' <https://www.schulschrift.at/> [accessed 23 February 2025].

71. Wiener Bildungsserver, 'Prima' <https://prima.wien/> [accessed 23 February 2025].

72. Wiener Schriften, 'WienerSchriften/Prima', 2025 <https://github.com/WienerSchriften/Prima> [accessed 23 February 2025].

73. Oona Kroisleitner, 'Wiener Kinder bekommen eine neue Schulschrift', *Der Standard*, 23 February 2023, 9; Miriam Krammer, 'Wiener Schulschrift Bekam Elegantes Facelifting', *Die Krone*, 2 March 2023 <https://www.krone.at/2937352> [accessed 23 February 2025]; wien ORF.at/Agenturen red, 'Eigene Schreibschrift für Wien', *wien.ORF.at*, 2023 <https://wien.orf.at/stories/3196108/> [accessed 23 February 2025]; Andreas Tanzer, 'Schnörkelmalen Ist Geschichte', *Die Presse*, 3 July 2023 <https://>

positive,⁷⁴ leading to publications,⁷⁵ presentations,⁷⁶ and television appearances.⁷⁷ Two months later, in the annual competition of the Type Directors Club New York, Primæ was awarded the coveted Certificate of Typographic Excellence, probably making it the first type for learning to read and write to receive a design award.⁷⁸

To extend the reach of the project, in parallel to our design work Tiefenthaler and I repeatedly approached the Austrian federal Ministry of Education. Already in December 2022, before the publication of the project, we submitted a formal application for subsidies from the Ministry's dedicated fund for school-related activities.⁷⁹ By 30 January 2023, we were notified that the minister, Martin Polaschek of the conservative Austrian people's party, saw no possibility to support the project.⁸⁰ By coincidence, one week earlier Polaschek had announced a 'reform' of the Austrian curriculum in a circular letter, whereby the 1969 model was phased out, making the Schulschrift 1995, nearly 30 years after its publication, the only endorsed model.⁸¹ Eventually, at our insistence a meeting with the Ministry's section head responsible for primary edu-

www.diepresse.com/13437843/schnoerkelmalen-ist-geschichte [accessed 23 February 2025].

74. Some reporting emphasised the Viennese origin of the type, giving rise to critique of a perceived exaggerated federalism of Vienna, suggesting that the new model for handwriting instruction would only be applicable in the state. This, however, was never suggested by any party to the project, saying more about the political reality of Austria, than the commission of Primæ.

75. Lars Harmsen and Julia Kahl, eds., *Yearbook of Type 6 2022/2023: Movie Edition*, 1st edn (2022); Helene Hohmann, 'Prima By Titus Nemeth and Martin Tiefenthaler', *Slanted*, 2023 <https://www.slanted.de/prima/> [accessed 23 February 2025].

76. Titus Nemeth and Martin Tiefenthaler, 'Prima Schreiben Lernen' (presented at the tga lecture series, Vienna, 2023).

77. 'TYPO 2.0: Neue Schrift Für Schulkinder', *Café Puls* (Vienna, 2023); 'Wie geht denn das: Schreibschrift', *Studio 2* (2023) <https://tvthek.orf.at/profile/Studio-2/13890037/Studio-2/14192717>.

78. The One Club For Creativity, *TDC Awards—69th Winners Showcase | The One Club | Wiener Bildungsserver | Prima* <https://www.oneclub.org/tdcawards/showcase/69th/-item/46232> [accessed 23 February 2025]. Primæ was also successful at the 2023 competition of the Tokyo Type Directors Club and was selected to feature in its annual as an 'excellent work'.

79. Förderungen schul- beziehungsweise bildungsrelevanter Vorhaben (Aktivitäten) sowie der Volksguppen und Südtirol, Bundesministerium für Bildung, Wissenschaft und Forschung, 'Beihilfen und Förderungen' <https://www.bmbwf.gv.at/Themen/schule/befoe.html> [accessed 24 February 2025].

80. Geschäftszahl 2022-0.887.631, für den Bundesminister, Franz Friedrich to Titus Nemeth, 'Prima, die österreichische Schulschrift', 30 January 2023, Private collection Titus Nemeth.

81. Gerhild Trummer, 'Österreichische Schulschrift; Information über die Neuerungen ab SJ 23/24', 23 January 2023, Rundschreiben Datenbank <https://rundschreiben.bmbwf.gv.at/rundschreiben/?id=1062> [accessed 24 February 2025].

cation was arranged in June 2023.⁸² During this encounter, it was made clear to us that the media coverage of the project had not been appreciated,⁸³ that it was not possible to alter the Ministry's position on the writing model because of January's circular letter, and that it generally did not perceive the project to be of relevance for its activities or worthy of support.

Regardless of this ministerial disinterest, Primæ was adopted in numerous schools across Austria and continued to garner interest—as shown by the uptake of training sessions for teachers through the Wiener Bildungsserver, presentations,⁸⁴ and publications⁸⁵—and received positive feedback from educators and designers alike. In spring 2024 our proposal to expand the scope of Primæ was selected in a competitive bid for funding from the Vienna business fund (Wirtschaftsagentur Wien). Throughout the remainder of the year, Primæ was developed into an extended type family for didactic material containing twenty styles in five weights that was published in March 2025.

Primæ now contains dedicated variants for various use cases: the light versions are best suited for initial writing instruction in large sizes. Their skeletal design ideally demonstrates letter architecture and stroke order without the distraction of surrounding 'flesh'. Regular and semi-bold weights are tailored towards use in text, their sturdier letterforms being more suitable for display in smaller sizes. Bold weights can be used for headlines and to create visual hierarchies in documents, playing a key role for improved clarity and accessibility in didactic materials. In its standard form Primæ, like other handwriting models, is characterised by long extenders. Whilst appropriate in writing instruction, it lends proportions to letterforms that are ill-suited for longer texts and denser document layout. We therefore designed a dedicated Primæ Text version of the typeface that has shortened extenders, lending it proportions that are more similar to printing type. Primæ Text is therefore particularly

82. Present in the meeting were, next to Nemeth and Tiefenthaler, section head Doris Wagner, Markus Benesch, Marcus Hufnagl, and Gerhild Trummer.

83. By May 2023 Niki Glattauer, a pundit writing a column on education in the widely read newspaper *Heute*, publicly called on the minister to endorse and adopt Primæ. Niki Glattauer, "'Zurück in die Türkei': Wutlehrerin entschuldigt sich', *Heute* (7 May 2023), section Glattauer gibt Noten, 8.

84. Nemeth and Tiefenthaler, 'Prima Schreiben Lernen'; Titus Nemeth and Martin Tiefenthaler, 'Prima: An Innovative Type for Learning to Read and Write' (presented at the Grapholinguistics in the 21st Century, 2024, Venice, 2024) <https://grafematik2024.sciencesconf.org/> [accessed 26 February 2025]; Titus Nemeth and Martin Tiefenthaler, 'Primæ: An Extensive Innovative Type for Learning to Read and Write' (presented at the BRNO BOLD Typo02, Brno, 2025) <https://www.brnobold.cz/udalosti/brno-bold-typo-2> [accessed 26 February 2025].

85. Antje Dohmann, 'Prima soll Kindern das Lesen- und Schreibenlernen erleichtern', *PAGE online*, 2024 https://page-online.de/typografie/schulschrift_prima/ [accessed 23 February 2025].

useful in more compact text composition, as for example in applications that are designed for small screens or for continuous text typography such as reading primers.

Conclusion

Reading and handwriting remain key competencies children acquire early in their education, and despite their frequently forecast demise, they are still integral parts of curricula worldwide. Whilst the role of handwriting has diminished in contemporary adult life, evidence of experimental studies suggests cognitive advantages of writing over typing.⁸⁶ The Stavanger declaration, an outcome of a four-year research project involving almost 200 scholars and scientists of reading, publishing, and literacy from across Europe investigating the impact of digitisation on reading practices, reflects this tension. Its concluding press release unambiguously states concern over an uncritical adoption of digital tools in primary education:

In today's hybrid reading environment, paper and digital technologies each offer different advantages for different purposes. In order to properly manage the digital transformation, we need to gain a better understanding when to use which to best advantage. Therefore, the Stavanger Declaration calls for caution when introducing digital technologies to education and urges for further research on pressing issues regarding screen technologies and cognition. Teachers and other educators must be made aware that rapid and indiscriminate swaps of print, paper, and pencils for digital technologies in primary education are not neutral. Unless accompanied by carefully developed digital learning tools and strategies, they may cause a setback in the development of children's reading comprehension and emerging critical thinking skills.⁸⁷

Conversely, the Stavanger declaration may have targeted the wrong audience: teachers and educators. For with the interruptions of the

86. For a summary of findings see Anne Mangen, 'Modes of Writing in a Digital Age: The Good, the Bad and the Unknown', *First Monday*, 23/10 (2018) <https://journals.uic.edu/ojs/index.php/fm/article/view/9419> [accessed 30 November 2018]. For studies comparing handwritten to typed notes see Mike Allen and others, 'Is the Pencil Mightier than the Keyboard? A Meta-Analysis Comparing the Method of Notetaking Outcomes', *Southern Communication Journal*, 85/3 (2020), 143–54; Luxi Feng and others, 'The Roles of Handwriting and Keyboarding in Writing: A Meta-Analytic Review', *Reading and Writing*, 32/1 (2019), 33–63; Satu-Maarit Frangou and others, 'Can You Put Your Finger on It? The Effects of Writing Modality on Finnish Students' Recollection', *Writing Systems Research*, 10/2 (2018), 82–94.

87. Anne Mangen, Adriaan van der Weel and Miha Kovac, 'The Stavanger Declaration on the Future of Reading: Press Release: The New Importance of Reading', 2019 <https://www.stavangerdeclaration.org/wp-content/uploads/2019/01/StavangerDeclarationPressRelease.pdf> [accessed 25 February 2025].

COVID-19 pandemic and the ensuing lobbying of large technology corporations, political decision makers were quick to follow calls to adopt digital and remote learning systems. As it is considerably easier and faster to purchase equipment and software licences than it is to ‘carefully develop digital learning tools and strategies’, today large parts of educational budgets flow into such easily quantifiable investments.⁸⁸ Yet, as a UNICEF review of the evidence of the effectiveness of digital learning solutions states, ‘expanding access to devices alone, for instance computers, does not yield a clear and positive impact on learning outcomes at basic education level’, but that digital learning solutions may be more promising if they are ‘thoughtfully designed around a carefully identified contextual issue (as opposed to an ‘off-the-shelf’ solution’).⁸⁹ According to the report,

Digital learning solutions that are designed to improve teacher instruction tend to be the most effective in improving learning outcomes, especially when they are designed to supplement—and not to replace—best practices for teaching.⁹⁰

Primæ fully corresponds to these criteria as a conceptually mature and technologically advanced tool for reading and writing instruction that can be used in conventional and digital teaching environments. This hybrid quality bridges established best practices for teaching with emerging approaches and may be used to leverage the advantages of manual handwriting and the interactive qualities of digital text display.

For as long as handwriting is considered a key component of primary education, the concepts and materials that are used in teaching it should be made to the highest possible standards. Children are acute observers and learn through imitation. They tend to follow models as closely as possible, placing enormous responsibility on adults setting examples, as every parent can attest to. Handwriting is not exempt from this dynamic

88. In October 2024 the Austrian Court of Audit criticised that from January 2021 to August 2023 the Ministry of Education had spent 140.88 million Euro on its digitisation campaign without defining any tangible markers for success and no palpable outcomes for students. Amongst its ‘investments’ during this period was the development of the web platform ‘Digitale Schule’ that, owing to a lack of use, was abolished in June 2023. Its cost up to that point had been 12.26 million Euro. *8-Punkte-Plan für eine digitale Schule: Auswirkungen auf digitale Kompetenzen der Schülerinnen und Schüler unklar* (Vienna, 2024) https://www.rechnungshof.gv.at/rh/home/home/2024_29_8_Punkte_Plan_digitale_Schule.pdf [accessed 25 February 2025].

89. UNICEF, ‘Effectiveness of Digital Learning Solutions to Improve Educational Outcomes: A Review of the Evidence’ (2021), 1 <https://www.unicef.org/documents/effectiveness-digital-learning-solutions-improve-educational-outcomes> [accessed 25 February 2025].

90. UNICEF, ‘Effectiveness of Digital Learning Solutions to Improve Educational Outcomes’, 1.

and the disruption of digital devices and learning solutions in formal education does not, as some triumphalist technological rhetoric suggests, relieve us of the need to think about the tools that we employ. Rather, new opportunities amplify the need to evaluate established formats and approaches, so that successful elements are not lost for the sake of novelty, and obsolete features can be safely put aside. There is a strong onus on political decision makers, educational authorities, the designers of didactic materials, and teachers to make sure that the models that are offered to children correspond to the state of the art. For as children respect the example that they are taught with utmost diligence, the least that we can do is to show the same respect to them, providing a writing model that is as thought-through and well-made as we can possibly achieve.

References

- Allen, Mike et al. (2020). "Is the Pencil Mightier than the Keyboard? A Meta-Analysis Comparing the Method of Notetaking Outcomes". In: *Southern Communication Journal* 85.3, pp. 143–154.
- Allgemeine Schulordnung, für die deutschen Normal-Haupt- und Trivialschulen in sämtlichen Kaiserl. Königl. Erbländern d.d. Wien, den 6ten December 1774* (1774). Vienna. URL: <http://data.onb.ac.at/ABO/%2BZ203311206> (visited on 01/19/2025).
- Andresen, Ute (Apr. 2011). "Einführung der Grundschrift: Keine pädagogischen Interessen". In: *Die Tageszeitung: taz*. URL: <https://taz.de/Einfuehrung-der-Grundschrift/!5123334/> (visited on 02/27/2025).
- Anleitung zum Schönschreiben nach Regeln und Mustern, Oder Vorschriften: Zum Gebrauche der deutschen Schulen in den kaiserl. königl. Staaten* (1775). Wien. URL: <http://data.onb.ac.at/rec/AC09658801> (visited on 01/12/2025).
- Antoni, Dieter, ed. (1996). *Kommentar Zum Lehrplan Der Volksschule*. Vienna.
- Bartnitzky, Horst, Ulrike Hecker, and Christina Mahrhofer-Bernt, eds. (2011). *Grundschrift: Damit Kinder Besser Schreiben Lernen*. Beiträge Zur Reform Der Grundschule 132. Frankfurt am Main.
- Boyer, Ludwig (1988). *Kommentar zur Ausgangsschrift*. Ed. by Wilhelm Wolf. 2nd ed. aps 12. Vienna.
- (1996). "6 Schreiben (1. und 2. Schulstufe)". In: *Kommentar zum Lehrplan der Volksschule*. Ed. by Dieter Antoni. Vienna, pp. 305–322.
- (2012). *Elementarschulen und Elementarunterricht in Österreich: illustrierte Chronik der Schul- und Methodengeschichte von den ältesten Quellen bis zum Ende des 19. Jahrhunderts*. Graz. URL: <https://permalink.obvsg.at/AC08970981> (visited on 01/19/2025).

- Buchberger, Reinhard and Nina Linke (2015). "Von den Tafelkratzern des Mittelalters bis zu den Tintenpatzern des fin de siecle". In: *Tafelkratzer, Tintenpatzer: Schulgeschichten aus Wien*. Ed. by Reinhard Buchberger et al. Vienna, pp. 38–67.
- Bundesministerium für Bildung, Wissenschaft und Forschung (2025). *Beihilfen und Förderungen*. URL: <https://www.bmbwf.gv.at/Themen/schule/befoe.html> (visited on 02/24/2025).
- Die Österreichische Schulschrift 1995: *gut lesbar, leicht erlernbar, besser vermittelbar* (1994). Vienna. URL: <http://data.onb.ac.at/rec/AC17317386>.
- Dohmann, Antje (2024). "Prima soll Kindern das Lesen- und Schreibenlernen erleichtern". In: *PAGE online*. URL: https://page-online.de/typografie/schulschrift_prima/ (visited on 02/23/2025).
- Dostal, Karl A. (1972). *Methodik des Schreibunterrichts: 1.–8. Schulstufe*. Vienna.
- Fairbank, Alfred (1975). *A Handwriting Manual*. rev. and enlarged. London.
- Felbiger, Johann Ignaz von (1776). *Methodenbuch für Lehrer der deutschen Schulen in den kaiserlich-königlichen Erbländern*. Vienna. URL: <http://data.onb.ac.at/ABO/%2BZ160248202> (visited on 01/12/2025).
- Feng, Luxi et al. (2019). "The Roles of Handwriting and Keyboarding in Writing: A Meta-Analytic Review". In: *Reading and Writing* 32.1, pp. 33–63.
- Frangou, Satu-Maarit et al. (2018). "Can You Put Your Finger on It? The Effects of Writing Modality on Finnish Students' Recollection". In: *Writing Systems Research* 10.2, pp. 82–94.
- Friedrich, Franz (Jan. 2023). *Letter to Titus Nemeth, "Prima, die österreichische Schulschrift"*. Private collection Titus Nemeth.
- Glattauer, Niki (May 2023). ""Zurück in die Türkei": Wutlehrerin entschuldigt sich". In: *Heute*. section: Glattauer gibt Noten, p. 8.
- Grünwald, Heinrich (1981). *Schreibenlernen: Faktoren – Analysen – methodische Verfahren*. Kamps pädagogische Taschenbücher. Bochum.
- Harmesen, Lars and Julia Kahl, eds. (2022). *Yearbook of Type #6 2022/2023: Movie Edition*. 1st ed.
- Hartmann, Silvia (1999). *Fraktur Oder Antiqua: Der Schriftstreit von 1881 Bis 1941*. 2nd ed.
- Heiderhoff, Horst (1971). *Antiqua oder Fraktur?: zur Problemgeschichte eines Streits*. Frankfurt am Main. URL: <https://permalink.obvsg.at/AC01802523> (visited on 01/21/2025).
- Hohmann, Helene (2023). "Prima By Titus Nemeth and Martin Tiefenthaler". In: *Slanted*. URL: <https://www.slanted.de/prima/> (visited on 02/23/2025).
- Home | Wiener Bildungsserver (2025). URL: <https://bildungsserver.wien/start/home-wiener-bildungsserver> (visited on 02/12/2025).
- James, Karin H. and Laura Engelhardt (2012). "The Effects of Handwriting Experience on Functional Brain Development in Pre-Literate Children". In: *Trends in Neuroscience and Education* 1.1, pp. 32–42.
- Jarolim, Franz (1996). *Schreiblebrgang Österreichische Schulschrift 1995*. Vienna.

- Kirschmann, August (1912). *Antiqua oder Fraktur? (Lateinische oder deutsche Schrift.) Kritische Studie*. 2nd ed. Monographien des Buchgewerbes 1. Leipzig. URL: <http://data.onb.ac.at/imgk/AZ00509810SZ00042976SZ003%2030831> (visited on 01/21/2025).
- Krammer, Miriam (Mar. 2023). "Wiener Schulschrift Bekam Elegantes Facelifting". In: *Die Krone*. URL: <https://www.krone.at/2937352> (visited on 02/23/2025).
- Kroisleitner, Oona (Feb. 2023). "Wiener Kinder bekommen eine neue Schulschrift". In: *Der Standard*, p. 9.
- Lang, Georg (2019). *Die Technik der Feder: Der Weg der Schreiblehrkunst, sachlich begründet und methodisch erläutert*. Reprint of first edition from 1905. Berlin, Boston. DOI: 10.1515/9783486732672. (Visited on 01/20/2025).
- Legrün, Alois (1922). *Naturgemäßer Schreibunterricht. Grundlagen und Wege*. Lehrerbücherei 12. Vienna. URL: <http://data.onb.ac.at/imgk/AZ00567646SZ01073846> (visited on 01/19/2025).
- (1924). *Auf dem Wege zur naturgemäßen Schrift*. Vienna. URL: <http://data.onb.ac.at/imgk/AZ00567640SZ01074222> (visited on 01/19/2025).
- Lichtenwallner, Hadmar and Brigitta Scheiber (1996). "Die Österreichische Schulschrift". In: *Kommentar zum Lehrplan der Volksschule*. Ed. by Dieter Antoni. 2nd ed. Vienna, pp. 663–677.
- Loew, Theodor (1913). *Gebrechen unseres Schulschreibsystems und ihre Herkunft mit Vorschlägen zur Abhilfe*. München. URL: <http://data.onb.ac.at/imgk/AZ00593006SZ01073849> (visited on 01/21/2025).
- Longcamp, Marieke, Marie-Thérèse Zerbato-Poudou, and Jean-Luc Velay (2005). "The Influence of Writing Practice on Letter Recognition in Preschool Children: A Comparison between Handwriting and Typing". In: *Acta Psychologica* 119.1, pp. 67–79.
- Mangen, Anne (2018). "Modes of Writing in a Digital Age: The Good, the Bad and the Unknown". In: *First Monday* 23.10. URL: <https://journals.uic.edu/ojs/index.php/fm/article/view/9419> (visited on 11/30/2018).
- Mangen, Anne, Adriaan van der Weel, and Miha Kovac (2019). *The Stavanger Declaration on the Future of Reading: Press Release: The New Importance of Reading*. URL: <https://www.stavangerdeclaration.org/wp-content/uploads/2019/01/StavangerDeclarationPressRelease.pdf> (visited on 02/25/2025).
- Marquardt, Christian et al. (2016). "Learning Handwriting at School – A Teachers' Survey on Actual Problems and Future Options". In: *Trends in Neuroscience and Education* 5.3. Writing in the digital age, pp. 82–89.
- McNamara, Danielle S., ed. (2007). *Reading Comprehension Strategies: Theories, Interventions, and Technologies*. New York.
- Meer, Audrey L. H. van der and F. R. (Ruud) van der Weel (2017). "Only Three Fingers Write, but the Whole Brain Works: A High-Density EEG Study Showing Advantages of Drawing Over Typing for Learning". In: *Frontiers in Psychology* 8. URL: <https://www.frontiersin.org/>

- journals/psychology/articles/10.3389/fpsyg.2017.00706/full (visited on 02/17/2025).
- Meier, Hans Eduard (2003). *Anleitung Zu Einer Zeitgemässen Schulschrift Für Alle, Die Schreiben Lernen: Ein Buch Für Die Lebrenden Und Übungshefte Für Die Lernenden*. Glarus.
- Mez (2024). *MezMerri/AU-School-Handwriting-Fonts*. Australia. URL: <https://github.com/MezMerri/AU-School-Handwriting-Fonts> (visited on 02/23/2025).
- Ministère de l'éducation nationale (2013). *Modèles d'écriture scolaire*. Paris. URL: <https://eduscol.education.fr/204/polices-de-caracteres-cursives-pour-l-enseignement-de-l-ecriture> (visited on 02/16/2025).
- Mueller, Pam A. and Daniel M. Oppenheimer (2014). "The Pen Is Mightier than the Keyboard: Advantages of Longhand over Laptop Note Taking". In: *Psychological Science* 25.6, pp. 1159–1168.
- Nemeth, Titus and Martin Tiefenthaler (2023). *Prima Schreiben Lernen*. Presented at the tga lecture series. Vienna.
- (2024). "Prima: An Innovative Type for Learning to Read and Write". In: *Grapholinguistics in the 21st Century*. Venice. URL: <https://grafematik2024.sciencesconf.org/> (visited on 02/26/2025).
- (2025). "Primæ: An Extensive Innovative Type for Learning to Read and Write". In: *BRNO BOLD Typo02*. Brno. URL: <https://www.brnobold.cz/udalosti/brno-bold-typo-2> (visited on 02/26/2025).
- Noordzij, Gerrit (1985). *Kind und Schrift*. München.
- (2005). *The Stroke: Theory of Writing*. Trans. by Peter Enneson. London.
- Palmer, Austin Norman (1894). *Palmer's Guide to Business Writing*. Cedar Rapids, IA.
- Pfoser, Alfred (2015). "Die österreichische Schulreform". In: *Tafelkratzer, Tintenpatzer: Schulgeschichten aus Wien*. Ed. by Reinhard Buchberger et al. Vienna, pp. 203–207.
- Primæ · Eine Schrift Zum Lesen- Und Schreibenlernen* (2025). URL: <https://www.schulschrift.at/> (visited on 02/23/2025).
- Rechnungshof Österreich (2024). *8-Punkte-Plan für eine digitale Schule: Auswirkungen auf digitale Kompetenzen der Schülerinnen und Schüler unklar*. Tech. rep. Vienna. URL: https://www.rechnungshof.gv.at/rh/home/home/2024_29_8_Punkte_Plan_digitale_Schule.pdf (visited on 02/25/2025).
- Sassoon, Rosemary (2007). *Handwriting of the Twentieth Century*. Bristol, Chicago.
- Sassoon, Rosemary and Gunnlaugur S. E. Briem (1993). *Better Handwriting*. Teach Yourself. London.
- Schulschriften von Will Software* (2025). URL: <https://www.will-software.com/infos/schlsoft.htm> (visited on 02/23/2025).
- Soennecken, Friedrich (1911). *Der Werdegang unserer Schrift*. Bonn.
- Sütterlin, Ludwig (1917). *Neuer Leitfaden für den Schreibunterricht*. Berlin.

- Tanzer, Andreas (July 2023). "Schnörkelmalen Ist Geschichte". In: *Die Presse*. URL: <https://www.diepresse.com/13437843/schnoerkelmalen-ist-geschichte> (visited on 02/23/2025).
- The One Club For Creativity (2025). *TDC Awards – 69th Winners Showcase | Wiener Bildungsserver | Prima*. URL: <https://www.oneclub.org/tdcawards/showcase/69th/-item/46232> (visited on 02/23/2025).
- Thornton, Tamara Plakins (1996). *Handwriting in America: A Cultural History*. URL: <http://archive.org/details/handwritinginame00tama> (visited on 02/03/2025).
- Tost, Renate and Frank Ortmann (2021). *Schreibenlernen mit der Hand bildet Formsinn und Verstand: Gestalterische Grundlagen der Schulausgangsschrift*.
- Trummer, Gerhild (Jan. 2023). *Rundschreiben Nr. 35/2022 (BMBWF): Österreichische Schulschrift; Information über die Neuerungen ab SJ 23/24*. Rundschreiben Datenbank. URL: <https://rundschreiben.bmbwf.gv.at/rundschreiben/?id=1062> (visited on 02/24/2025).
- TypeTogether s. r. o. (2025). *Primarium: Handwriting Education in Primary Schools*. URL: <https://primarium.com/> (visited on 02/23/2025).
- TYPO 2.0: *Neue Schrift Für Schulkinder* (2023). Café Puls. Vienna.
- UNICEF (2021). *Effectiveness of Digital Learning Solutions to Improve Educational Outcomes: A Review of the Evidence*. Tech. rep. URL: <https://www.unicef.org/documents/effectiveness-digital-learning-solutions-improve-educational-outcomes> (visited on 02/25/2025).
- Verordnungsblatt für den Dienstbereich des Bundesministeriums für Unterricht* (1946a). Vienna. URL: <http://data.onb.ac.at/ABO/%2BZ14447290X> (visited on 02/04/2025).
- Verordnungsblatt für den Dienstbereich des Bundesministeriums für Unterricht* (1946b). Vienna. URL: <http://data.onb.ac.at/ABO/%2BZ14447290X> (visited on 02/04/2025).
- Walker, Sue (2007). "Letterforms for Handwriting and Reading: Print Script and Sanserifs in Early Twentieth-Century England". In: *Typography Papers* 7, pp. 81–114.
- Wie geht denn das: Schreibschrift* (2023). Studio 2. URL: <https://tvthek.orf.at/profile/Studio-2/13890037/Studio-2/14192717>.
- wien ORF at/Agenturen (2023). *Eigene Schreibschrift für Wien*. wien.ORF.at. URL: <https://wien.orf.at/stories/3196108/> (visited on 02/23/2025).
- Wiener Bildungsserver (2025). *Prima*. URL: <https://prima.wien/> (visited on 02/23/2025).
- Wiener Schriften (2025). *WienerSchriften/Prima*. URL: <https://github.com/WienerSchriften/Prima> (visited on 02/23/2025).
- Zilch, Reinhold (2013). "Sütterlin, Ludwig". In: *Neue Deutsche Biographie*, pp. 688–689. URL: <https://www.deutsche-biographie.de/sfz129700.html#ndbcontent> (visited on 01/21/2025).

Parametric Type Design in the Era of Variable and Color Fonts

Santhosh Thottingal

Abstract. Parametric fonts are programmatically defined fonts with variable parameters, pioneered by Donald Knuth with his METAFONT technology in the 1980s. While Donald Knuth's ideas in METAFONT and subsequently in METAPOST are often seen as legacy techniques from the pre-graphical user interface (GUI) era of type design, recent trends such as variable fonts suggest a resurgence of certain principles. This paper explores a modern type design process built on parametric design principles, specifically using METAPOST. The author created two variable fonts with this method and released them under a free, open-source license. The paper details the methodology, workflow, and insights gained from this process.

1. Introduction

Parametric type design uses algorithms to create customized and complex typography. It involves defining parameters such as stem width, serifs, and other letter-form components, which can be adjusted to generate a wide range of variations within a single font. The parametric type design approach was pioneered by Donald Knuth with his METAFONT (Knuth, 1979) technology in the early 1980s. However, this approach has not gained widespread acceptance in mainstream type design due to the perceived need for close collaboration between designers and programmers to mathematically define the design. Knuth attributes this to the fact that “asking an artist to become enough of a mathematician to understand how to write a font with 60 parameters is too much.” (Knuth, 1985).

The contemporary type design process uses advanced graphical user interface (GUI) editors. These editors not only facilitate the design aspect but also streamline the entire workflow, encompassing the creation of a fully functional typeface and its subsequent proofing. It is worth

Santhosh Thottingal  0009-0004-7350-5234
Swathanthra Malayalam Computing
E-mail: santhosh.thottingal@gmail.com

Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century 2024. Proceedings*
Grapholinguistics and Its Applications (ISSN: 2681-8566, e-ISSN: 2534-5192), Vol. 12.
Fluxus Editions, Brest, 2026, pp. 757–787. <https://doi.org/10.36824/2024-graf-thot>
ISBN: 978-2-487055-12-4, e-ISBN: 978-2-487055-13-1

noting that these GUI-based tools often come at a substantial cost, are proprietary, and, in some cases, depend on specific operating systems.

Nevertheless, certain foundational concepts introduced by Knuth have persisted and evolved over time. One such concept was the notion of generating multiple instances of a font by manipulating key parameters, a concept now recognized as variable fonts, which have garnered considerable popularity in contemporary typography (Constable, n.d.[b]; Hudson, n.d.).

In light of the fact that typefaces have evolved into increasingly complex software entities rather than mere digital renditions of calligraphic designs, the discipline of type design has transformed into a branch of software engineering. This transformation has necessitated that type designers either possess a working knowledge of software engineering and mathematical principles or collaborate closely with individuals skilled in the realm of ‘type engineering’.

As a professional with a background in software engineering who later ventured into type design, I set out to revisit METAFONT and integrate it into the modern type design workflow. The author created two variable fonts with this method and released them under a free, open-source license. The paper details the methodology, workflow, and insights gained from this process.

2. Parametric Design

The fundamental premise of parametric design is that design outcomes are governed by explicitly defined parameters. Altering these parameters independently yields distinct outputs without necessitating a complete redesign. METAFONT is a programming language that helps to define such designs.

2.1. METAFONT and METAPOST

Donald Knuth started work on font creation software in 1977 and produced the first version of METAFONT in 1979. Due to shortcomings in the original METAFONT language, Knuth developed an entirely new METAFONT system in 1984, and it is this revised system that is used today. The AMS Euler typeface was created by Hermann Zapf with the assistance of Donald Knuth using METAFONT. Computer Modern is another typeface created using METAFONT. METAFONT produces bitmap fonts that can be embedded in PostScript documents.

METAPOST, a successor to METAFONT, is a graphics programming language developed by John Hobby that allows users to produce high-quality graphics (Hobby, 1994). METAPOST produces vector graphics

from a geometric/algebraic description. The language shares METAFONT's declarative syntax for manipulating lines, curves, points, and geometric transformations. Unlike METAFONT, METAPOST can produce SVG output.

```

1  beginfig(1);
2  side:=10;
3  draw (0,0) -- (side,0) -- (side,side) --(0,side) -- (0,0);
4  endfig;

```

LISTING 1. METAPOST code to draw a square

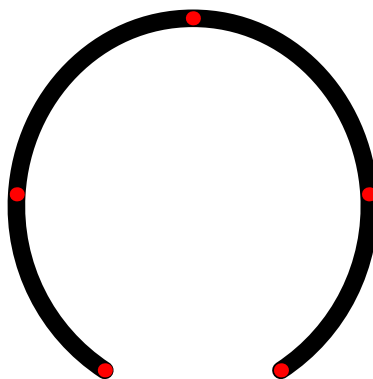
Listing 1 is an example METAPOST program. It produces a square like this.  Changing the value of *side* to say, 20, draws the same square with

a bigger size like this: . Here, the *side* is a parameter to the design of the square. By changing the value of *side* and without any other modifications to the design, we produce distinct renditions. This is the simplest explanation of parametric design. Let us try to draw the Malayalam letter Ra.

```

1  beginfig(0);
2  width:=100; height:=100;
3
4  z0 = (x1 + width/4, 0);
5  z1 = (0, y0 + height/2);
6  z2 = (x1 + width/2, y1 + height
7    /2);
8  z3 = (x2 + width/2, y1);
9  z4 = (x3 - width/4, y0);
10
11 pickup pencircle scaled 10;
12 draw z0..z1..z2..z3..z4;
13
14 % Add dots to indicate the points
15 pickup pencircle scaled 4;
16 for i=0 upto 4:
17   draw z[i] withcolor red;
18 endfor;
19 endfig;

```



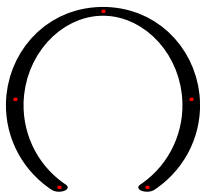
LISTING 2. METAPOST code to draw the Malayalam letter Ra

From the program Listing 2, we can see that we are drawing along the 5 points z_0 to z_4 and using curves to connect them. We are using a 'pen' called **pencircle scaled 10**. Pencircle is just a circle, and it will be moved along the curve and filled. There are *width* and *height* that control

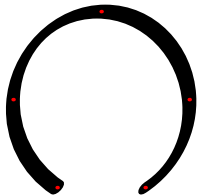
the sweep of the arc too. Similar to ‘pencircle’, there are other predefined pens like ‘pensquare’.

2.2. The Pens

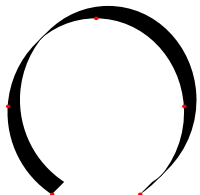
The concept of pens, also known as nibs, is the powerful component of METAPOST. A pen could be of any shape¹. Let us use a pencircle, but deform it first by scaling 10 in x dimension and 5 in y dimension. `pickup pencircle xscaled 10 yscaled 5` makes it an elliptical pen:  Then, if we move that pen along the same path, we get:



We can rotate this elliptical nib to an angle and use it as a nib using `pickup pencircle xscaled 10 yscaled 5 rotated 45`. We get this nib:  Now, if we draw the same shape using this slanted nib, we get:



Let us attempt to define a broad nib calligraphy pen. They are straight lines with little thickness (we can assume 0 thickness, or razor-thin), held at an angle like 40 or 45. It will look like this:  If we draw with this calligraphy pen, we get:



1. Any convex polygon, to be precise.

As we saw from the examples above, we were able to produce a varying number of strokes from the simple pens defined. However, more complex character shapes, such as those found in serif fonts, cannot be adequately represented using pen strokes alone. One approach is to use a combination of different pens. Another approach is to draw the outlines directly instead of using the outline created using pens.

Not only the type of pen but also its aspects can be parameterized. For example, if we change the length of the calligraphic nib in the previous example, we can generate the same drawing with varying stroke width:



This is particularly useful in type design for generating weight variants such as thin, light, regular, bold, black, etc. Since each of the drawings will have an exact number of nodes, they are easily interpolatable to generate a variable font with a ‘weight’ axis.

2.3. The Curves

The `draw` command of METAPOST connects the points using straight lines or curves. The points are defined by coordinates in the form of (x,y) . Points connected using dots are curves ... Points connected using `--` are straight lines. `---` connect a straight line and curve with a smooth joint. So examples:

```
draw (0, 0) -- (20,0) --(20, 10) => └─┐
draw (0, 0) .. (10,0) .. (20,0) =>  ⌒
draw (0, 0) -- (10,0) .. (20,0) =>  ⋀
draw (0, 0) --- (10,0) .. (20,0) =>  ⌒
```

When METAPOST draws a smooth curve through a sequence of points, each pair of consecutive points is connected by a cubic Bézier curve, which needs, in order to be determined, two intermediate control points in addition to the end points. The points on the curved segment from points p_0 to p_1 with post control point c_0 and pre control point c_1 are determined by the formula

$$p(t) = (1-t)^3 p_0 + 3(1-t)^2 t c_0 + 3(1-t) t^2 c_1 + t^3 p_1,$$

where $t \in [0, 1]$. METAPOST automatically calculates the control points such that the segments have the same direction at the interior knots.

In the Figure below, the additional control points are drawn as green dots and connected to their parent point with green line segments. The curve moves from the starting point p_0 in the direction of the post control point of p_0 , but bends after a while towards p_1 . The further away the post control point is, the longer the curve keeps this direction. Similarly, the curve reaches a point from the direction of the pre-control point. The further away the pre-control point is, the earlier the curve gets this direction. It is as if the control points pull their parent point in a certain direction, and the further away a control point is, the stronger it pulls.

```

1  beginfig(1);
2  u := 2cm;
3  pair p[];
4  p0 = (0,0); p1 = (2u,0); p2
    = (4u,0);
5  path q; q := p0{dir 90}..p
    1..{dir 90}p2;
6  draw q withpen pencircle
    scaled 2 withcolor blue;
7
8  for i=0 upto length(q):
9      dotlabel.rt("p" & decimal
10     (i), point i of q);
11     draw point i of q
12     withpen pencircle
13     scaled 4
14     withcolor blue;
15     p3 := precontrol i of q;
16     p4 := postcontrol i of q;
17     draw p3--p4 withcolor
18     green;
19     draw p3 withpen pencircle
20     scaled 4 withcolor green;
    draw p4 withpen pencircle
    scaled 4 withcolor green;
18 endfor;
19 endfig

```

By default in METAPOST, the incoming and outgoing direction at a point on the curve are the same so that the curve is smooth. The algorithm behind the curve smoothening in METAPOST is developed by John D. Hobby. (Hobby, 1986b)². METAPOST allows the control points to be specified directly in the following format:

2. The hobby package with Tikz package of L^AT_EX can also create similar smooth curves. Before developing the METAPOST- based workflow, I attempted to create SVGs using Tikz; however, I abandoned it for various reasons, including inflexibility

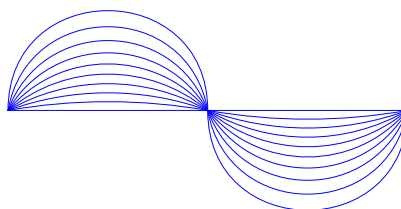
```
draw (0,0)..controls (26.8,-1.8) and (51.4,14.6)..(60,40)
```

It is easy to adjust these control points in a GUI editor, but in METAPOST, we want to focus only on the curves. For this, METAPOST provides a mechanism to declare the direction, tension, and curl of the curves along with the path expression.

```
draw (0, 0){dir 30}..{dir 45}(10, 10)..{right}(20, 0)..{dir 30}(30, 10) = 
```

To illustrate how the direction specification changes the curves, let us plot curves with varying directions as below:

```
1 beginfig(0)
2 for a=0 upto 9:
3   draw (0,0){dir 10a}
4   ..{dir -10a}(4cm, 0)
5   ..{dir 10a}(8cm, 0) withcolor
6   blue;
7 endfor
8 endfig;
```



METAPOST also allows specifying the tension and curl of the curves. Since they are not used in the typefaces I designed, we are skipping the explanation here for brevity.

2.4. SVGs from METAPOST

The latest version of METAPOST can output SVGs. The previous examples of rendering a glyph with different pens might lead us to believe that we can directly use those SVGs in a font. However, a close inspection of the SVGs produced will disappoint us. Let us revisit the 'Ra' example:

In Figure 1a, the white line is the path we defined and drew. The thick black line along that path is just the path's stroke width. So this is an SVG with just 5 nodes. This is not an SVG we can use for type design. In a glyph, we need a closed outline. Our expected drawing should be as shown in Figure 1b.

While designing fonts with METAFONT Knuth outlines (Knuth, 1989) a method for 'envelope' calculation. Internally, in METAFONT all the pen-circles are approximated by convex polygons with 24 sides. Then this polygon is used just like pensquare (that has 4 sides). Then the outlines of the polygon pen are calculated to get the 'envelope' or outline

and SVG-related issues. <https://ctan.math.illinois.edu/graphics/pgf/contrib/hobby/hobby.pdf>.

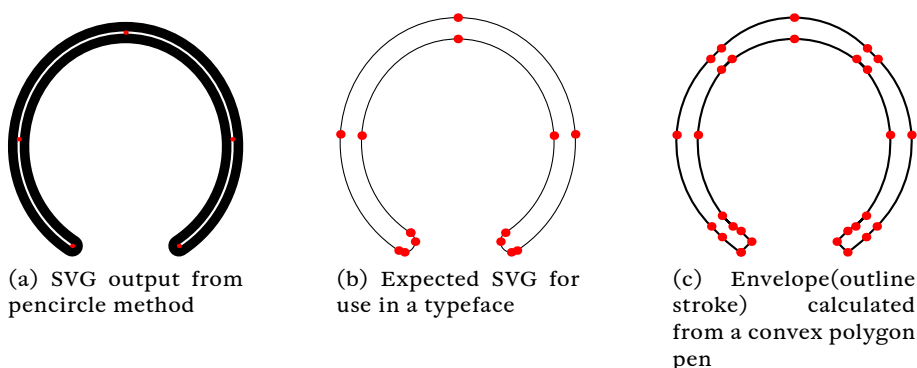


FIG. 1. Comparison of SVGs produced by METAPOST

stroke. This works well for the METAFONT since it outputs bitmaps. But for METAPOST, since the output is a vector image and we want the SVG to be a very clean vector with very few nodes, this solution has issues, as we see in Figure 1c. It produces several unwanted nodes, and they are unpredictable when parameters such as width/height are changed. We resolved these issues by using the macros provided by the MetaType1 package.

2.5. MetaType1

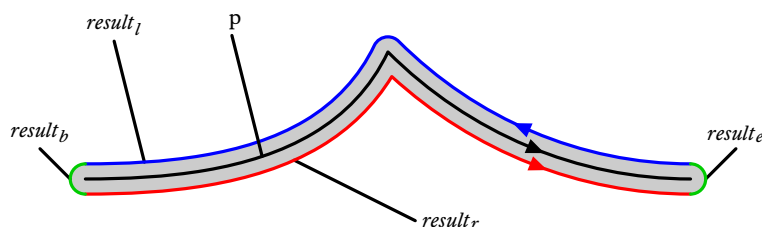
MetaType1 is a tool created by Bogusław Jackowski, Janusz Nowacki, and Piotr Strzelczyk for creating PostScript Type 1³ fonts (Jackowski, Nowacki, and Strzelczyk, 2001). MetaType1 was used to create the Latin Modern fonts, which are derived from Computer Modern fonts and include many more accented characters (Jackowski and Nowacki, 2003). Most important fonts produced with MetaType1 are: Latin Modern, Latin Modern Math, T_EX Gyre, Antykwa Toruńska, Antykwa Półtawskiego, Kurier, and Iwona.

Even though we are not generating any PostScript fonts here, MetaType1 was very crucial in the development of the workflow. The utility library, as part of MetaType1, includes many macros to produce accurate pen envelopes suitable for typefaces.

The Nupuram project extensively used the macro *pen_stroke* defined in MetaType. Macro *pen_stroke* performs an operation known as “expanding stroke”; we’ll call the result of the operation a “pen envelope” (for a

3. Type 1 fonts are a legacy format created by Adobe in 1984. See Haralambous (2007, pp. 655–676).

given path). The macro has one optional parameter, *opts* (*text*), and two obligatory ones: input path *p* (*expr*) and a *result* (*suffix*). A user has an access to subpaths of the envelope, namely: *result_r* is the right edge of the envelope, *result_l*—its left edge, *result_b*—is a fragment of the pen outline joining left and right edge of the envelope at the beginning node of the path, *result_e*—is a similar fragment at the ending node of the path (see the picture below). If the path *p* is cyclic, then *result_e* and *result_b* are undefined; the variable *result* also contains the fully expanded stroke.



For finding an envelope, a default path (*default_nib*, returned by *fix_nib*) is used except for nodes for which the parameter *opts* sets another pen. Mastering the usage of the parameter *opts* allows a user to achieve nontrivial effects. The parameter *opts* is a list (space-separated or semicolon-separated) of the following operators: (1) *nib*, (2) *cut*, (3) *tip*, and (4) *ignore_directions*.

The macro *nib* has two parameters: *nib*(*pen*)(*list_of_nodes*), where 'pen' is a path returned by macro *fix_nib*, and 'list_of_nodes' contains comma-separated numbers (times) of the nodes of the path *p* at which a given pen is to be used.

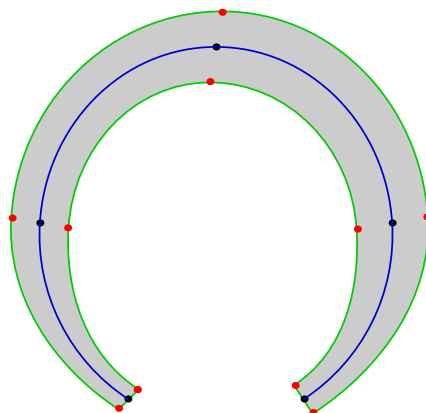
To illustrate this, let us revisit the same arc examples. As shown below, by using the *pen_stroke* macro and using different pens at different nodes in the path, we get a perfect vector output. We can see the arc is drawn using 5 points. And corresponding to each node, 2 nodes are present in the outline stroke, on the outer and inner sides of the outline stroke. Depending on the pen thickness at each node, we get smooth curves that vary in thickness.

The resulting stroke modulation and its extrapolatable nature with respect to parameters such as nib thickness are key tools for building a typeface, potentially a variable typeface. The terminals can be cut at any angle, and the nibs at any angle or width. Each node in the path can be any nib at any width, shape, and angle.

```

1  input plain_ex;
2  beginfig(0);
3  width:=200;    height:=200;
4  thick:=width/5; thin:=thick*2/3;
5  % .. path definition goes here ..
6  path p, s; p := z0..z1..z2..z3..
   z4;
7
8  vardef thicknib = fix_nib(thick,
9  0, 0) enddef;
10 vardef thinnib = fix_nib(thin, 0,
11 0) enddef;
12 pen_stroke(
13   cut(thinnib, 45)(0)
14   nib(thinnib scaled 1.2
15   rotated -10)(1)
16   nib(thicknib rotated 80)(2)
17   nib(thicknib rotated 10)(3)
18   cut(thinnib scaled 1.25, rel
19   90)(4)
20 )(p)(s);
draw s withpen pencircle scaled
1;
fill s withcolor .8white;
endfig;

```



LISTING 3. Usage of *pen_stroke* macro

3. Earlier Attempts

Although METAFONT never became mainstream, hundreds of fonts have been created with it: an incredible list has been compiled by Luc Devroye⁴.

Jeroen Hellingman created Malayalam metafonts in 1994 (Hellingman, 1998). These were created as uniform strokes. Karel Piska later converted all these fonts to Type 1 fonts. He did this by an accurate analytic conversion to outlines using METAPOST output. After theoretical conversion, FontForge is used for removing overlap, simplification, rounding to an integer, auto hinting, generating outline fonts, and necessary manual modifications.⁵

4. List of fonts created using METAFONT. Compiled by Luc Devroye. <http://luc.devroye.org/metafont.html>.

5. CTAN: indic-type1—Indic Type 1 fonts converted from public METAFONT sources <https://ctan.org/pkg/indic-type1>.

4. Modern Typeface Design Workflow With METAPOST

As we explained earlier, the first step is to define the glyphs using METAPOST. Then we compile them to SVGs. These SVGs are then converted to the GLIF format of Unified Font Object format⁶. The Unified Font Object (UFO) is a cross-platform, cross-application, human-readable, future-proof format for storing font data. This is the modern format used by type designers. Type design tools offer a feature to export their internal format to UFO too⁷.

Once we have the UFO-formatted font source, we need to write the OpenType features and save them as part of the same UFO file. Then type compiling tools like fontmake⁸ can compile this UFO to a font binary such as .ttf, .otf, or webfonts. The opentype features, glyph to unicode mapping, kerning, and font meta information—these are all part of the prepared UFO. A set of programs prepares all of these based on a simple configuration file.

Preparing the OpenType features used to be a major task in Malayalam typeface design. We used to manually write them. In the Nupuram typeface, they are automatically generated based on the script grammar encoded in the application logic.⁹ For a script, Malayalam, OpenType rules are an integral part of the typeface. Rapid experimentation and variation generation with Nupuram were possible due to the automatic generation of OpenType rules.

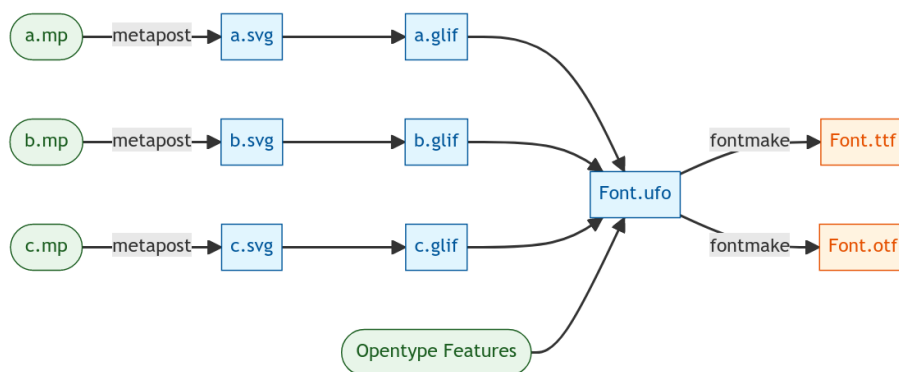


FIG. 2. High level workflow of type design with METAPOST

6. <https://unifiedfontobject.org/versions/ufo3/>.

7. For example, Glyphs application's .glyphs format can be converted to ufo format.

8. fontmake : <https://github.com/googlefonts/fontmake>.

9. Source code repository of Nupuram <https://gitlab.com/smc/fonts/Nupuram>.



FIG. 3. Vilakkum Velichavum title design by SA Nair

5. Nupuram Type Family

5.1. Design

Nupuram¹⁰ draws inspiration from the title posters of early Malayalam movies around 1960-1970, particularly those crafted by the renowned title designer, S Appukkuttan Nair (Popularly known as SA Nair)¹¹. These title designs feature letterforms with wide, flat, sharp terminals, thin vertical strokes, and thick horizontal strokes.¹² Even though there are hundreds of posters done by SA Nair with same design concept, there is no strict uniformity in these designs due to their entirely handmade nature. Adapting these distinctive traits to a typeface required many efforts. In this endeavor, while I departed from the pronounced sharpness of the terminals, I preserved the broad strokes while slightly reducing their thickness.

The vertical stems in glyphs are thin, and horizontal ones are thick, akin to the characteristics of reverse contrast typefaces. The letters are closer to a handwritten style than a regular print style. One can easily notice the playful, casual, personal aesthetic. Usable at display and text sizes too.

10. The word Nupuram means 'anklet' <https://en.wikipedia.org/wiki/Anklet>.

11. SA Nair, Malayalam Movie and Music Database <https://m3db.com/sa-nair>.

12. Examples: Thakilu Kottampuram (<https://tinyurl.com/52enjcaa>), Vilakkum Velichavum (<https://tinyurl.com/49s97eup>), Angadi (<https://tinyurl.com/7cpnzy4s>).



FIG. 4. Nupuram design

Based on the macros we explained in Section 2.5, the nibs of Nupuram glyphs are defined. There are three nibs—*thicknib*, *thinrib* and *terminalnib*. Here, *thicknib*, *thinrib* are razor nibs or nibs with 0 width. Their lengths are parameterized. *terminalnib* is a razor nib or an elliptical nib based on whether the terminals are rounded (soft) or flat (sharp).

5.2. Typographic Units

The nib length (which results in the thickness of strokes) is defined by *thick* and *thin* configurations. The value *thick* is expressed in relation to EM Size. the emsize is defined as $em := 1000$. Then this Em value is divided by basic typography units, defined as $u := em/10$. The u is the unit we will use to define all typographic parameters such as ascent, descent, bearing, thick, thin, etc.

```

1   em :=          1000;          % Height of characters - Em square
2   u :=          em/10;          % Unit width. Em square divisions.
3   ascent :=      8u;            % Ascender Height
4   descent :=     2u;            % Descender Height
5   xheight :=    2/3*ascent;     % Height of English small letters
6   mheight :=    3/4*ascent;     % Height of Malayalam letters
7   Xheight :=     8u;            % Height of English capital letters
8   thick :=       1u;            % Thickness of thickest lines
9   thin :=        0.7;           % Thickness of thinnest lines-ratio of
    thick.
10  subthick :=    0.666u;        % Thickness of thickest lines in
    subscribed characters
11  xthick :=       1;             % Extra thickness for terminals
12  slant :=        0;             % Slant of characters. Give angle values
13  condense :=     1;             % Condense factor. < 1 for condense, > 1
    for expand
14  lbearing :=     0.4u;          % Default left bearing
15  rbearing :=     0.4u;          % Default right bearing
16

```

LISTING 4. Basic typographic parameters defined in Nupuram typeface

By changing any of these base parameters, we can build a new design. But not all changes produce a good or useful design. To make a typeface

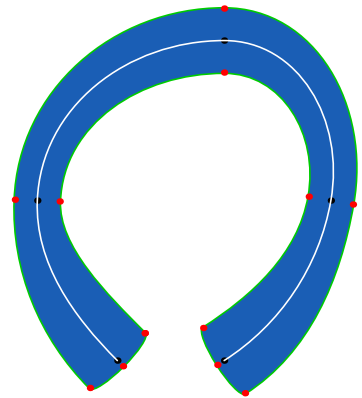
with weight variants, we change the *thick* parameter alone. To change the extra thickness of terminals, we change the *xthick* parameter. To get a slanted glyph with 15, we give *slant* = 15 and so on. We will discuss this in detail in the next section about variable fonts.

Using all these parameters, let us try to draw the letter 'Ra', but this time as per the Nupuram design. See Listing 5.

```

1 input plain_ex;
2 beginfig(0);
3 width:=200; height:=200; thick:=width/5;
4 thin:=0.7; m:=width; xthick:=1.1;
5 terminalround:=0.5;
6 z0=(x1 + m/4 , 0); z1=(0, m/2);
7 z2=(x0 + m/3, y1 + m/2); z3=(x2 + m/3, y2-
  m/2);
8 z4=(x2, 0);
9 path p,s; p:=z0{dir 135}..z1.. z2{right}..z
  3{dir 260}..z4;
10
11 vardef thicknib = fix_nib(thick, thick, 0)
  enddef;
12 vardef thinnib = fix_nib(thick*thin, thick*
  thin, 0) enddef;
13 vardef terminalnib = fix_nib(thick*xthick,
  thick*terminalround, 0) xyscaled(xthick,
  terminalround) enddef;
14 vardef terminalangle expr t of p = angle(
  direction t of p)+90 enddef;
15 pen_stroke(
16 nib(thinnib)(1,3) nib(thicknib)(2)
17 nib(terminalnib rotated terminalangle 0
  of p)(0)
18 nib(terminalnib rotated terminalangle 4
  of p)(4)
19 )(p)(s);
20 draw s; fill s;
21 endfig;
22

```



LISTING 5. The 'Ra' letter in Nupuram

5.3. Variable Fonts

The glyphs and their variations are fully controllable by simple configuration files. On top of these common configurations, we define font-specific variations in simple configuration files. For example, the configuration for creating Nupuram-Bold font will look like this

```

1  input ./config/Regular;
2  thick:= 1.25u;
3

```



It imports (includes) the Regular configuration and sets *thick* = 1.25*u*. You will quickly see that it is an increase on the *thick* value set in the configuration for the 'Regular' variant

```

1  thick := 0.90u;
2  soften := 0;
3

```



Let us look at the configuration for the Nupuram Thin variant by setting *thick* = 0.5*u*.

```

1  input ./config/Regular;
2  thick := 0.5u;
3

```



Similarly, the configuration for Nupuram Condensed is defined by setting *condense* := 0.8

```

1  input ./config/Regular;
2  condense := 0.8;
3

```



An oblique variant will have the following configuration *slant* := 15

```

1  input ./config/Regular;
2  slant :=15; % Degree of slanting
3

```



Whether the terminals are flat (sharp edge) or rounded (smooth) is controlled by the *terminalnib* that uses *terminalround* parameters. By setting it *terminalround* := 0.15 we can get a sharp terminal.¹³

13. Note that we are not setting it to 0 because, at zero, the curve segment at the terminal becomes a straight line. This affects the interpolation. We can only do interpolation of a curve with another curve with more or less curvature.

TABLE 1. Nupuram variation axis tags, their ranges, default, and descriptions

Axis	Tag	Range	Default	Description
Weight	wght	100 to 900	400	Thin to Black. Can be defined with <code>font-weight</code> CSS property.
Slant	slnt	-15 to 0	0	Upright (0) to Slanted (about 15).
Width	wdth	75 to 125	100	Condensed to Expanded. Can be defined with usual <code>font-stretch</code> CSS property.
Soft	SOFT	0 to 100	50	Sharp to normal to Super-Soft terminals.

```

1  input ./config/Regular;
2  terminalround:=0.15;
3

```



Since all of the above variants are the same design, with the exact number of SVG nodes and the same curves, they are interpolatable. We can use them as master designs in a variable fonts design space and get a variable font with ‘weight’, ‘width’, ‘slant,’ and ‘soft’ axes.

All 4 axes can be considered a 4-dimensional space. By carefully choosing the values of any of these 4 axes, we can practically produce an infinite number of styles. Modern typesetting software and web pages (CSS) allow selecting this style with quick previews. Even though a user can choose any of these styles, the typeface also comes with a predefined ‘named instances,’ which are predefined combinations of these values. For example, ‘Nupuram Condensed Thin’ is a named instance that sets the ‘width’ and ‘weight’ axis values to ‘Condensed’ and ‘Thin’. Nupuram has 32 such named instances.

Nupuram is the first variable font in Malayalam with 4 design axes.

5.4. Debugging and Proofing

GUI-based font editors usually have advanced preview and proofing systems integrated. This is also an essential requirement for any type design system. While designing Nupuram, I used the Visual Studio IDE along with a live SVG preview. Figure 8 shows an example setup. In development mode, in addition to glyphs, guidelines, and coordinates, points are also visualized to support the design process.

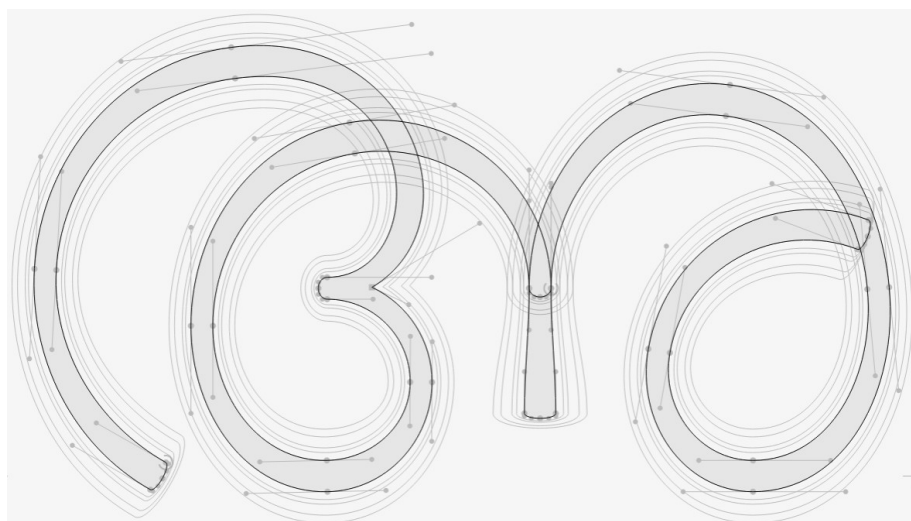


FIG. 5. Visualization of Nupuram `wght` axis. The thickness of strokes varies here.

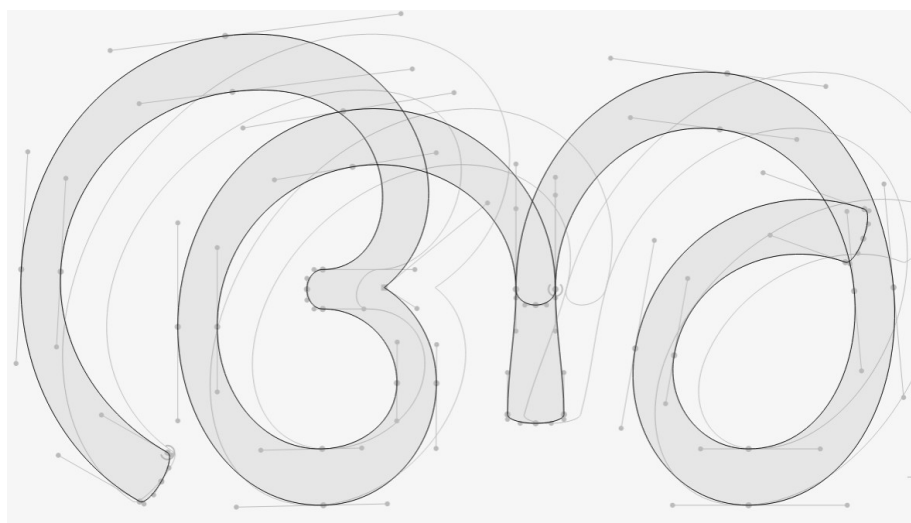


FIG. 6. Visualization of Nupuram `slnt` axis. The slant angle changes from 0 to -15.

However, we also need a more advanced proofing system to render an arbitrary text content with the given font to evaluate and fine-tune

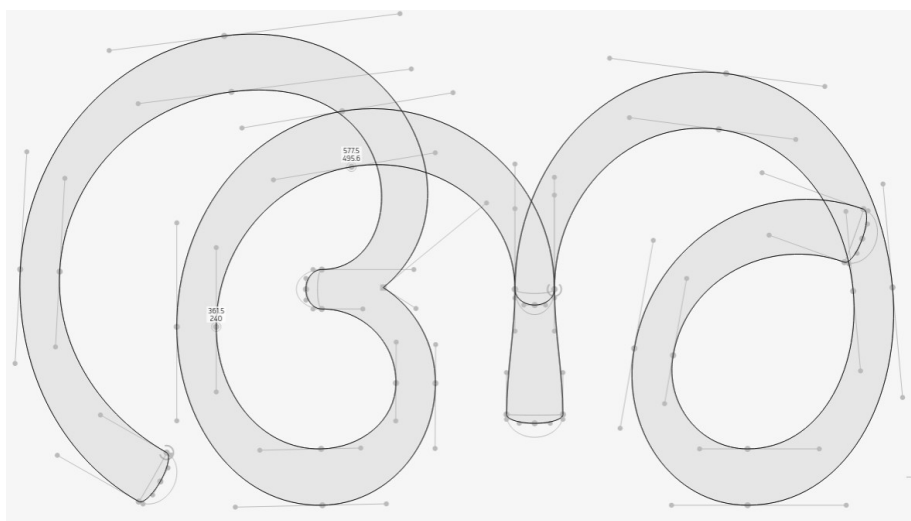


FIG. 7. Visualization of Nupuram SOFT axis. The sharpness or softness varies from 0 to 100.

various design aspects. For this, I developed a web-based type test and preview system¹⁴. See Figure 9.

To ensure the quality of glyphs and various technical details to be taken care of for a production-ready typeface, automatic testing is incorporated using the fontbakery tool¹⁵.

5.5. Latin Glyphs

All the Malayalam characters defined in Unicode version 15 are present in the font. Nupuram also has Latin script support. Nupuram supports 294 languages covering approximately 2.8B speakers¹⁶

The Latin glyphs follow the same design as Malayalam. See Figure 10.

5.6. Nupuram Calligraphy

Nupuram Calligraphy simulates a wide-nib calligraphy pen, with a 40 ° nib rotation. This is a variable font with a ‘weight’ axis. The width of the

14. This online tool is available at <https://smc.gitlab.io/fonts/Nupuram/tests/>.

15. fontbakery: A font quality assurance tool <https://github.com/fonttools/fontbakery>.

16. Calculated using hyperglot tool <https://hyperglot.rosettatype.com/>.

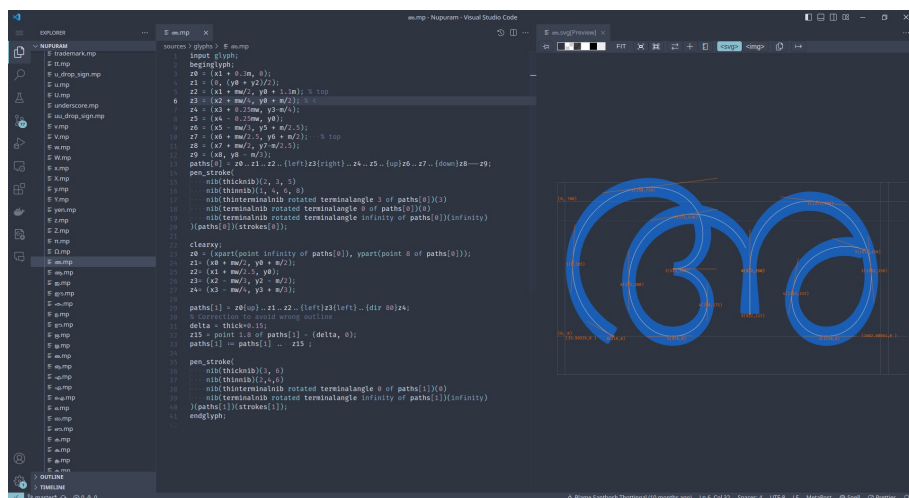


FIG. 8. An example typedesign setup with VS Code IDE with METAPost and SVG generated, shown side by side. Changing the code automatically refreshes the image.

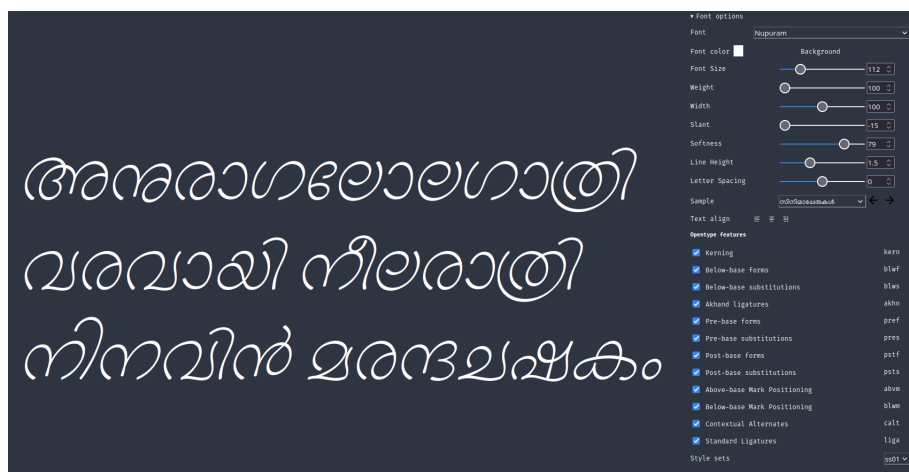


FIG. 9. Web-based type testing, proofing, playground used in the Nupuram design process

calligraphy pen can be varied to get different weights. The width of the nib can be varied as required. So by defining 3 widths, narrow, medium, and wide, we can get 3 variants of this glyph. Using these master glyphs, we can interpolate to any nib size using the variable font technology.

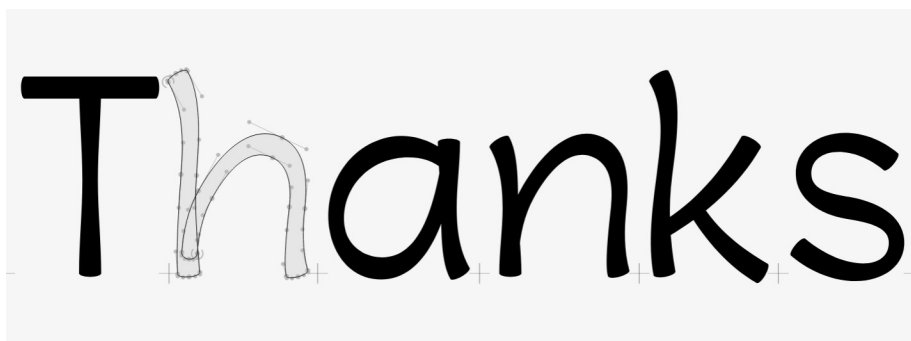


FIG. 10. Nupuram English sample

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become momentary masters of a fraction of a dot. Think of the endless visited by the inhabitants of one corner of this pixel the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds. The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate.

FIG. 11. Nupuram sample English paragraph

That is how we made the Nupurum Calligraphy variable font. An illustration of weight axis variations is given in Figure 12.

5.7. Nupuram Color

Color fonts (also known as chromatic fonts) can use multiple colors, including gradients, in a single glyph, rather than the flat, single color used by typical, non-color (monochromatic) fonts. This relatively new technology allows designers to set the font's color palette to express themselves with color in ways that previously would not have been possible outside advanced graphics applications.¹⁷ Nupuram has a Color font version with COLRV1 specification. The colors can be customized by users, for example, using CSS. Nupuram Color is also a variable font with a customizable 'wght' axis.

17. Introducing color fonts, Rod Sheeter https://fonts.google.com/knowledge/introducing_type/introducing_color_fonts.

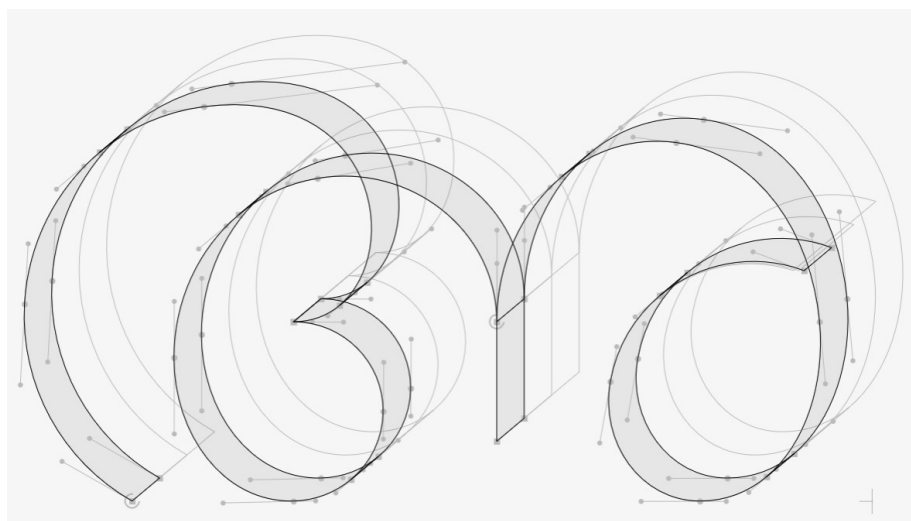


FIG. 12. Weight axis variations of Nupuram Calligraphy subfamily



FIG. 13. Nupuram Calligraphy sample

Nupuram Color creates a solid 3D object illusion. The anatomy of the color font is based on an observation in Nupuram Calligraphy. In the calligraphy variant, we moved a calligraphic pen through the glyph path. If we use pen strokes with thick and thin strokes as explained earlier, we get a modulated glyph outline as Figure 15a. If the calligraphic pen we used for Nupuram Calligraphy moves through the outline, we will get Figure 15b.

It is slightly confusing, but we start to see a 3D shape in it. Let us fill this with blue to get a clearer picture. See Figure 15c. Now we can relate this to the calligraphy glyph we constructed earlier. Same stroke modulation, but two times—for outer and inner lines.

If we look at 15c carefully, this is a 3D structure, but a hollow one. The facing size and backside is void, creating a hollow structure. To get a solid 3D shape, let us take the envelope of the whole drawing. What I mean by that is to take the outline of this structure. See Figure 15d.

Now it is not hollow. If you look carefully, you will see it is a 3D letter of 'va'. But to help your eyes with the 3D perspective, it needs colors or lighting to create depth. To start with, let us place our original 'va'



FIG. 14. Sample rendering of Nupuram color font with default color palette

outline on top of it in a lighter color. And let us make the lighting and coloring a bit more realistic by using color gradients. We get the final rendering as Figure 15f.

Nupuram Color font offers 18 predefined palettes that users can select. Or a user can specify the colors using CSS, for example. This color font uses 3 colors for its shadow-ish look. They are Dark, Light, and Base colors. Base is the facing color, Light is the central glowing area color. Dark is the color for the shadow part. The colors are used to create an internal gradient.

Nupuram is the first color font in Malayalam.

Each glyph in Nupuram color is constructed of two layers. The facing layer is Nupuram Regular. The background layer is constructed using the techniques explained above. Then each of these layered glyphs is compiled into a UFO. For each layer, we define a linear gradient from the top to the middle, then reflect it vertically. By choosing complementary colors for the gradients on the front and background layers, we create the illusion of a 3D object illuminated. This kind of sophisticated glyph manipulation and layer generation was possible thanks to METAPOST's ease of experimentation and variant generation. Drawing each of these glyphs by hand in a GUI environment would be quite tiresome and would take months of effort.

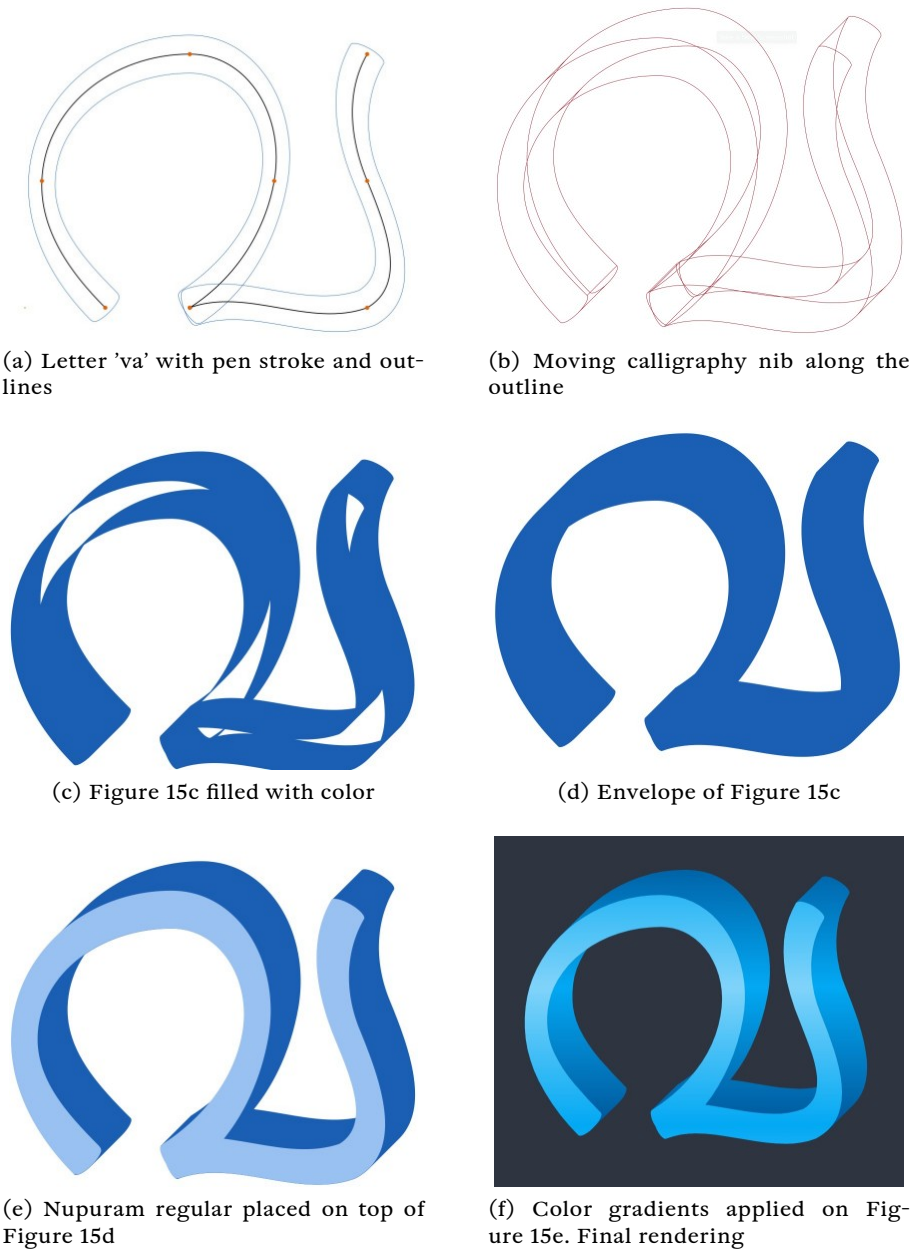


FIG. 15. Construction of Nupuram Color glyph

5.8. Nupuram Dots and Arrows

Since a pen can be any shape that covers a predefined path, one experiment I did in Nupuram was to produce a variant in which the paths are filled with equally spaced dots. We get a dotted font, often used in an educational context, to learn how to write a letter by writing on top of it. We call this variant Nupuram Dots. See Figure 16.

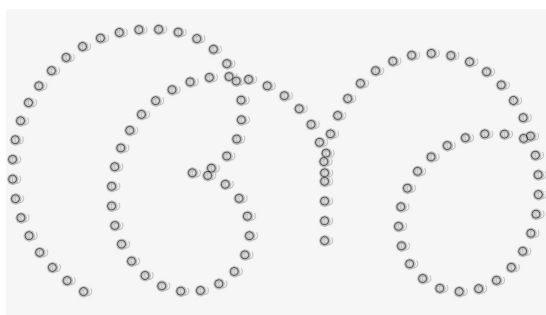


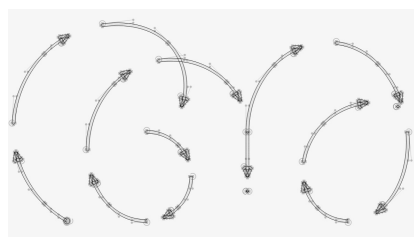
FIG. 16. Nupuram Dots—a font for learning to write

I tried to replace the dots with arrows to indicate the direction of writing. These arrows are equally placed on the pen path. See Figure 17a. To make it more useful, I placed the arrows font on top of the regular font. And gave two colors for each layer, making it a color font. This color can be customized on the user side, as we explained in the section about Nupuram color. See Figure 17b.

Special fonts, such as dot fonts, play a valuable role in facilitating the learning to write letters, especially for young learners and those with fine motor skill challenges. By tracing arrows or connecting the dots, students develop the muscle memory and hand-eye coordination necessary for proper letter formation. Dot fonts are particularly popular in early childhood education, where they help children transition from drawing shapes to writing letters.

Developing a dots or arrow font like this is a full-blown typeface project in the common typeface design approach. Here, we see a quick derivation of an existing typeface.

Optimizing these curves with the curve harmonization techniques was required for aesthetic reasons. Linus Romer’s implementation of Curvature combs and harmonization (Romer, 2023) of METAPOST was used for the purpose.



(a) Nupuram Arrows—Showing writing direction



(b) Nupuram arrows color font with default color palette

FIG. 17. Nupuram Arrows

6. Type Design Workflow

A design and development workflow fine-tuned for this kind of type design was also required. It is important to see the results of an METAPOST instantly for fast feedback loops. I integrated METAPOST-based type design into the popular Visual Studio Code so that the designer can work on METAPOST code and live-preview the results with all design utilities, such as a design grid, point coordinates, anchors, and so on. I also prepared an online sandbox for METAPOST so that quick, cheap experiments are possible and sharing and collaboration on design concepts are feasible¹⁸.

7. Derivatives

The educational typefaces featuring arrows and dots were the first of their kind in Malayalam. I used the SVGs generated by METAPOST code to create a website to learn to write Malayalam¹⁹. The SVG stroke paths are animatable to simulate a drawing animation. Along with Arrows and Dots variants, and by incorporating example words and pronunciation audio samples, this website has serious users now.

8. Malini Typeface

After Nupuram, I also designed another typeface with the same workflow, a typeface optimized for body text, which has stricter stroke modulation and optical fine-tuning requirements. Malini has 4 variable axes:

18. The metapost sandbox <https://mpost.thottingal.in>.

19. <https://learn.smc.org.in>.

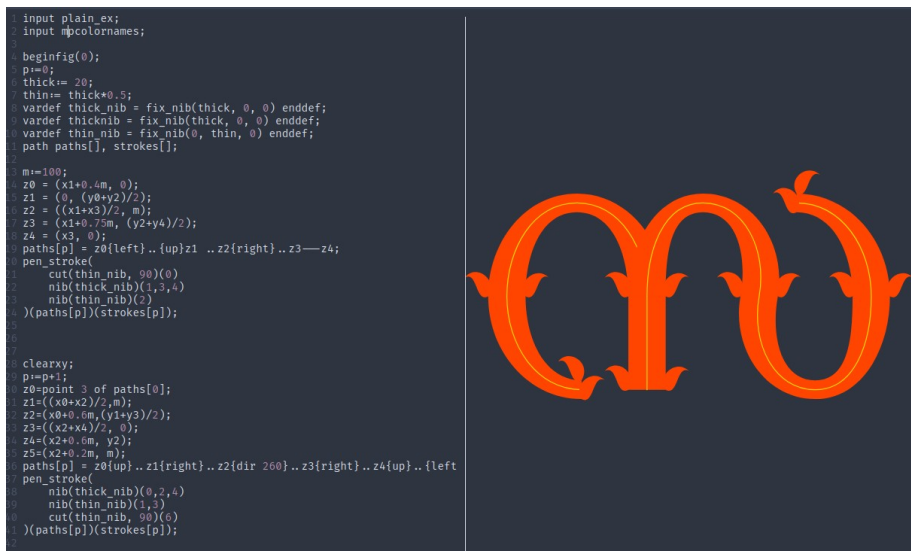


FIG. 18. METAPOST code and live preview setup. Glyph designed by the author

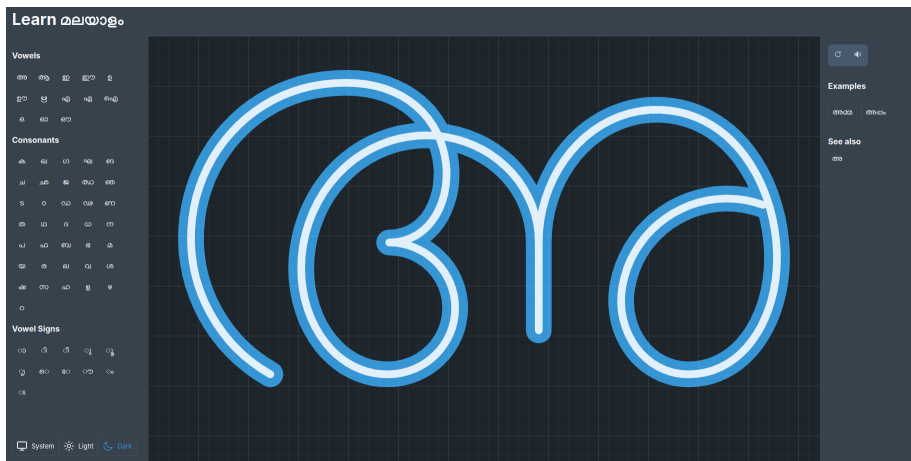


FIG. 19. Educational website to learn how to write letters of Malayalam, created using the same SVGs used for the typeface

Weight, Width, Slant, and Optical Size. Malini is the first typeface in Malayalam script with optical sizing. While Nupuram allowed more freedom in drawing, as it is designed as a display typeface with handwriting-like characteristics, Malini demanded more precise drawing. This chal-

lenge helped fine-tune the workflow again and to retrospectively apply some of the improvements to the Nupuram typeface.

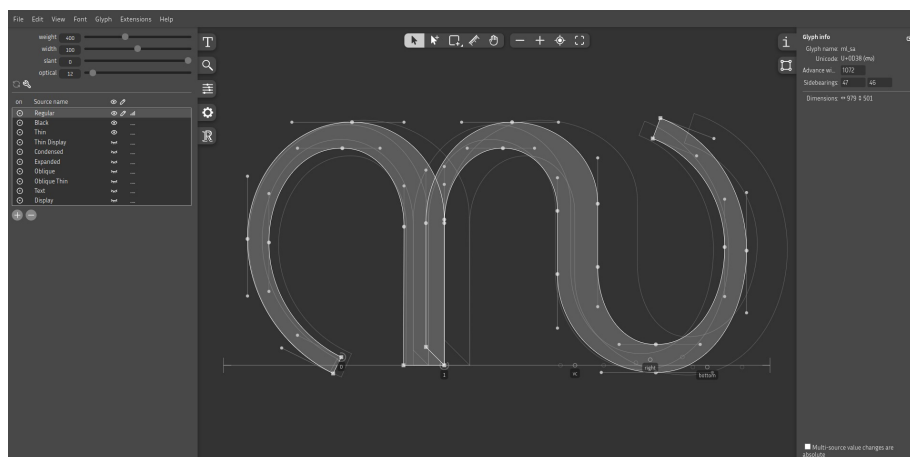


FIG. 20. Malini typeface—Letter Sa of Malayalam showing stroke modulation and various axes

അയാൾ കിണറ്റിലേക്ക് കൂപ്പു കുത്തി. കിണറു കടന്ന് ഉൾ
 കിണറ്റിലേക്ക്. വെള്ളത്തിന്റെ വില്ലിനു പടുതകളിലൂടെ
 അയാൾ നീങ്ങി. ചില്ലുവാതിലുകൾ കടന്ന്, സ്വപ്നത്തിലൂടെ
 സാന്ധ്യപ്രജ്ഞയിലൂടെ, തന്നെ കൈനീട്ടി വിളിച്ചു പൊരുളി
 ന്റെ നേർക്ക് അയാൾ യാത്രയായി. അയാൾക്കു പിന്നിൽ
 ചില്ലുവാതിലുകൾ ഒന്നൊന്നായിടുന്നു.

FIG. 21. Malini sample text rendering

9. Lessons

The parametric approach helped me to do easy experimentation. The traditional type design approach is inflexible once the key typographic metrics are set. In the METAPOST based approach, fine-tuning these parameters is possible at any stage of the project. It is very easy to experiment with different parameters and pick one that is satisfactory to the designer. Sometimes these experiments also reveal surprising results. The approach for a 3D-like color font was born from such an experiment.

Leveraging my background as a software engineer and my adeptness with source code, I found that applying this familiar paradigm to type design significantly enhanced productivity. Shapes were manipulated as modularized methods within the source code, and this modular approach proved instrumental in generating design outputs that were not only consistent but also coherent. This marked a notable departure from the challenges I had encountered in traditional typeface design projects, where maintaining consistency and cohesion had often been a struggle.

Producing a superfamily of Malayalam typefaces with multiple variable and color fonts can easily take multiple years of effort and the collaboration of multiple individuals. However, the majority of Nupuram's work was finished in my free time in 6 months.

Capturing the details of all required glyphs and their OpenType features in the program was not easy, but it is an investment for future fonts. I could reuse most of the METAPOST code and the framework in the Malini typeface project²⁰, even though that is a typeface optimized for body text.

The ability to define the design precisely in mathematical language will guide the designer to stringent mathematical proportions for letter forms. Nevertheless, it is essential to recognize that such precision does not inherently guarantee the production of aesthetically pleasing glyphs. This tension between mathematical precision and aesthetic appeal emerged as a recurring theme throughout my type design process. For example, the programmer's inclination to align an element exactly at the 0.5 mark of the entire width versus the more subjective choice of proportions that align with visual harmony and appeal.

The ability to swiftly generate variations and, consequently, produce variable fonts proved to be a significant advantage in my work. As an advocate of free and open-source principles, my objective was to construct the entire type design workflow and develop typefaces without relying on proprietary software. Notably, at the time, there was a lack of reliable free software tools for typeface design tailored to variable font creation.

20. Malini is a new typeface project that the author is working on with METAPOST based workflow <https://github.com/smc/malini>.

I overcame that limitation with this new workflow. Nupuram is one of the early color fonts following the publication of the OpenType Color 1 specification. It is worth noting that support for variable and color fonts has yet to catch up in common software applications.

It is tempting to proliferate numerous subfamilies from a single typeface because it is easy to do so. In this regard, it is pertinent to recall Knuth's cautionary advice regarding this issue. In the Nupuram project, driven by a desire to explore the myriad possibilities, I created numerous subfamilies. Nevertheless, it remains a verifiable fact that an abundance of variations does not necessarily equate to an abundance of genuinely useful fonts.

I must acknowledge that METAPOST is not a programming language one can easily learn. It diverges significantly from the conventions of popular programming languages, presenting a distinctive learning curve. While valuable documentation resources do exist, there is a noticeable dearth of practical examples that designers can readily reference and learn from. Given this challenge, prior to advocating for the adoption of this workflow among fellow type designers, I recognized the need to address this limitation. So I documented Nupuram extensively. The project is published under a free and open source license for anybody to refer to and learn²¹. I created a simple METAPOST playground website <https://mpost.thottingal.in> where people can quickly write METAPOST code and preview the result. I started a repository of various type design concepts illustrated using METAPOST²².

Upon embarking on this exploration with METAPOST, I encountered several articles that explain why METAPOST or METAFONT did not catch up. A recurring theme in these discussions was the debate over whether an arbitrary type design can be expressed using the pen-based approach, in which outlines are essentially the outputs of pen strokes. It is undeniable that outline-based design has established itself as a tried-and-true, successful design methodology, and this criticism is indeed valid. However, I contend that there is no inherent necessity for the exclusive use of pen-based design in every aspect of glyph creation. Whether it manifests as a stroke path or an outline, it essentially boils down to an array of coordinates from my perspective. The manipulation of arrays is a skill that I have honed as a programmer. For example, the serif shape for a Latin letter cannot be created using the outlines of a pen. But nothing prevents an METAPOST programmer from quickly drawing that outline without a pen definition.

21. Nupuram source code repository: <https://github.com/smc/nupuram>. Licensed under SIL Open Font License, Version 1.1.

22. Typeface design concepts illustrated using METAPOST <https://github.com/santhoshtr/type-concepts>.

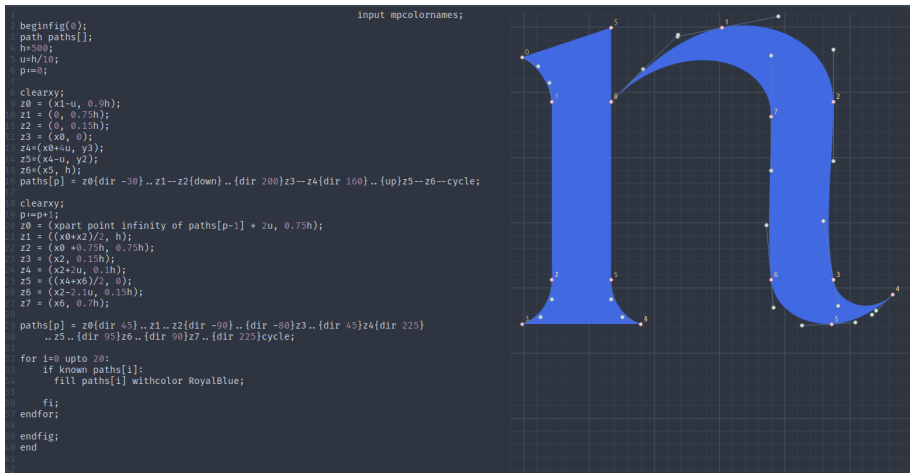


FIG. 22. Letter 'n' drawn using METAPOST using outline technique, without using any pens

10. Conclusion

In this paper, I have provided an outline of the parametric type design methodology, using the Nupuram typeface as an illustrative example. I also elaborated on the lessons learned. While this new approach enabled me to create a typeface with many features hitherto deemed unattainable, it is important to underscore that I am not proposing it as a replacement for the existing type design workflow. The approach outlined here is suitable for designers proficient in software engineering. As typefaces are becoming sophisticated software these days, I am hopeful that this approach will find utility among a broader spectrum of designers. I aspire to see the Nupuram and Malini typefaces, born from this exploration, become valuable assets for a diverse community of users.

References

- Constable, Peter (n.d.[a]). *COLR—Color Table (OpenType 1.9.1)—Typography — learn.microsoft.com*. <https://learn.microsoft.com/en-us/typography/opentype/spec/colr>. [Accessed 08-06-2024].
- (n.d.[b]). *OpenType Font Variations overview (OpenType 1.9.1)—Typography — learn.microsoft.com*. <https://learn.microsoft.com/en-us/typography/opentype/spec/otvaroverview>. [Accessed 08-06-2024].
- Haralambous, Yannis (2007). *Fonts & Encodings. From Advanced Typography to Unicode and Everything in Between*. Sebastopol, CA: O'Reilly, pp. xx+1018.

- Hellingman, Jeroen (1998). “Malayalam fonts”. In: *CTAN: language/malayalam*.
- Hobby, John D. (1986a). “Smooth, easy to compute interpolating splines”. In: *Discrete and Computational Geometry* 1, pp. 123–140. DOI: 10.1007/BF02187690.
- (1986b). “Smooth, easy to compute interpolating splines”. In: *Discrete & computational geometry* 1.2, pp. 123–140.
- (1994). “A User’s Manual for METAPOST. AT&T Bell Laboratories”. In: *Computing Science Technical Report* 162.
- Hudson, John (n.d.). *Introducing OpenType Variable Fonts* — *medium.com*. <https://tinyurl.com/323xypke>. [Accessed 08-06-2024].
- Jackowski, Bogusław and Janusz M. Nowacki (2003). “Latin Modern: Enhancing Computer Modern with accents, accents, accents”. In: *TUGboat: Proceedings of the 2003 Annual Meeting* 24.
- Jackowski, Bogusław, Janusz M. Nowacki, and Piotr Strzelczyk (2001). “MetaType1: A MetaPost-based engine for generating Type 1 fonts”. In: *Proc. of EuroTEX*, pp. 111–119.
- Knuth, Donald E. (1979). *TEX and METAFONT: New Directions in Typesetting*. USA: American Mathematical Society. ISBN: 0932376029.
- (1985). “Lessons learned from METAFONT”. In: *Visible Language* 19.1, p. 35.
- (1989). *The METAFONTbook*. Addison-Wesley Longman Publishing Co., Inc. Chap. 16, p. 150.
- Romer, Linus (2023). “Curvature combs and harmonized paths in MetaPost”. In: *TUGboat* 44, pp. 236–239. DOI: 10.47397/tb/44-2/tb137romer-curvetools.

