Sound Symbolism Across Diverse Writing Systems

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Abstract

It is now well-established that the visual features of objects influence the sounds we make to refer to them. This is called *sound symbolism.* We present the results of a two-part study that explores the extent to which the visual features of writing systems correspond to the smallest spoken units of language. In Study 1, participants (n = 322) classified the shape of a set of glyphs, representative of the world's script families. The purpose was to create an open-source database of normed glyphs for future research in cognitive linguistics. In Study 2, participants (n = 73) were prompted to select either a round or angular glyph after hearing one of two kinds of phonemes (vowel or consonant) from the International Phonetic Alphabet. Results from a logistic regression suggest that the type of sound had a significant effect on the choice of glyph, and that vowel sounds increased the likelihood of choosing round glyphs by 30%. The significant correlation between what subjects heard and their choice of glyph suggests that the effect may extend to such sound symbolic relations in real-world writing systems. Our ongoing research seeks to substantiate these findings with increased glyph contrast and more diverse populations.

Keywords: Sound Symbolism; Writing Systems; Kiki-Bouba Effect; Cognitive Anthropology; Cognitive Linguistics

Introduction

What is the relationship between written and spoken forms of language? There is a robust history in cognitive psychology showing that the visual features of objects—shape, size, directionality, and movement—influence the linguistic utterances and representations we make of them. This is referred to as sound-symbolism (Carbajal, Peperkamp, Tsuji, 2021; Fort, Lammertink, Peperkamp, Guevara-Rukoz, Fikkert, & Tsuji, 2018). Recent work argues for a pressing philosophical need in cognitive science to deepen our understanding of how sound symbolism is foundational during language acquisition and symbolic development in early childhood (Porto, 2023). It argues that the long-standing philosophical account of language offered by Wittgenstein and Sellars (among others), which posits a one-to-one relation between reality and cognitive representational abilities, can be tested empirically with real language (Morris, 2008; Sellars, 1997; Wittgenstein, 1921/2001). By doing so, the extent of sound symbolic relational structure between the physical and linguistic world can be assessed.

A widely known, and well-replicated example of sound symbolism (across language systems and populations) is Köhler' work (Ćwiek et al., 2022). Köhler demonstrated that the artificial words *maluma* and *takete* (and later, *kiki* and *bouba*) are associated with angular and round objects respectively. This has been shown with other artificial words, graphics, and shorter sounds (Callaghan & Corbit, 2015; Ćwiek et al., 2022; Treiman & Kessler, 2011, 2006). Perniss et al. (2010) state: "If iconic mappings are common across languages and cultures, there may be some basic predisposition to mapping properties of visual objects and actions in the environment to specific acoustic properties" (p. 7).

However, there is only minimal research which has explicitly investigated the kiki-bouba effect with either (a) single phonemes, or (b) the individual glyphs of real-world writing systems (Cuskley, Simner, & Kirby, 2017; Turoman & Styles, 2017). That is, despite the fact that the kiki-bouba effect holds across speakers of different language families, research about whether the shape of glyphs used to symbolically represent spoken language corresponds to their phonetic counterpart in real-world writing systems at the smallest unit of language is just beginning to be done. The issue is that potentially non-arbitrary properties of sound-shape symbolism remain unclear, as past work suggests that the kiki-bouba phenomenon is mediated by orthographic letter designs instead of sounds. In fact, Cuskley et al. (2017) suggest that it is not a matter of "matching properties of a non-word's sound to properties of a shape, but rather mapping letter shape in the written form of a non-word to an abstract shape" (p. 120).

The present work starts with the assumption that consonants and vowels follow the kiki-bouba effect on the individual glyph and phoneme level. It proposes that as long as glyphs are round, then persons will match them to vowel sounds and that angular glyphs will be matched with consonant phoneme sounds by persons unfamiliar with particular writing systems. As a first step toward testing our hypothesis, we began by norming the degree of roundness of glyphs of several scripts (see below: Study 1 Results). To our knowledge, this is the first time the world's writing systems have been normed on the dimensions of roundness and angularity.

Thus, the overall task of this ongoing work is to understand if, and to what extent, the visual features of writing systems generally correspond to their sounds. In other words: Is there a real-world relationship between the shape and sound of individual glyphs across writing systems? Ultimately, we are interested in understanding such relationships in different writing systems across place, time, and development. Indeed, the present work is part of a larger, ongoing project that investigates the sound symbolism of writing systems on a multimodal level beyond glyph categorization including drawing production and classification tasks in children and adults.

Our broad research question is as follows: Do established findings in sound-symbolism continue to obtain using real-world writing systems?

Study 1: Stimuli Norming

The aim of Study 1 was to establish a normed set of glyphs to be used as stimuli in Study 2 and other planned research. It did not test for sound-symbolic properties of writing systems. A secondary aim was to provide the scientific community with an open-source, normed set of 400 glyphs from real-world writing systems based on shape (round or angular), currently in development.

Methods

Participants. Participants (*n* = 322) were recruited from a pool of undergraduate and graduate students at a private university in the United States of America. Demographic information was not collected.

Procedure. An online experiment was built on lab.js and delivered via the open-lab.online server (Henninger, Shevchenko, Mertens, Kieslich, & Hilbig, 2021; Shevchenko, 2022). Participants (n = 322) classified the shape of a set of 368 glyphs in a forced-choice paradigm. Participants were shown a single glyph and were asked to classify it as round or angular. Every participant saw the same set of glyphs with fully randomized counterbalancing.

Materials. The stimuli set was comprised of glyphs~~,~~ representative of the world's script families (Abjad, Abugida, Alphabet, Featural; we also included glyphs from Logosyllabary and Syllabary scripts to norm for future research). The basic properties of each script are as follows: (1) *Abjad:* Each glyph stands for a consonant; vowels are depicted through so-called vowel points. (2) *Abugida:* Each glyph stands for a consonant accompanied by a particular vowel and other vowels (or none) are indicated by consistent additions to consonant symbols. (3) *Alphabet:* Each glyph stands for either a vowel or consonant. (4) *Featural:* Each glyph construction conveys phonological features of the represented phoneme. (5) *Logosyllabary:* Each glyph stands for a syllable and can be used to convey both sound and meaning. (6) *Syllabary*: Each glyph stands for a syllable.

In total, 4,747 glyphs were produced with a Python script as PNG images from standard Unicode ranges (Figure 1). Glyphs were uniformly rendered in black and placed on transparent background, using Noto typefaces for each writing system.

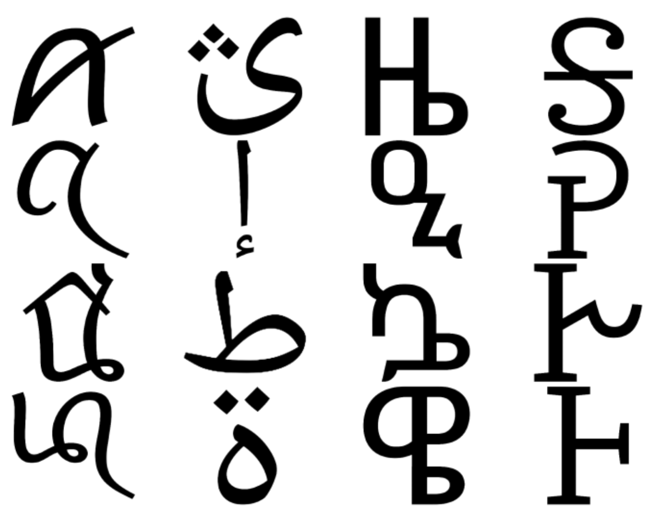

Figure 1: Glyph rendering samples (column-wise left-to-right: Tai-Viet, Arabic, Ethiopic, and Cherokee).

Results

Out of 368 randomly sampled glyphs (76.5% consonants; 23.5% vowels; 32 glyphs were omitted due to lack of available transliteration or randomly sampling numeric glyphs) from a set of 4,747, 72.6% of written vowels were normed to be round; 44.4% of written consonants were normed to be angular. We attribute the difference to the fact that there are significantly more consonants across scripts than vowels. Our findings suggest that there is a general roundness effect for vowels, but that, at this gross level of categorization, consonants vary more along the roundness-angularity dimension, but we cannot say anything about their sound symbolism.. For example, it may be that "rounder-sounding" consonants tend to be *voiced* or *continuants*, and more "angular-sounding" ones tend to be *unvoiced* or *stops*. However, the scope of Study 1 was only to provide a normed stimuli set; future studies will interrogate more fine-grained contrasts explicitly.

Final stimuli selection for Study 2 was achieved at a minimum bound (Fleiss' $\kappa > 0.74$) for inter-rater reliability per individual glyph. This resulted in a set of 247 glyphs. Next, computational methods were used to produce the actual transliterated sound of the entire stimuli set using AnyAscii for each of the glyphs in the stimuli set (https://github.com/anyascii/anyascii). Mistakes in automatic coding (< 10) were manually corrected. The purpose of this step was to provide a robust measure for comparing sound types to participant responses in Study 2. The final stimuli set for Study 2 was sampled from these 247 normed glyphs.

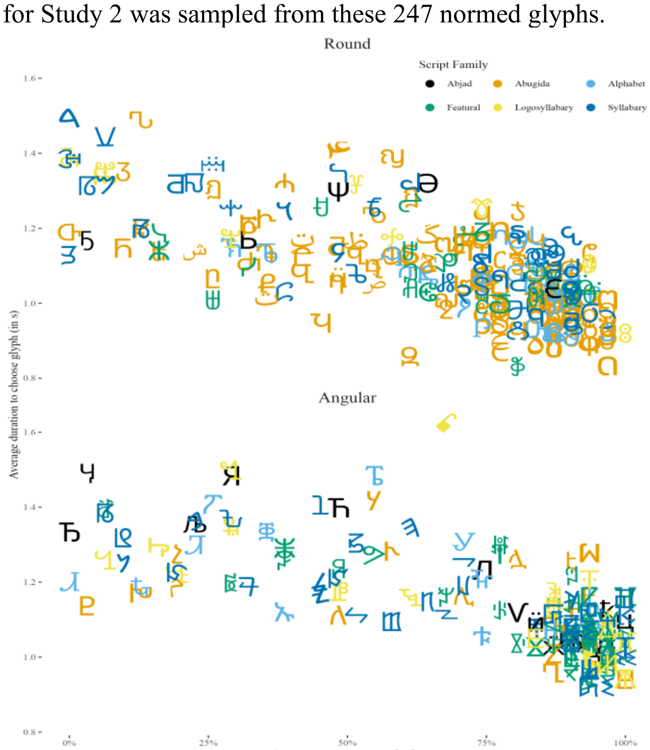

Figure 2: Agreement rating per glyph by shape. 100% agreement means total agreement on glyph shape. Y-axis shows decision-time per glyph, used here for visualization purposes.

Selected stimuli glyphs for **Study 2** (32 angular consonants; 31 round vowels) were sampled from diverse language families (Abjad: 5 angular, 1 round [$\kappa = 0.742$]; Abugida: 5 angular, 10 round [$\kappa = 0.871$]; Alphabetic: 5 angular, 8 round [$\kappa = 0.742$]; Featural: 7 angular, 3 round [$\kappa = 0.774$]; Logosyllabary: 4 angular, 2 round [$\kappa = 0.871$]; Syllabary: 6 angular, 7 round [$\kappa = 0.742$]). One glyph (Abugida; Tai-Viet) was miscoded by shape and sound type and was omitted after data collection.

Study 2: Sound Symbolism & Writing Systems

The purpose of Study 2 was to conduct a first-order proof of concept test to determine if the most basic parameters of our stimuli set have sound-symbolic properties. The reason for this was to provide robust grounding for future planned studies. Specifically, we hypothesized that single phoneme vowel sounds would be significantly correlated with round vowel glyphs and that single phoneme consonant sounds (pronounced without vowel vocalization) would be significantly correlated with angular consonant glyphs. That is, we predicted that the kiki-bouba effect would hold for both round and angular glyphs: (1) vowels would be matched to round glyphs whose real sounds were vowels and (2) consonants to angular glyphs whose real sounds were consonants.

To this end, we used binomial logistic regression to discern the effects of multiple sets of predictors (sound, language, demographics) on the subjects' choice of glyph. To protect against violations of the assumptions of logistic regression, we report bootstrapped p-values and confidence intervals (10,000 samples).

In our models, the choice of round glyph served as the response measure. Other predictors included sound type, subject multilingualism, geographic location, handedness, age in years, education level, and native language (Table 1).

Methods

Participants. Participants (n = 73) were recruited via Prolific. Collected demographics of relevance included age ($M = 29$, $SD = 8.4$) and multilingualism (82%). Participants were sampled from 5 continents (Europe, North America, South America, Asia, Australia, Africa) and spoke 15 different native languages (English, Italian, Spanish, Tagalog-Filipino, Polish, Portuguese, Russian, Vietnamese, Swedish, German, Dutch, Czech, Greek, French, Dari).

Materials. Glyphs were produced through a Python script as PNG images from standard Unicode ranges. Glyphs were uniformly rendered in black and placed on transparent background, using relevant Noto typefaces. The experiment was programmed with *jsPsych* and hosted on MindProbe.eu (de Leeuw, 2015). Audio was sourced from a single male speaker using standard pronunciation of the International Phonetic Alphabet (IPA).

Procedure. Participants completed an online experiment using a forced-choice paradigm. Following a familiarization trial, they were shown two glyphs (one round and one angular) and heard one audio sound from the IPA (phonemes of consonants or vowels). They were prompted to assign the sound to the glyph that they thought corresponded to it. Importantly, spoken audio of consonant sounds did not include vowel vocalizations affixed to the consonant (e.g., the affricative back consonant sound /kx^w/ was not pronounced with a vowel; sample audio recordings that are not affiliated with the authors can be found here: https://jbdowse.com/ipa/). All participants were shown the same stimuli set, which was delivered with full randomization. Participants also completed additional phases where they produced drawings based on the same audio; those results are not reported in this work. We also included syllabaries in Study 2 to test general sound symbolic properties of diverse glyphs for future research, despite their real-world vocalization.

Results

Our results show that the type of heard sound had a significant effect on the choice of glyph, and that vowel sounds increased the odds of choosing round glyphs by 30% (*OR:* 1.30, *CI:* 1.10, 1.54, p=0.001; see Table 1 below). Including the shown glyphs as crossed random effects in the model did not have a notable effect on the result. More, vowels were marginally more associated with round glyphs than consonants were with angular glyphs (Figure 3).

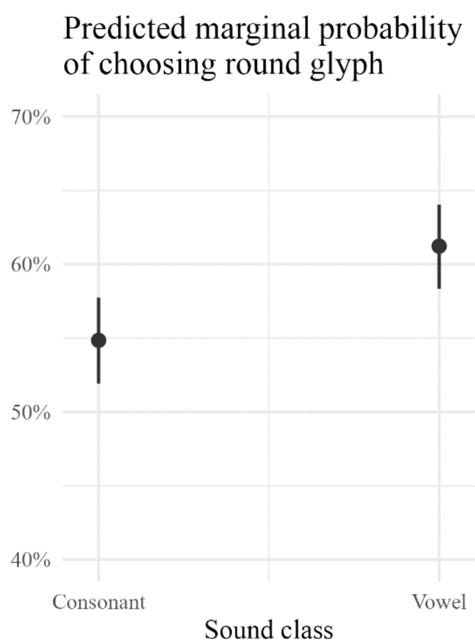

Figure 3: Y-axis represents predicted marginal probability of choosing glyphs by matched sound class (Consonant = Angular; Vowel = Round).

Notably, the individual language differences in writing systems (detailed by language in Table 1), participant multilingualism (*OR:* 1.07, *CI:* [0.86 - 1.34], *p*=0.560), and geographic location (*OR:* 0.88, *CI:* [0.72 - 1.07], *p*=0.209) were not significantly associated with responses. That is, there were no significant cultural differences across responses. Thus, the effect holds across participants' different native languages, geographic location, and whether or not subjects were multilingual. Differences across writing systems were not significant in the overall result; however, there were differences in participant responses across individual systems.

Conclusion

The purpose of this work was to provide ground-level data to permit further research investigating the sound symbolics of real-world writing and speech. The results justify future research to further test if, and to what extent, the shape of glyphs of diverse writing systems, and their respective phoneme vocalizations, have a deeper connection.

This research seeks to add ecologically-valid evidence to past findings in sound symbolism by indicating that the kiki-bouba effect holds for the shapes and sounds of glyphs from real language. The results suggest that the connection between the shape and the sound of round glyphs whose real sounds are vowels, and angular glyphs whose real sounds are consonants, is sound symbolic in a first pass exploration.

As the real sounds of glyphs paralleled subjects' responses (angular glyphs were always consonants and round glyphs were always vowels), we suggest that well-established findings in sound symbolism may continue to hold at the smallest unit of spoken and written language, but future research must take better aim to test this claim. Nonetheless, we provide a stimulus set, and evidence from two studies that demonstrates a general roundness effect for vowel sound symbolism.

Additionally, our findings validate the idea that single-phoneme glyph consonants vocalized without vowel sounds—which are arguably non-speech-like—may still have sound symbolic effects. Especially as other linguistic or geographic variables did not have significant effects on the model, we suggest that there is reason to believe that this effect would continue to hold in more diverse populations with a more diverse set of glyphs.

Future research will only include glyphs from writing systems whose vowels and consonants are written separately (e.g., alphabetic systems). Planned studies will further interrogate the present findings using contrasting glyph shapes (i.e., we will examine if including angular vowel glyphs and round consonant glyphs changes the overall effects reported here). We will also explore whether intuitively "rounder-sounding" phonemes represented by *voiced* or *continuant* sounds or more "angular-sounding" *unvoiced* or *stop* sounds correspond to their visually analogous glyphs. In sum, the present study underscores the potential for the possibility of sound symbolic effects at the most basic units of writing and speech, serving as a foundation for future research aimed at investigating sound symbolism across diverse linguistic context.

Table 1: Results from logistic regression. Odds Ratios and p-values.
Sound type was strongly associated with glyph shape. Multilingualism, geographic location, and script family were not significantly correlated to response. Differences across languages are included for contrast but are not significant in the overall result.

		95% CI		
Parameter	*Coefficient*	*LL*	*UL*	*p-values*
(Intercept)	0.70	0.37	1.35	0.287
Sound Class: Vowel	1.30	1.10	1.54	**0.001**
Multilingual	1.07	0.86	1.34	0.560
Handedness (Right)	0.97	0.78	1.21	0.819
Geographic Location (Europe)	0.88	0.72	1.07	0.209
Age (years)	1.00	0.99	1.01	0.747
Education Level: High School or Equivalent	1.21	0.95	1.54	0.122
Education Level: Master's or Equivalent	1.20	0.96	1.48	0.094
Effects of individual languages on response; Arabic serves as the baseline category.				
Anatolian Hieroglyphs	1.46	0.82	2.60	0.193
Bassa Vah	1.38	0.78	2.50	0.261
Canadian Aboriginal	1.82	1.06	3.20	0.035
Cherokee	3.03	1.67	5.59	<0.001
Cyrillic	1.43	0.86	2.42	0.166
Ethiopic	2.33	1.29	4.23	0.004
Mro	2.07	1.06	4.21	0.036
Phags-Pa	1.58	0.79	3.15	0.188
Tai-Viet	1.18	0.71	1.96	0.518
Thai	1.89	0.96	3.81	0.067
Vai	2.04	1.04	4.15	0.036
Yi	1.53	0.91	2.62	0.111

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