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ORIGINAL ARTICLE

How does one's first language writing script modulate second language reading: evidence from the English Reading Online Project (ENRO)

Naima Mansuri[1,2,3], Antonio Iniesta[2,3,4,5], Esteban Hernández-Rivera[1,2,3], Pauline Palma[1] and Debra Titone[1,2,3]

[1]Department of Psychology, McGill University, Montreal, Canada, [2]Montreal Bilingualism Initiative, Montreal, Canada, [3]Centre for Research on Brain, Language, and Music, McGill University, Montreal, Canada, [4]The Mind, Brain and Behavior Research Center (CIMCYC), University of Granada, Granada, Spain and [5]Department of Developmental and Educational Psychology, University of Granada, Granada, Spain
Corresponding authors: Naima Mansuri, Debra Titone; Emails: naima.mansuri@mail.mcgill.ca, debra.titone@mcgill.ca

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Abstract

Approximately half of the world's population is multilingual, and many read in a second language. Thus, an open question is whether and how people's multilingual knowledge impacts their second language reading processes. To this end, we investigated whether competing influences from people's first language (L1) writing system (i.e., alphabetic, logographic, or alphasyllabic) impact second language (L2) reading of English (alphabetic). Based on models of L1 and L2 reading, we hypothesized that matches/mismatches in people's L1 and L2 writing scripts would modulate the expected relationship between L2-English reading proficiency and how often people use their L2 in daily life. Using a subsample of 1073 adults from Siegelman et al. (2023), we found that readers with mismatching L1 writing scripts varied on both English Single Word Accuracy and Speed Measures, and English Extended Word Measures, over and above the expected effects of L2 reading usage. L1-alphabetic and alphasyllabic readers were faster and more accurate than L1-logographic speakers on Single Word Speed and Accuracy Measures. L1-logographic readers were also faster but lower in accuracy on Extended Word Measures vs. L1-alphabetic and alphasyllabic readers. These findings indicate that multilingual knowledge and experience mutually constrain L2 reading and suggest future avenues of theoretical and empirical inquiry.

Keywords: Bilingualism; language use; orthography; reading comprehension; scripts; writing systems

Reading is one of the primary language skills necessary for both personal and academic success (Cain et al. 2004; Kim & Schatschneider, 2017; Krashen, 2004; Stanovich, 1986; Wolf & Barzillai (2009). This is because it underlies psychological

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(Ahmed et al., 2014; Berninger & Abbott, 2010), cognitive (Berninger & Winn, 2006; Berninger et al., 2010; Kim & Graham, 2022; Lovett et al., 2022), and social well-being (Watson & Boman, 2005). Reading also serves as a primary means of knowledge transfer between people (Kim, 2020). Reading comprehension in any language is crucial to a variety of real-world opportunities and needs, such as employment, legal, and medical needs (Hernández-Rivera et al., 2022; Koda, 2007; Palma & Titone, 2020; Whitford & Titone, 2019). Thus, people who lack strong reading comprehension abilities can face multiple challenges every day (Mullis & Martin, 2019).

Roughly half the world's population speaks more than one language (Grosjean, 2010), and a large percentage of those people also read in a second language (Lallier et al., 2021). Recently, studies in bilingualism have emphasized the role of individual differences within bilingual groups (e.g., Luk & Bialystok, 2013; Gullifer & Titone, 2019). Of the several dimensions that contribute to individual differences in bilingual experience, relatively less attention has been paid to how the characteristics of people's first languages (L1s) affect how a second language (L2) is acquired or processed (Bassetti, 2008; D'Anselmo et al., 2013; Lallier et al., 2016; Wang et al., 2003). However, there is some evidence that bilingual adults use resources acquired in one language to perform tasks in their other language (Lallier & Carreiras, 2018), suggesting that characteristics of the L1 may affect how L2 reading is achieved (Lallier et al., 2016; Wang et al., 2003).

Most bilingualism research on reading uses writing systems as the primary measure of L1/L2 distance. Writing systems are methods for representing spoken languages (Katz & Frost, 1992), and different writing systems in the world map spoken language onto different orthographic units (Wang & Koda, 2007). Systems/scripts can be broadly classified into alphabetic (e.g., Spanish or Italian), logographic (e.g., Mandarin), abjads (e.g., Arabic or Hebrew), or abugidas (e.g., Thai). Various scripts can differ in complexity, consistency, and predictability with which graphemes map onto their corresponding phonemes (Schmalz et al., 2015). Much of the research into the world's languages focuses on alphabetic writing systems, which is only one type of orthography in use in the world, and not necessarily the most widely used one (Vaid, 2022).

Consequently, theories of literacy development have been largely based on English and other alphabetic scripts (Katz & Frost, 1992; Ziegler & Goswami, 2005). However, to understand the universal aspect of literacy development, there is a need to consider development across other scripts. In fact, most bilingual speakers who become literate in more than one language are likely to be readers of at least one non-alphabetic script (biscriptal readers; Vaid, 2022), yet word recognition research is based almost entirely on users of English and another European language (with an alphabetic orthography). Given that biscriptal readers represent most bilinguals in the world (Vaid et al., 2022), this leads to a substantial gap in the literature with respect to reading and literacy in languages that use non-alphabetic writing systems.

In alphabetic writing systems, the smallest written unit corresponds to the smallest spoken sound; for example, a single written unit in English could be "r," which maps onto the single spoken unit of the sound /r/. In comparison, abugidas and abjads do not have letters or symbols depicting vowel sounds. Abjads (e.g., Arabic) omit vowels, and thus the smallest unit نا would map onto a syllable sound /nɑ/. In Abugidas, consonant-vowel clusters are depicted together, with

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vowels modifying the character for the consonant, for example, क (/k/) becoming की (/ki/). Abugidas are thought to have evolved from abjads, as both writing systems follow a similar structure where consonant-vowel clusters are written as one unit, the smallest unit in that language. Abjads and abugidas are both examples of phoneme-based writing systems that differ from Alphabetic languages (Bright, 2000; Daniels & Share, 2018). Thus, here we refer to both as alphasyllabic languages. Consistent with Bright (2000), alphasyllabic writing systems will be defined as languages that denote vowels in a status dissimilar to consonants. Finally, logographic systems select morphemes or words to represent spoken language, mapping printed characters to a corresponding monosyllabic morpheme (Wang & Koda, 2007). In Mandarin, typically the smallest written unit depicts meaning instead of sound; for example, a single written unit such as 树 would map onto /ʃu/ meaning "tree." Visually, the three language types differ as well, as alphabetic and alphasyllabic writing scripts are typically written linearly, and their smallest units are combined to dictate pronunciation (Perfetti, 1999; Wang et al., 2003). Logographic languages, in contrast, consist of interwoven strokes in a square-like shape (Wang et al., 2003).

Such differences between scripts are characterized by the Psycholinguistic Grain-Size Theory (Ziegler & Goswami, 2005). This states that the size of the smallest unit (the grain size) that must be learned to read in a specific language has an impact on reading performance (Gottardo et al., 2016). When reading, the assembly of alphabetic languages (with a grain size of a single sound; /r/) and alphasyllabic languages (with a slightly larger grain size of a syllable; /nɑ/) allows larger units to be assembled from smaller grain-size mappings. In alphabetic languages such as English, mapping letters to sound is important in word recognition (Bialystok et al., 2005); for example, the letter-phoneme-mappings of /k/ /a/ /n/ /e/ can be assembled for "cane" (/ˈka.ne/, "dog" in Italian). In alphasyllabic languages like Urdu, the grain size is of a syllable, and multiple syllables are combined to create words. For example, "food" in Urdu is composed of two syllables: "کھا" (/kɑ/) and "نا" (/nɑ/), which assembled, create "کھانا" (/ˈkɑːnɑ/). This assembly, or additive structure, is present in both alphabetic and alphasyllabic languages, but is lacking in logographic reading, where a single unit constitutes a meaning and has an associated pronunciation (Wang et al., 2003). Chinese, for example, does not possess the segmental structure that is basic to alphabetic writing systems (Wang et al., 2003); therefore, the pronunciation of Chinese is recalled from memory and is not constructed through the assemblage of individual sound units (Wang & Koda, 2007). Logographic languages such as Chinese require the readers to be sensitive to overall visual cues (Koda, 2007) because each Chinese character represents a morpheme but carries little phonological consistency.

The difference in linguistic and cognitive processing across systems could result in different cognitive overloads (Paas, et al., 2003), as readers would need to use a variety of different mental processes to decode words and review text structure (Cartwright, 2015; Pollock et al, 2002). Thus, different reading and cognitive processes are required to mitigate the constraints imposed by differences across systems (Iniesta et al., 2023; Zhang & Duke, 2008) and can impact the strategies employed during L2 reading (Lallier et al., 2016). The requirements of inhibitory control, mental task switching, or working memory can be impacted by L1-L2

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similarities and differences (see Antoniou & Wright, 2017), as well as the attentional and cognitive resources on the learners' part to learn to read in the new language (see Ghazi-Saidi & Ansaldo, 2017).

The system accommodation hypothesis (Perfetti & Liu, 2005; Perfetti et al., 2007) has been proposed to explain how bilinguals acquire and process reading in different languages. This hypothesis predicts that when reading is acquired in a new writing system, L2 reading procedures should be assimilated to those used in the L1. However, when the writing systems are significantly different from each other, the reading network is supposed to accommodate the development of new neural and cognitive resources needed to read in the L2. Language distance between L1 and L2 is thought to influence the balance between assimilation and accommodation (Kim et al., 2017). Previous studies have shown a negative impact of distant L1-L2 reading processes on L2-orthographic learning, highlighting the modulatory role of L2 proficiency in this process (Fu et al., 2023, 2024).

From the language-specific perspective, the available evidence suggests that second-language readers with varying first-language backgrounds can employ qualitatively different procedures when reading the same second language (e.g., Green & Meara, 1987). Regarding L2 word recognition, previous research has found that people with different L1 orthographic backgrounds perform differently on L2 word recognition processes (Hamada, 2017; Hayes-Harb 2006; Haynes and Carr 1990; Morfidi et al., 2007; Muljani et al., 1998; Sui et al., 2025; Wang & Koda 2007). In this direction, Wang et al. (2003) demonstrated that the L1 (Korean vs. Chinese) reading skills impact L2 (English) reading. Wang et al. (2003) found that Korean learners of English, compared to Chinese learners, were more sensitive to phonological information of English words because Korean relies more on phonological aspects, being an alphabetic language. However, Chinese learners of English were more sensitive to orthographic information of English words, because Chinese relies more on orthographic information, being a logographic language. In addition, different studies suggest reading advantages for an English L2 by readers of alphabetic L1s (Korean, Indonesian, and Dutch) compared to their logographic (Chinese) counterparts, on measures such as lexical decision (Muljani et al., 1998), semantic category judgment (Wang et al., 2003), morphological awareness (Koda, 2000), English-specific word properties (frequency and regularity; Wang & Koda, 2007), and reading eye-tracking measures (Sui et al., 2025).

Less emphasized in previous work are discussions of the impact of alphasyllabic writing scripts. Also, most studies use one specific language as a representative for a given orthography (for example, Korean representing alphabetic versus Mandarin representing logographic), which leads to results that are difficult to generalize to the orthography itself (Lallier & Carreiras, 2018). This leads to an open question as to how different readers of different writing scripts perform in reading comprehension tasks in a second language.

The present study

One of the most learned second languages globally is English (Ushioda, 2017). Thus, English as an L2 is important as it is highly pervasive and an essential skill for people worldwide (Crystal, 2003; Jenkins, 2015), critical to world advances in technology,

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health, politics, and education (Arkoudis et al., 2014, Bleakley & Chin, 2010)—so much so that many non-English-speaking countries have dedicated programs for teaching English as a second language (Jenkins, 2015; Tao, 2019). Despite this, how different bilingual speakers learn English as a second language is lightly explored.

The present study examined a large set of L2 English readers around the globe, with different L1s from the 3 main writing systems (alphabetic, logographic, and alphasyllabic), to shed light on how a person's first language can impact their second language reading, modulated through their L2 exposure. L2 exposure is understood as the time spent using the language (Purdie & Oliver, 1999) and has been proposed as a useful predictor of reading comprehension in L2 (Grey et al., 2015; Tagarelli et al., 2011), facilitating learning (Khamkhien, 2010), lexical retrieval and reading fluency (Vingron et al., 2021; Whitford & Titone, 2012; 2017), and impacting the cognitive resources underlying language processing (Gullifer et al., 2023; Gullifer et al., 2021). This study explored whether matches or mismatches in people's L1-L2 writing script modulate the expected relationship between L2 exposure and L2 English reading performance.

To pursue this question, we required a set of participants who had a broad range of L1 languages from different writing scripts and with different L2 English experiences. To achieve this goal, we subsampled participants from the English Reading Online (ENRO) Project (Siegelman et al., 2023). ENRO consists of a collection of reading and listening comprehension tasks with data for over 7000 participants (Siegelman et al., 2023). The project used a variety of tasks to assess English reading performance in participants across 19 countries and over 70 languages. The size and breadth of the data make the ENRO project unique and ideal for evaluating our hypotheses.

Examining L1-L2 writing script similarities using the ENRO sample can help further the knowledge from current studies on reading in a second language for several reasons. Firstly, as mentioned above, most research focuses on alphabetic versus logographic L1 readers of English, whereas the ENRO sample also included alphasyllabic readers. Secondly, previous studies typically only use one language per writing script category (for example, only Korean readers versus Chinese readers), whereas ENRO allowed us to group languages to create larger categories that are more suitable for generalization (for example, grouping all alphabetic languages together). Thirdly, we could compare language experience in English from a large subset of L2 English readers around the globe by analyzing percentage scores for how often English is read at home, with friends, with family, etc.

Our general hypothesis was that matches or mismatches between people's L1 and L2 writing scripts would modulate the expected relationship between L2 reading usage and L2 reading performance. Firstly, we expected a better performance in bilinguals with an L1 with a matching script to English (an alphabetic script), as alphabetic language systems will tend to have an easier time learning other alphabetic languages, such as English, compared to people with a logographic or alphasyllabic L1. Additionally, we hypothesized that this effect would be moderated by L2 English reading usage. We predicted that more experience reading in an L2 would increase L2 English reading proficiency across language scripts and reduce the differences caused by L1 writing scripts.

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Method

Participants

The ENRO project included a total of 7338 participants across 19 countries and 70 languages (Siegelman et al., 2023). The current study capitalized on this large dataset to subsample a more refined set of 1073 bilingual participants, all of them with English as a second language, and a wide range of L1s (*see* Table 1). Specifically, 646 participants with an alphabetic L1, 176 participants with an alphasyllabic L1, and 251 participants with a logographic L1. All participants were sequential bilinguals (i.e., English age of acquisition (AoA) was greater than 5 years).

Specifically, we preprocessed and subsampled the data to address our specific research questions (see *Supplemental Materials*, Figure 1). We first included only participants without any missing background data ($n = 6319$). Then, we chose only participants who reported exactly 2 languages ($n = 2529$) to ensure that each participant had exactly one L1 writing script and one L2 writing script. To ensure our sample was exclusively composed of sequential bilinguals, we only included participants who had an English L2 after the age of 4 and an L1 before the age of 4 ($n = 1135$). Following previous bilingual research, we classified an L1 as any language spoken before the age of 4 and an L2 as any language learned after the age of 4 (Gullifer et al., 2021). Then, we excluded participants whose data were collected through the Prolific platform for online data collection ($n = 1132$), as it was hard to verify the source country of each participant. Lastly, we chose only to include participants with one L1 writing script ($n = 1073$). This excluded Korean L1 ($n = 19$ participants) and Japanese L1 ($n = 40$) participants; Korean uses an alphabetic writing system, and Japanese uses a syllabary system, but both borrow the logographic writing system from Chinese.

Materials

All participants completed a brief language background questionnaire (based on Gullifer & Titone, 2020), which asked for basic demographic and linguistic information about both the L1 and L2. In addition, all participants across all testing sites completed the same battery of tasks to assess reading performance in English (detailed in Siegelman et al., 2023). This included a test of reading comprehension (1), a reading speed test (2), and seven texts evaluating English reading proficiency, which focused on the component skills of reading: vocabulary and word identification (3), orthographic knowledge (4), and grammar knowledge (5).

For the whole passage reading comprehension test (1), participants read a set of fifteen English texts, followed by three comprehension questions. The measure of whole passage reading comprehension was the participants' percentage of correct responses out of the 45 questions (three questions per text). Furthermore, whole passage reading rate (2) was calculated as the number of words in each text divided by the total reading time.

To explore vocabulary and word identification (3), a vocabulary knowledge test (adapted from Nation & Beglar, 2007), a lexical decision task, and the Lexical Test for Advanced Learners of English (LexTALE; Lemhöfer & Broersma, 2012) were administered. For the vocabulary knowledge test, participants read a series of questions

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Table 1. Participant information

	Alphabetic[a]	Alphasyllabic[b]	Logographic[c]
n	646	176	251
Age	21.05 (3.53)	21.04 (3.54)	21.04 (3.5)
% female	71.3%	51.7%	56.6%
English AoA	7.83 (2.77)	7.85 (2.78)	7.85 (2.78)
Living in an E-country (%)	21%	31.8%	59.36%
Living in an E-country (years)	7.22 (6.8)	7.05 (6.67)	7.01 (6.62)
English Proficiency Tasks			
Vocabulary Knowledge	50.75 (14.86)	50.69 (14.86)	50.64 (14.88)
Spelling Recognition	0.80 (0.12)	0.80 (0.12)	0.80 (0.12)
Gramaticality Judgment	0.73 (0.15)	0.72 (0.15)	0.72 (0.15)
LexTALE	0.73 (0.13)	0.72 (0.13)	0.72 (0.13)
Lexical Decision	0.74 (0.13)	0.74 (0.13)	0.73 (0.13)
Orthographic Awareness	0.85 (0.11)	0.85 (0.12)	0.85 (0.12)
Segmentation	31.4 (13.86)	31.3 (13.83)	31.27 (13.82)
LexTALE (rt)	1213.75 (565.5)	1215.119 (565.97)	1216.21 (567.11)
Lexical Decision (rt)	790.85 (176.25)	791.33 (176.5)	791.52 (176.67)
Reading Comprehension	0.71 (0.17)	0.71 (0.17)	0.71 (0.17)
Reading Rate	209.98 (112.3)	209.75 (112.47)	209.32 (112.50)

Note: AoA: Age of Acquisition; E-Country = English Speaking Country; rt = Reaction Time
[a]Afrikaans, Bulgarian, Croatian, Dutch, Filipino, French, German, Hungarian, Italian, Mongolian, Polish, Romanian, Russian, Serbian, Slovenian, Spanish, Tagalog, Turkish, Ukrainian, Uzbek, and Vietnamese.
[b]Arabic, Bengali, Farsi, Gujarati, Hebrew, Hindi, Malayalam, Punjabi, Sinhalese, Tamil, Thai, and Urdu.
[c]Cantonese and Mandarin.

where a target word was embedded in a short context and asked to choose its correct definition from four options. The LexTALE task is an untimed lexical decision task of 60 trials (40 real-word trials, and 20 non-word trials) where participants see a string of letters and determine whether the letters form a real English word or not. The final test for vocabulary and word identification was a second lexical decision task, consisting of 300 stimuli (150 real-word trials and 150 non-word trials).

To explore orthographic knowledge (4), a spelling recognition test (adapted from Andrews & Hersch, 2010), an orthographic awareness test (Siegel et al., 1995), and a segmentation test were administered. For the spelling recognition test, participants were presented with 44 words, half of which were misspelled, and asked to decide whether each word was a correctly spelled word in English. For the orthographic awareness test, participants were presented with two nonwords and asked to judge which one resembled an English word more (for example, "filk" versus "filv"). In the segmentation task, participants were given a sentence without spaces and asked to insert them into the text as quickly and accurately as possible.

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Finally, to explore grammar knowledge (5), a grammatical judgment test (adapted from Nassajizavareh & Geva, 1999) was administered. In this task, participants were presented with 30 sentences, half of which contained grammatical errors, and asked to judge whether each of the 30 sentences was grammatically correct. For more information and a full description of each task, see Siegelman et al., 2023, Appendix S3.

Procedure

The participants were recruited online via university-based laboratories to ensure cross-sample consistency (Siegelman et al., 2023). The same tests were administered to all participants, in the same order, eliminating the variability due to study design, administration, and apparatus (Seigelman et al., 2023, Procedure section). The experiment had a duration of approximately 1.5 hours. This study was approved by the Research Ethics Board of McMaster University (protocol #4968). In addition, each lab from the different countries obtained an ethics clearance from the ethics research board of the corresponding institution or country (protocol #21-04-054[0921] at McGill University).

Research questions

This paper poses the following research question.

Does a matching L1-L2 Writing Script modulate the expected relationship between L2 English reading usage and L2 reading performance?

Independent variables

To test our research question, we classified L2 English reading usage as the percentage of English reported by each participant. Second, we used the participants' reported L1 to determine their L1 writing script, to test whether their L1 writing script affected the expected relationship between our dependent variables and L2 English reading usage.

We categorized each language as alphabetic, logographic, or alphasyllabic based on Omniglot (an encyclopedia of writing systems and languages; see Ager, 2023) and Scriptsource.org (i.e., https://scriptsource.org./cms/scripts/page.php). However, within the categorization of L1 writing scripts, there were some inconsistencies. For example, a language like Kurdish could be categorized as either alphabetic in some parts of the world (such as Turkey) or alphasyllabic in other parts (such as Iraq). For these languages, the L1 writing script was determined based on where the data was collected or the language background questionnaire. Secondly, some languages are in the process of changing their written script to use the Latin alphabet; in these situations, the L1 writing script and language family were calculated as the official writing script at the time the data was collected. Next, as all languages were self-reported, some languages had to be recoded; these included languages with spelling mistakes (Frnch), languages with different dialects (Tagalog vs. Filipino), and languages that were not specified enough (Chinese vs. Mandarin). Finally, to retain the largest number of participants, abjads and abugias (as labeled on Omniglot.com

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and Scriptsource.org) were combined under one writing system, an alphasyllabic system, for languages that do not depict vowels yet are still aligned in a linear fashion similar to alphabetic languages.

Dependent variables

To assess our variable of interest (i.e., reading performance), we took a bottom-up, data-driven approach by conducting an exploratory factor analysis (EFA) to identify underlying latent factors for the totality of the English reading measures (for more information on an exploratory factor analysis, see Goretzko et al., 2021). Specifically, the ENRO project tested participants on 11 English reading tasks, specifically chosen to test multiple components that have been theorized to encompass reading comprehension. These tasks included whole passage reading comprehension, whole passage reading rate, grammaticality judgment, spelling recognition, orthographic awareness, text segmentation, vocabulary knowledge, the Lexical Test for Advanced Learners of English (LexTALE), and a lexical decision task. We conducted an EFA with an Oblimin rotation to identify the underlying structure of participants' reading performance across tasks. Oblimin rotation was chosen over orthogonal rotation, as the latter assumes factors are uncorrelated—a condition we cannot presume in our data (Flake & Fried, 2020). This technique simplifies and clarifies the factor structure by maximizing high loadings and minimizing low ones, providing a more interpretable relationship between the observed variables and the underlying factors.

The results of the EFA identified 3 distinct factors determined by visual analysis of a parallel analysis scree plot, discussed in detail in the results section.

Data preprocessing and analytic approach

The resulting factors from L2 English reading performance tasks were designated as DVs, while the L1 writing script (alphabetic, logographic, or alphasyllabic) and the overall percentage of English reading usage were designated as the IVs. L2 English language usage was included as a scaled continuous predictor of the overall percentage of English reading usage reported on the ENRO project.

Three models were run for each dependent variable. The first model was to confirm the expected relationship between L2 English reading usage on L2 English reading proficiency, in isolation from L1 writing script. The second and third models (the interaction models) were identical, with a changed reference level, to address the research question: whether L2 English reading usage mitigates the effects of L1 writing script on L2 English reading proficiency.

Writing script, as a categorical predictor, was treatment-coded by assigning binary values (0 or 1) to each script type. To determine the difference between all 3 writing scripts, we ran a linear model with alphabetic serving as the reference level (coded as 0) and the other script types coded as 1. Then, we ran the same linear model, changing the reference level to logographic to determine the difference between logographic and alphasyllabic participants.

Thus, in sum, a series of linear mixed models were run with Single Word Accuracy Measures, Single Word Speed Measures, and Extended Word measures as

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the dependent variables (explained in detail in the results section); we tested whether L2 English reading usage affected each DV, and critically, whether the effect of L2 English reading usage was impacted by L1 writing script (*see* Figure 1).

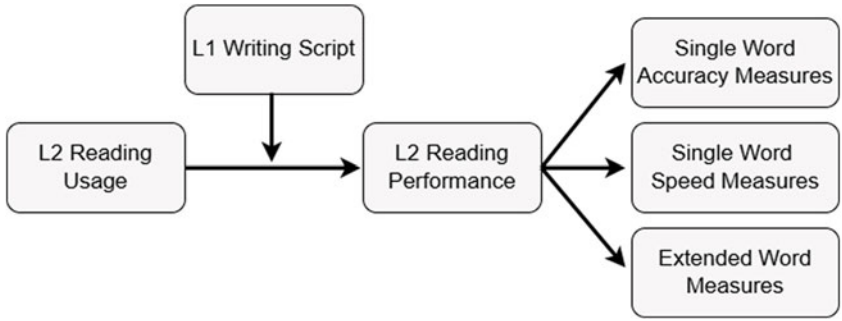


Figure 1. Data analytic approach.

The analysis was conducted in R (R Core Team, 2021) using the lme4 package (Version 1.1-27.1; Bates et al., 2015). We report the beta estimates from the lme4 package (Bates et al., 2015). Each model was fitted utilizing a restricted maximum likelihood criterion. All models controlled for the fixed effect of participants' L2 English AoA as L2 AoA is an important aspect of the bilingual language experience, differentially associated with language use (e.g., Bialystok et al., 2005; Gullifer et al., 2021). For all models, we included random intercepts for country and testing site to account for the inherent linguistic variability in each source country as well as the multi-site clustered nature of the data collected as part of the ENRO project. It is important to note here that we took this step to ensure that within-country variance was accounted for, given that there were multiple testing locales within some of the sampled countries (i.e., Canada).

Results

Result of the exploratory factor analysis (EFA)

Three factors resulted from the reading performance tests (*see* Figure 2*)*. The first factor (Single Word Accuracy Measures; 26.12% of total variance) included the scores of the lexical decision, LexTALE, grammar judgment, vocabulary knowledge, segmentation, and spelling recognition. The second factor (Single Word Speed Measures; 13.98% of total variance) included the reaction times of the lexical decision and LexTALE tasks. The third factor (Extended Reading Measures, 12.64% of the variance) included the scores of the whole passage reading comprehension task, the orthographic awareness task, and the whole passage reading rate of the participants (*See* Figure 2*)*. Two goodness-of-fit metrics, Bartlett's Test of Sphericity and the Kaiser-Meyer-Olin measure (KMO), indicated that the data were suitable for factor analysis ($\chi 2\ (55) = 4923.24$, $p < .001$; $KMO = 0.80$). Participant scores for the subset of the participants included in this study were computed for the three resulting dependent variables (i.e., Single Word Accuracy Measures, Single Word

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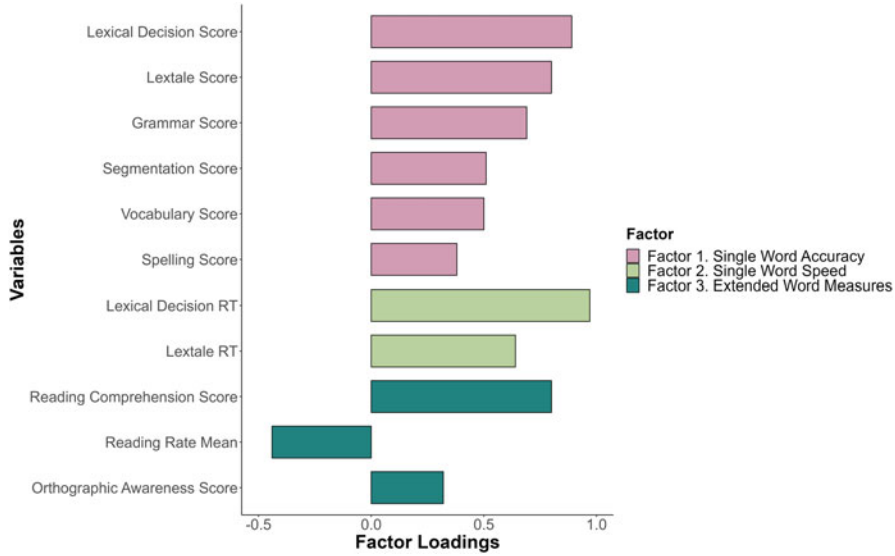


Figure 2. The latent structure for the L2 English reading proficiency tasks.

Speed Measures, and Extended Reading Measures) using the Thurstone estimation method.

To investigate the research question, we examined whether the expected result of L2 Reading Usage on each dependent variable will be moderated by L1 writing script. Below we discuss each dependent variable (Single Word Accuracy Measures, Single Word Speed Measures, and Extended Word Measures), as predicted by our independent variables (L2 Reading Usage and the interaction between L2 Reading Usage and L1 writing script).

Single-Word Accuracy Measures

The first dependent variable is Single Word Accuracy Measures (i.e., the latent factor scores of LexTALE, grammar judgment, vocabulary knowledge, segmentation, and spelling recognition).

The first model predicted the latent factor of Single Word Accuracy Measures by L2 English reading usage to determine whether there was a significant effect of L2 English reading usage on Single Word Accuracy Measures. We found a simple effect of L2 English reading usage on Single Word Accuracy Measures. As expected, L2 English reading usage positively predicted Single Word Accuracy Measures ($\beta = 0.34$, $t = 9.92$, $p < .001$), indicating that the more participants use English, the better they performed on Single Word Accuracy Measures.

The second model predicted Single Word Accuracy Measures, including the interaction between L2 English reading usage and L1 writing script. In this model, L2 AoA was controlled for as a fixed effect. Contrary to our hypothesis, we did not find a significant interaction between L1 writing script and L2 English reading usage. Across all writing scripts, more usage of English reading predicts higher proficiency scores. However, this model did show a difference between the

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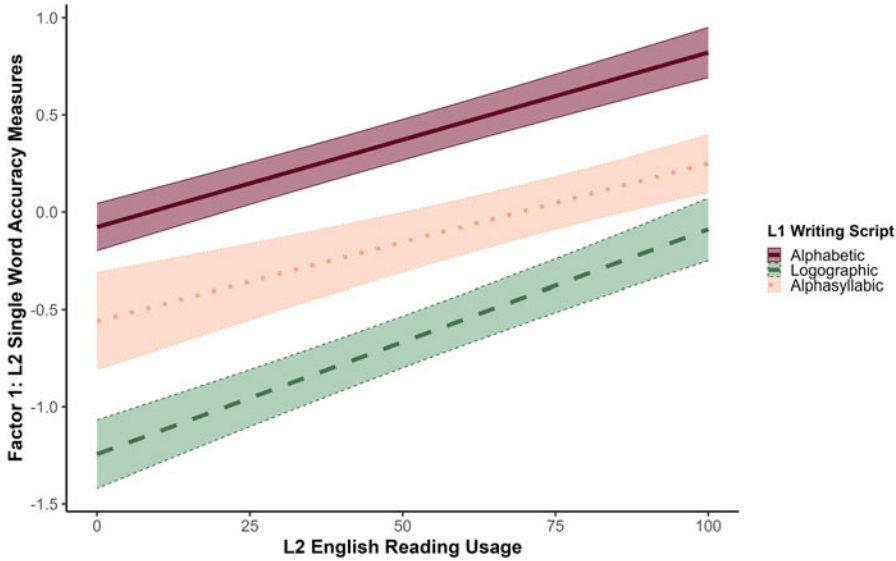


Figure 3. Relationship between L2 English Reading Usage and Single Word Accuracy Measures by L1 Writing Script.

alphabetic and logographic writing scripts ($\beta = -1.05$, t $= -9.813$, $p < .001$), and the alphabetic and alphasyllabic writing scripts ($\beta = -0.52$, t $= -3.288$, $p = .001$), where participants with an L1 alphabetic writing script performed better on L2 English Single Word Accuracy tasks than participants with an L1 alphasyllabic or an L1 logographic writing script, regardless of L2 English reading usage (*see* Figure 3; the computed models used a scaled version of L2 English reading usage; however, the figures do not for ease of understanding).

To determine any difference between the logographic and alphasyllabic writing scripts, we re-ran the second model after changing the reference level to logographic. This third model showed a significant simple effect of writing script between the L1 logographic participants and the L1 alphasyllabic participants ($\beta = 0.53$, t $= 3.26$, $p < .001$), where the L1 alphasyllabic participants performed better than the L1 logographic participants on L2 English Single Word Accuracy tasks. There was no significant interaction between L1 writing script and L2 English reading usage for the L1 logographic and L1 alphasyllabic comparison.

Finally, we ran a partial eta-squared on the third model which demonstrated a large effect size of L1 Writing Script ($\eta p2 = 0.36$) and a medium effect size of L2 English Reading Usage ($\eta p2 = 0.08$).

Single Word Speed Measures

We then examined the second dependent variable, Single Word Speed Measures (i.e., the latent factor scores of the LexTALE reaction time and the lexical decision reaction time). The first model predicted Single Word Speed Measures from L2 English reading usage. Similar to above, L2 AoA was controlled as a fixed effect. As

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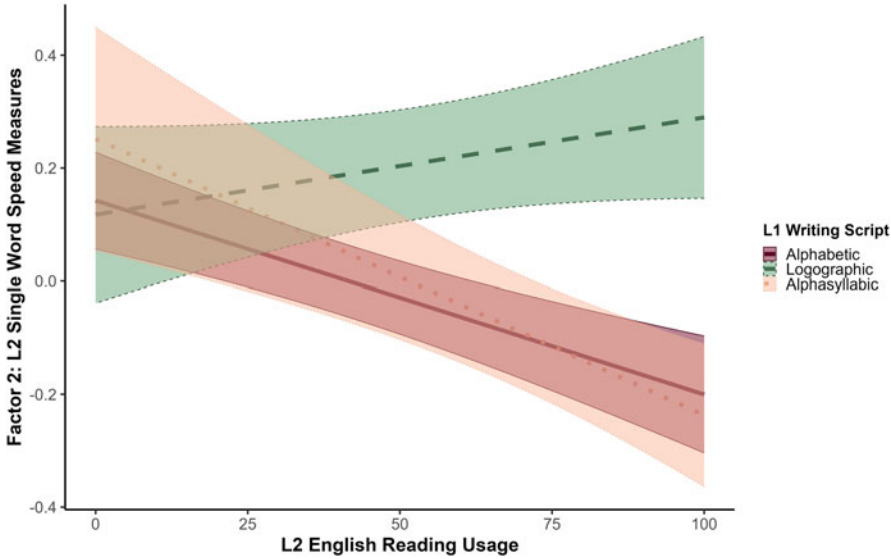


Figure 4. Relationship between L2 English Reading Usage and Single Word Speed Measures by L1 Writing Script.

expected, we found a main effect; L2 English reading usage negatively predicted Single Word Speed Measures ($\beta = -.10$, t $= -2.97$, $p = .003$), indicating that the more participants use English, the faster they performed on LexTALE and the lexical decision task.

The second model showed a significant interaction between L1 alphabetic and L1 logographic writing script groups and L2 English reading usage on Single Word Speed Measures ($\beta = .16$, t $= 1.99$, $p < .047$). Changing the reference level and running a third model showed a significant interaction between L1 logographic and L1 alphasyllabic writing script groups and L2 English reading usage on Single Word Speed Measures ($\beta = -.21$, t $= -2.01$, $p < .045$). Thus, indicating that as L2 English reading usage increases, Single Word Speed Measures decreased for both L1 alphabetic readers and L1 alphasyllabic readers, but not for the L1 logographic readers (*see* Figure 4; the computed models used a scaled version of L2 English reading usage; however, the figures do not for ease of understanding). For the L1 logographic readers, their Single Word Speed Measures increased as their L2 English reading usage increased *(see* Figure 4*)*. There is no significant interaction between L1 alphabetic and L1 alphasyllabic writing script groups and L2 English reading usage ($\beta = -.05$, t $= -.53$, $p = .6$). Finally, a partial eta-squared demonstrated a medium effect size of L1 Writing Script ($\eta p2 = 0.06$) and a small effect size of L2 English Reading Usage ($\eta p2 = 0.01$).

Extended word measures

The first model predicted Extended Reading Measures (the latent factor scores of the whole passage reading comprehension task, the orthographic awareness task, and whole passage reading rate) by the factor score of L2 English reading usage to see if there was a significant effect of L2 English reading usage on Extended Reading

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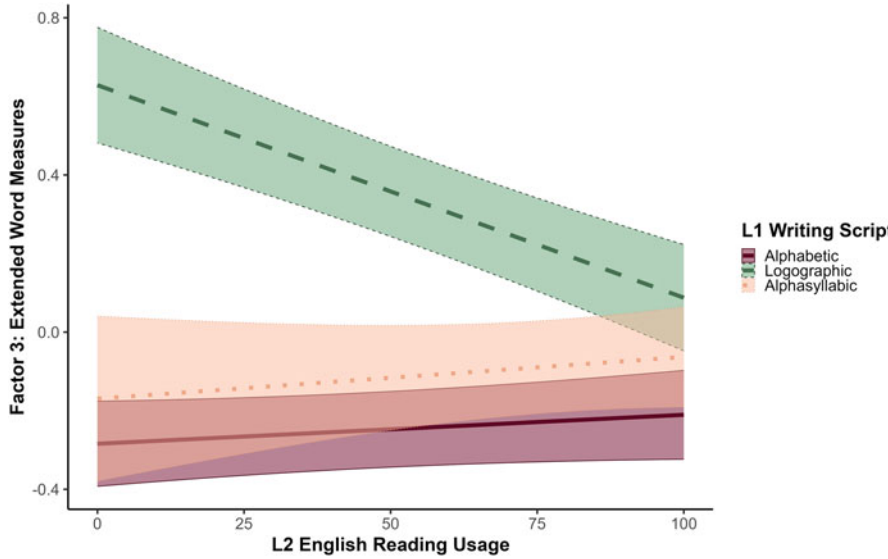


Figure 5. Relationship between L2 English Reading Usage and Extended Word Measures by L1 Writing Script.

Measures. The first model found a significant simple effect of L2 English reading usage on Extended Reading Measures; L2 English reading usage negatively predicted Extended Reading Measures ($\beta = -.06$, t $= -2.27$, $p < .02$), indicating that the more participants use English, the worse they performed on Extended English Reading Measures.

The second model showed a significant interaction between L1 alphabetic and L1 logographic writing script groups and L2 English reading usage on Extended Reading Measures ($\beta = -.19$, t $= -3.14$, $p = .002$). Changing the reference level and running a third model showed a significant interaction between L1 logographic and L1 alphasyllabic writing script groups and L2 English reading usage ($\beta = .20$, t $= 2.35$, $p = .02$). As L2 English reading usage increases, performance on Extended Reading Measures increases for both L1 alphabetic readers and L1 alphasyllabic readers, but not for the L1 logographic readers (*see* Figure 5; the computed models used a scaled version of L2 English reading usage, however, the figures do not for ease of understanding). For the L1 logographic readers, their performance on L2 English Extended Reading Measures decreased as their L2 English reading usage increased *(see* Figure 5*)*. A partial eta-squared on Extended Reading Measures demonstrated a large effect size of L1 Writing Script ($\eta p2 = 0.2$), and a small effect size for L2 English Reading Usage ($\eta p2 = 0.02$).

Discussion

This paper investigated whether bilingual adults' L2 reading performance in English (which uses an alphabetic script) was impacted by their having an L1 that uses a different script (i.e., alpha-syllabic or logographic), after statistically controlling for the amount of time they read in English. To examine this, L2 English readers were

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subsampled from the ENRO project (Siegelman et al., 2023) and thus came from around the globe. They had different L1s from the three main writing systems (alphabetic, logographic, and alphasyllabic). Our rationale for this investigation was that surprisingly little attention has been paid to how the characteristics of first languages (L1s) of people affect how L2 is acquired or processed (Fu et al., 2023; Bassetti, 2008; D'Anselmo et al., 2013; Lallier et al., 2016; Wang et al., 2003).

Our general hypothesis was that matches or mismatches in people's L1 and L2 writing scripts would modulate the expected relationship between L2 English reading usage and L2 reading performance. Below, we discuss the results found in this study for language scripts and language usage, in parallel with theoretical reading, language processing, and learning models, and previous evidence that can explain the different result patterns.

To assess reading performance, we identified three reading measures through an exploratory factor analysis: Single Word Accuracy Measures, Single Word Speed Measures, and Extended Word Measures. For the first factor, we found a positive relationship between L2 English reading proficiency and L2 English reading usage, after controlling for L2 English AoA, which by itself exhibited a significant effect. As expected, the more an individual uses a language, the better they perform on L2 English reading proficiency tasks. Moreover, there was a significant simple effect of L1 writing scripts for the reference group of alphabetic L1 speakers. L1 alphabetic readers performed better than L1 logographic readers and alphasyllabic readers. Additionally, L1 logographic readers had lower scores than the participants in the alphasyllabic group on L2 English reading proficiency measures in general.

For the second factor, there was a significant interaction between L1 writing scripts and L2 English reading usage on Single Word Speed Measures. For L1 alphabetic and L1 alphasyllabic readers, Single Word Speed Measures decreased as L2 English reading usage increased, suggesting faster reaction times on English reading comprehension measures; however, this effect was untrue for L1 logographic readers. These results suggest that people's L1 can impact their L2 English reading, presumably due to the large differences between the writing scripts of alphabetic, logographic, and alphasyllabic languages, both in Single Word Accuracy Measures and Single Word Speed Measures.

The results for the third factor, Extended Reading Measures, were unexpected in suggesting the opposite of the first two dependent variables. Here, logographic individuals performed better than the other two L1 writing script groups, and increased L2 English reading usage, leading to decreases in Extended Reading Measures. However, these unexpected results could be a product of including the three different latent factor scores together, confounding the results, particularly including variables that focused on accuracy (i.e., whole passage reading comprehension task, the orthographic awareness task), and others at times (i.e., whole passage reading rate). To further understand these results, we ran separate linear models for each of the dependent variables in the Extended Reading Measures factor (*see Supplemental Materials,* Figures 2, 3, and 4 *for more information)*. Splitting up the factor, we found that logographic participants did indeed have a higher reading rate than alphabetic and alphasyllabic participants (i.e., reading more words per minute), but both orthographic awareness and reading

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comprehension scores were higher for alphabetic participants compared to logographic participants. This suggests a speed-accuracy trade-off for the logographic group, where faster reading rates correlate with lower accuracy measures (Rayner et al., 2016). These results are consistent with previous studies on L1-L2 orthographic reading, suggesting a speed-accuracy trade-off for L1-logographic learners of English (Fu et al., 2023). For example, Fu et al. (2023) found L1-logographic participants were more precise, but slower when categorizing pseudowords orthographically related to previously trained stimuli.

Overall, the results presented here corroborate those of previous studies, suggesting that L1-L2 variation negatively impacts the process of L2 learning (Fu et al., 2023; Koda, 2000; Muljani et al., 1998; Sui et al., 2025; Wang et al., 2003; Want & Koda, 2007). These differences between L1 writing scripts and their effect on L2 English reading proficiency may be interpreted in the context of the grain size of processing used in each language system (Ziegler & Goswami, 2005). Alphabetic languages rely mainly on the smallest grain size, with each individual letter corresponding to a grain. A grain size bigger than alphabetic languages is found in alphasyllabic languages, which use a syllable sound as their smallest grain. These differences in grain size between alphabetic and alphasyllabic languages are demonstrated in the results of this study, where participants with a smaller L1 grain size, matching English, perform better on L2 English reading proficiency tasks than participants with a larger L1 grain size, like alphasyllabic languages.

Even larger than alphasyllabic language grain sizes are the grain sizes of logographic languages, which use whole words as their smallest grain. In this study, participants were tested on English, a language with a smaller grain size; however, participants with alphasyllabic L1s (which use a bigger grain size than English) still outperformed participants with L1s with the largest grain size of logographic languages, despite not matching writing scripts with English. This finding demonstrates that while matching L1 and L2 writing scripts can be beneficial to L2 reading comprehension, grain size is still an important factor to consider, as even languages with mismatching L1 and L2 writing scripts can have high L2 English reading proficiency scores if the grain size is similar, even if not identical, to that of the L2. Different reading and cognitive processes can be underlying the differences between scripts (Iniesta et al., 2023; Zhang & Duke, 2008) and can impact the strategies employed during L2 reading (Lallier et al., 2016).

Logographic L1 speakers tended to be disadvantaged in processing alphabetic languages. This disadvantage could be explained by the processing complexity effect (see Ghazi-Saidi & Ansaldo, 2017) and the system accommodation hypothesis (Perfetti & Liu, 2005; Perfetti et al., 2007). For the distant languages (i.e., logographic system), the processing can be less automatic, requiring more attention and cognitive control, and necessitating additional neural resources for lexical processing. This idea extends to the learning phases, where these additional resources make English more difficult to learn, resulting in lower L2 proficiency in reading tasks for these bilinguals. This is further corroborated by previous studies suggesting a greater emphasis on grapheme-to-phoneme matching skills during L2-alphabetic vocabulary learning in non-alphabetic communities (Fu et al., 2024). Because the writing systems differ significantly, the reading network must

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accommodate the development of new neural and cognitive resources needed to read in the L2, to a greater extent than alphasyllabics (Kim et al., 2017).

Our results are also compatible with previous evidence of nonselective access and a shared lexicon in bilinguals. A substantial body of research demonstrates that when bilinguals comprehend or produce messages in one language, representations of the non-target language are activated in parallel (Costa et al., 1999; Libben & Titone, 2009; Marian & Spivey, 2003; Tarin et al., 2025; Lauro & Schwartz, 2017). Models such as the Bilingual Interactive Activation Plus (BIA+) model propose a unified orthographic lexicon containing lexical nodes for words in both languages. In this model, the visual presentation of a word co-activates orthographic, phonological, and semantic representations across languages (Dijkstra & van Heuven, 2002; Lemhöfer & Dijkstra, 2004). Coactivation during reading has been shown to be strongly orthographically driven. For example, cognate facilitation is greater for identical cognates than for non-identical cognates (Comesaña et al., 2015; Guasch et al., 2017), with larger facilitation effects observed for words with greater orthographic similarity (OS; Dijkstra et al., 2010). Although cross-language activation occurs across all bilinguals—regardless of the specific languages they speak, including those with different scripts (Thierry & Wu, 2007) or modalities, such as bimodal bilinguals (Shook & Marian, 2012), significant differences between L1 and L2 scripts, such as alphabetic versus logographic systems, can impose additional constraints. In such cases, the shared orthographic lexicon may function less effectively, and connections between the two languages may rely more on abstract semantic or conceptual links than on direct orthographic overlap. This raises important questions about how script differences and proficiency influence the strength of cross-language activation and the nature of shared representations.

Among alphabetic languages, scripts can be further broken down in terms of their language family. English uses a modified Roman alphabet, like French or Spanish, whereas other languages follow a Cyrillic alphabet, such as Russian or Ukrainian. Previous work has found that the differences in alphabetic scripts may have an impact on reading proficiency (Kempe & MacWhinney, 1996; Bermúdez-Margaretto et al., 2022, 2023). For example, Bermúdez-Margaretto et al. (2022) found that Russian L1 speakers had higher reaction times for both novel and familiar words written in a Latin script compared to a Cyrillic script. Additionally, Russian L1 speakers, during a lexical decision task, had poorer performance on word categorization for L2 Latin scripts compared to L1 Cyrillic scripts (Bermúdez-Margaretto et al., 2022). Although training reduced the performance difference between Latin and Cyrillic scripts, the difference in performance remained significant.

Thus, in addition to our two research questions, to explore whether the distinction between Latin and Cyrillic language groups was significant in our data, we reran the above models, splitting alphabetic participants into Latin and Cyrillic groups (*refer to Supplemental Materials, Figures 5, 6, and 7 for more information).* We found that Latin and Cyrillic groups did not differ significantly on Single Word Accuracy measures, and both groups performed significantly better than the logographic group and the alphasyllabic group. The distinction between the two groups did not result in an interaction between L2 English reading usage and L1 writing script for Single Word Accuracy Measures.

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For Single Word Speed Measures, there was an approaching significant difference between L1 Cyrillic and L1 Latin participants, consistent with previous studies which support the idea that Cyrillic participants perform slower on Latin-based proficiency tasks (Bermúdez-Margaretto, et al., 2022); however, this effect failed to reach significance. Furthermore, Latin participants performed significantly faster than L1 logographic participants on measures of Single Word Speed. The distinction between Latin and Cyrillic participants did not affect the interaction between L1 writing script and L2 Reading Usage on Single Word Speed Measures; Latin, Cyrillic, and alphasyllabic participants all decreased on Single Word Speed Measures, whereas logographic participants increased. Greater L2 English reading usage resulted in shorter reaction times on Single Word Speed Measures for all writing script types except for logographic participants, whose reaction time increased on Single Word Speed Measures.

Lastly, on Extended Word Measures, we found that Cyrillic participants significantly differed from logographic participants (performing worse than logographic participants) but did not differ significantly from alphasyllabic or Latin participants. Latin participants performed significantly worse than logographic participants. The distinction between Latin and Cyrillic participants did not affect the interaction between L1 writing script and L2 Reading Usage on Extended Word Measures; Latin, Cyrillic, and alphasyllabic participants all increased on Extended Word Measures, whereas logographic participants decreased (*refer to Supplemental Materials, Tables 1-3 for more information).*

Conclusion and directions for future research

This paper investigated whether matches/mismatches in people's L1 and L2 writing scripts modulated the expected relationship between L2-English reading proficiency, over and above the expected results of L2 reading usage. The ENRO dataset, from Siegelman et al. (2023), allowed us to compare large samples of populations around the country, who were all administered the same English tests. Differences between writing scripts and their effect on L2 English reading proficiency can be interpreted in the context of the grain size of processing used in each language system (Ziegler & Goswami, 2005). Different reading and cognitive processes can be underlying the differences between scripts (Iniesta et al., 2023; Zhang & Duke, 2008) and can impact the strategies employed during L2 reading (Lallier et al., 2016).

Taken together, this study represents a first but important step to better understand the impact of a person's L1 when learning a second language. However, additional caveats must be mentioned. First, the sample size we used for the three types of L1 writing scripts was uneven, with alphabetic L1 speakers having almost 3 times the number of participants as logographic and alphasyllabic L1 speakers (646 alphabetic participants compared to 176 alphasyllabic participants and 251 logographic participants). Secondly, for ease of analysis, we only included participants with only one L1 language; further studies can look at how multiple L1s can contribute to reading proficiency in an L2. Additionally, future work should also address second languages other than L2 English.

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While most research on L1 writing script differences tends to focus on L2 reading in English, some studies have shown an advantage in sharing writing scripts across first and second languages during the process of learning artificial logographic scripts (Ehrich & Meuter, 2009). For example, Ehrich and Meuter (2009) tested alphabetic and logographic L1 readers. They found that L1 Mandarin-Chinese readers were faster for a lexical decision task for an artificial logographic language compared to L1 English monolinguals and English-French bilinguals. This suggests that the advantage of a shared writing script across first and second languages can be beneficial for other languages than just English. Ultimately, understanding these and other key factors could inform our basic understanding of L1 and L2 reading, as well as language education policies and practices to help readers learn an L2 more effectively.

However, one potential caveat is that differences between languages are more complicated than what is simply illustrated through L1 writing scripts. For example, languages can differ in orthographic depth (the degree to which a language deviates from a simple 1-1 letter-phoneme correspondence; Schmalz, 2015; Van den Bosch et al., 1994). Theoretical concepts like the orthographic depth hypothesis suggest that writing systems with highly consistent letter-sound correspondence are acquired more easily than orthographies with irregular and inconsistent spellings (Borleffs et al., 2019; Katz & Frost, 1992), and can also have a differential impact on reading proficiency and orthographic learning depending on the L1-L2 transparency distance (van Daal & Wass, 2017). It is important to note that within each system, there was a wide variability in orthographic transparency that should be explored in future studies. The global comprehensiveness of the ENRO dataset allows us to further compare participants' L1s to better understand L2 English reading proficiency, as languages in the ENRO dataset can be further broken down into measures of their orthographic depth, their directionality, as well as other features.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0142716425100076

Competing interests. The authors declare none.

Replication package. The data used for this analysis is from the English Reading Online Project, available at the project repository page at https://osf.io/gzyqf/ (Siegelman et al., 2023). The data and scripts to reproduce the analyses and figures are available on the Open Science Framework (https://osf.io/c9gbq/).

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