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Abstract

Orthographic knowledge, the general ability to learn, store, and use information about the orthographic form of words (Stanovich & West, 1989), is a crucial skill for supporting literacy. Although the development of first language (L1) orthographic awareness is impacted by the characteristics of a learner's L1 writing system, relatively little is known about what impact the L1 may have on second language (L2) orthographic awareness. In this study, English language learners from three L1s (French, Hebrew, Mandarin Chinese), plus L1 English speakers, were tested on their English spelling knowledge using a word-pseudohomophone discrimination task. In addition to allowing for the cross-linguistic comparisons, items were designed to examine whether learners had differing performance on pseudohomophones (misspellings) that targeted vowels versus consonants. Consistent with previous research (e.g., McBride-Chang, Bialystok, Cong, and Li 2004), the L1 Chinese speakers had the highest (L2) accuracy, followed by the L1 Hebrew and the L1 French speakers. The participants from non-alphabetic languages (Hebrew and Chinese) had significantly lower accuracy on items with misspellings involving vowels compared to consonants, and the size of the vowel-consonant accuracy difference varied substantially across L1 groups. The results demonstrate that the characteristics of a learner's L1 writing system, particularly the existence of vowel and consonant graphemes, impact the development of L2 orthographic knowledge and sensitivity to different types of word misspellings.

Keywords: L2 literacy, orthographic awareness, ESL, spelling

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Literacy requires the coordination many complex skills, from text-driven visual processing to the top-down influence of real-world knowledge (e.g., Carr & Levy, 1990; Grabe, 2009; Koda, 2004). Among these many skills are two crucial abilities: phonological awareness, the ability to segment and manipulate phonological units (Goswami, 1999); and orthographic knowledge, the ability to learn, store, and use information about the orthographic form of words (Stanovich & West, 1989). Although phonological awareness, and how it is shaped by a speaker's first language (L1), has been well studied, our understanding of orthographic knowledge is less complete. To address this issue, this paper reports on a study examining the impact of L1 on orthographic knowledge in a second language (L2), and the consequences for practical skills like recognizing spelling errors.

Phonological awareness has been studied extensively and its importance for literacy development has been demonstrated in a range of languages, from German, Spanish, and Turkish to Greek, Hebrew, and Chinese (e.g., Domínguez, 1996; Durgunoğlu & Öney, 1999; Harris & Giannouli, 1999; McBride–Chang & Kail, 2002; Schneider, Küspert, Roth, Visé, & Marx, 1997; Shatil, Share, & Levin, 2000; Ziegler et al., 2010). At the same time, literacy acquisition reciprocally impacts the development of phonological awareness. Awareness of large phonological units (e.g., syllables) develops prior to and independently from literacy experience, but awareness of smaller units (especially individual phonemes) only develops with literacy experience in a language with graphemes representing phonological units smaller than a syllable (e.g., Goswami & Bryant, 1990; Holm & Dodd, 1996; McBride-Chang, Bialystok, Chong, & Li, 2004; Morais, Bertelson, Cary, & Alegria, 1986; Morais, Cary, Alegria, & Bertelson, 1979; Perfetti, Beck, Bell, & Hughes, 1987; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001).

The degree to which readers rely on phonological information during reading also varies across L1s. Readers of L1s with consistent mappings between graphemes and phonemes (e.g., German) rely more on phonological information than readers of L1s with inconsistent mappings (e.g., unpointed Hebrew, Arabic, Japanese kanji) (Frost, Katz, & Bentin, 1987; Kimura & Bryant, 1983; Näslund & Schneider, 1996; Saiegh-Haddad, 2003). Importantly, this tendency also transfers into and impacts literacy behaviors in an L2. L2 readers who come from alphabetic L1s show stronger relationships between phonological skills and literacy outcomes than those from non-alphabetic L1s (Koda, 1998; McBride-Chang et al., 2005; Wade-Woolley, 1999). Although much of this research has targeted L2 English, similar results have been found for learners of Chinese and Japanese, as well (Chikamatsu, 1996; Chitiri, Sun, Willows, & Taylor, 1992; Koda, 1989; Perfetti et al., 2007). Overall, this work demonstrates that although phonological awareness supports literacy acquisition cross-linguistically, the characteristics of the L1 writing system (and the corresponding structure of the L1 morphophonology, see Frost, 2012) also reciprocally impact phonological awareness and the degree to which both L1 and L2 readers rely on phonological information.

Although it is less widely studied, orthographic knowledge is also critical for literacy acquisition. Awareness of sequences of letters that are shared across words with similar sounds provides a starting point for learning about spelling patterns, which in turn can serve as a source for analogies to read or spell unfamiliar words (Baron, 1979; Campbell, 1985; Goswami, 1988a, 1988b; Goswami & Bryant, 1990). Knowledge of orthographic forms also allows words to be recognized as whole units, helping to automatize the process of word recognition and freeing up cognitive resources for higher-level processing (Adams, 1990; Ehri, 1994, 1998; Perfetti, 1988; Seidenberg & McClelland, 1989; Torgesen, 2002).

Despite the recognition of orthographic knowledge as a crucial literacy skill, relatively little research has focused on how it is shaped by the L1. One relevant line of research explores the transposed-letter effect. In one of the original demonstrations, Forster, Davis, Schoknecht, and Carter (1987) showed that a form prime with a pair of transposed letters (anwser-ANSWER) provided similar priming as true identity primes (answer-ANSWER). This effect has been demonstrated in English, French, Spanish, and Japanese (e.g., Perea & Carreiras, 2006; Perea & Lupker, 2003; Perea & Pérez, 2008; Schoonbaert & Grainger, 2004). However, it is not universal: transposed letters are detrimental in Hebrew and Arabic, in which the relative position of consonants impacts the identity of the root (Frost, 2012; Perea, Mallouh, & Carreiras, 2010; Velan & Frost, 2009). Another relevant line of research has revealed that, in contrast to phonological awareness, readers of languages with non-alphabetic or inconsistent writing systems rely more on orthographic information during word recognition and text processing (Abu-Rabia, 2001; Arab-Moghaddam & Sénéchal, 2001; Frost, 2012; Frost et al., 1987; Goswami, 2012; Kang & Simpson, 1996; Kimura & Bryant, 1983; Näslund & Schneider, 1996; Nassaji & Geva, 1999; Saiegh-Haddad, 2003; Seidenberg, 1992).

Orthographic knowledge has received even less attention in the L2 literature. However, there is some evidence that, similar to phonological skills, L2 orthographic knowledge can be impacted by a learner's L1. First, L2 readers of English often process letters and perform tasks such as visual search in a way that is fundamentally different from native readers (e.g., Green, Liow, Tng, & Zielinski, 1996; Green & Meara, 1987; Ktori & Pitchford, 2008; Randall & Meara, 1988). In addition, readers with different L1s are differentially sensitive to sub-lexical orthographic information (letter frequency, letter sequence legality) versus whole-word orthographic information (whole-word spellings, orthographic shapes). For example, L1 Chinese speakers of L2 English tend to be less sensitive to the details of individual letters and their distributions, and instead rely more on the overall visual form or shape of words, than speakers from alphabetic L1s (Akamatsu, 1999, 2003; Fender, 2003; Haynes & Carr, 1990; Koda, 1999; Wang & Koda, 2005; Wang, Koda, & Perfetti, 2003).

There is also evidence that readers from different L1s are varyingly sensitive to different types of graphemes. For example, L1 Arabic speakers are significantly worse at detecting missing vowels than consonants, have reduced sensitivity to vowels during word recognition, and also have greater difficulty with vowel spellings than learners from other L1s (Fender, 2008; Hayes-Harb, 2006; K. I. Martin & Juffs, 2011; Ryan & Meara, 1991, 1996; Saigh & Schmitt, 2012). The prevailing explanation attributes this to the characteristics of the Arabic writing system, in which (short) vowels are only optionally written as diacritics and are usually excluded from writing (Abu-Rabia, 2001).

Given the importance of orthographic knowledge for literacy, especially accurate spelling knowledge and rapid, automatic word recognition, a better understanding of this ability in L2 readers is needed. The research reviewed above suggests that readers from particular L1s are predisposed to certain attentional biases or difficulties based on the characteristics of their L1 writing system. If this is true, a solid understanding of these challenges can highlight promising areas for pedagogical focus and also contribute to our general understanding of the cognitive underpinnings of text processing.

The goal of the current study was therefore to conduct a cross-linguistic investigation of orthographic knowledge in L2 English learners, focusing specifically on whole-word spelling knowledge. To determine whether learners with different L1s have varying orthographic knowledge performance, data were collected from three L2 English groups with L1s representing the continuum of possible writing systems: French (an alphabet), Hebrew (an abjad), and Mandarin Chinese (a morphosyllabary). Comparison data were also collected from L1 English speakers. Stimuli were chosen to examine whether participants had similar levels of performance identifying misspellings involving consonants versus vowels, in order to determine whether one was more challenging than the other for the speakers from different L1s.

Method

Participants

Data were collected from 60 L1 French speakers, 67 L1 Hebrew speakers, 73 L1 Mandarin Chinese speakers, and 60 L1 English speakers. Data were excluded from participants who did not complete all tasks or failed to follow instructions, fell below a minimum score of 68 on the reading comprehension test, had extensive experience with another language early in life, self-reported a neurological condition, were older than age 60, or due to equipment failure or experimenter error (43 total). Data from an additional 33 participants were excluded to match sample sizes and scores on three different English proficiency tests across the non-native speaker groups (see below). As a result, data from 46 L1 French speakers, 46 L1 Hebrew speakers, 46 L1 Mandarin Chinese speakers, and 46 L1 English speakers were used.

All non-native English-speaking participants had studied English throughout their primary and secondary schooling and all L1 English speakers had grown up without exposure to other languages before age 12. Demographic information for each group is provided in Table 1 along with participants' self-rated proficiency in both L1 and L2 skills. L1 French speakers were recruited at a large regional university in central France, L1 Hebrew speakers were recruited at a large university in northern Israel, L1 Mandarin Chinese speakers were recruited at a research university in northern Taiwan, and L1 English speakers were recruited at an urban university in the United States.

Materials

Orthographic Knowledge. Participants' knowledge of whole-word English spellings was measured via a word-pseudohomophone discrimination task. For each item, participants heard an English word and saw two possible spellings on a computer screen, one on the left and one on the right. One spelling was correct (e.g., *cloud* for /kloʊd/), and the other was a pseudohomophone (e.g., *kloud*). Because both choices had the same pronunciation, participants had to rely on their orthographic knowledge of specific spelling patterns to answer correctly. After hearing each item participants were asked to indicate the correct spelling of the word, as quickly as possible, by pressing either the far left or the far right button on a response box. The side on which the correct response appeared was counter-balanced across stimuli and the trials appeared in a different randomized order for each participant. Participants were given up to 7500 ms to respond before automatic advancement to the next item. The interstimulus interval was 1200 ms.

Six practice trials were followed by 80 test trials. Items were adapted from prior studies using homophones and pseudohomophones (Borowsky, Owen, & Masson, 2002; Davis, 1998; Laxon, Masterson, Pool, & Keating, 1992; Lukatela, Eaton, Lee, Carello, & Turvey, 2002; Lukatela & Turvey, 1991; Lupker & Pexman, 2010; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; R. C. Martin, 1982; Rastle & Coltheart, 1999; Reynolds & Besner, 2005; Seidenberg, Petersen, MacDonald, & Plaut, 1996; Taft & Russell, 1992; Yates, Locker, & Simpson, 2003) and were checked to ensure that they did not have form overlap with French, Hebrew, or Mandarin Chinese words. Approximately half of the items (38) had misspellings that exclusively involved the vowel segment(s), and the other half (42) had misspellings that involved consonant segment(s). Lexical characteristics from the E-Lexicon (Balota et al., 2007) were used to match items across the two conditions. All real word (correct answer) items were matched on word length, frequency, age of acquisition, concreteness, imageability, orthographic and phonological neighborhood sizes, the frequencies of orthographic and phonological neighbors, bigram sum and mean, and number of phonemes, *p*s > .10. All pseudohomophone (distractor) items were matched on length, orthographic neighborhood size, and bigram sum and mean, *p*s > .10. Thus, any differences in performance on items involving misspelling of a vowel vs. misspelling of a consonant could not be due to differences in these lexical characteristics. A full list of stimuli appears in the Appendix.

General Cognitive Abilities. Participants completed two tests of their general cognitive abilities: operation span (Turner & Engle, 1989) for working memory, and Flankers (Eriksen, 1995) for executive control. In the operation span task, participants saw an arithmetic operation, (e.g., (12/3) – 2 = 2) for 2500 ms. Participants then had 5000 ms to indicate whether the answer had been correct. Following this, they saw a concrete noun in their L1 (e.g., ‘uncle’) for 1250 ms. Participants were told to remember the word. They then saw another operation, made another correctness judgment, and saw a second noun. This procedure repeated for a set number of iterations, after which participants were asked to recall as many words from that list as they could remember. Participants began with two practice trials, after which they completed three trials each with two to six iterations of operations and words. Participants’ score was the maximum set size at which they correctly recalled all of the words for at least two of the three trials, before failing to get at least two full trials correct.

In the Flankers task, participants saw a horizontal sequence of five arrows, of which the first and last two always pointed in the same direction (left or right). On congruent trials, the middle arrow pointed the same way as the others; on incongruent trials, the middle arrow pointed the opposite way from the others. Participants pressed either the left or right button on a response box as quickly as possible to indicate which direction the middle arrow was pointing. Participants had up to 3000 ms to respond. The interstimulus interval was 500 ms plus a randomly generated wait time of 1-1000 ms. Eight practice trials were followed by 120 test trials without feedback. Participants' score was a congruency effect reflecting the reaction time (RT) advantage on congruent versus incongruent trials, calculated as a standardized difference in individual participant RTs to incongruent and congruent trials (incongruent RT – congruent RT / average RT).

English Proficiency. Participants completed three tests of their English language proficiency: reading comprehension, listening comprehension, and productive vocabulary knowledge. These tests were used to match the three non-native speaker groups on their English proficiency. For reading comprehension all participants completed a test produced by AccuPlacer (The College Board). Native English speakers completed the "Reading Comprehension" test and non-native speakers completed the "ESL Reading Sills" test. AccuPlacer was chosen because these assessments were specifically and separately designed for native and non-native English speakers. They thus provided parallel assessment instruments, with comparable lengths, formats, and scoring procedures, with a level of language appropriate for each group. Each was an adaptive, computer-administered test with 20 multiple-choice questions. Participants were given up to 30 minutes to complete the test. The maximum possible score for each test was 120.

Listening comprehension was assessed with an instrument developed in-house by the English Language Institute at [SCHOOL NAME] and used to place English language learners in the appropriate level for intensive English study. The test included three types of listening: narratives, lecture excerpts, and conversations. Participants listened to each selection and were permitted to take notes. After each selection they heard two or three multiple-choice questions and were given approximately 15-20 seconds of silence to answer each. Although the answer choices were provided in a written booklet, the questions themselves were not written. Each question was asked only once. There were a total of 30 questions. Participants' score was the number of questions answered correctly, with a maximum possible score of 30.

Vocabulary knowledge was assessed using an adaptation of the Vocabulary Levels Test (Laufer & Nation, 1999) published by Cobb (2000) that excludes items that are cognates with French. This is a productive, cloze-style test. For each question participants read a sentence with a blank in it and were asked to write the word that best fit the blank. For all but one question, one or more letters from the beginning of a word were provided as a clue. There were a total of 72 items of increasing difficulty (decreasing word frequency). Participants were given up to 30 minutes to complete this test and were strongly encouraged to guess even if they were unsure of their answer. Because there is no standard answer key for this test (Nation, personal communication), acceptable answers were discussed and agreed upon by two native English speakers (one American and one British). Participants were given credit for their answer only if the spelling was exactly correct. The maximum possible score was 72.

Overall Procedure

Informed consent was obtained from all individual participants included in the study. After this, participants completed the word-pseudohomophone task. The task began with six practice trials with feedback, followed by the 80 test trials without feedback. Participants had a short break halfway through. Participants next completed the operation span and Flankers tasks. After the tests of cognitive abilities participants completed the three English proficiency tests. Finally, participants completed a language history questionnaire (based on Tokowicz, Michael, & Kroll, 2004) that elicited demographic information and details of their language learning experiences, with a particular emphasis on their study of and exposure to English. All participants were tested individually. All procedures performed in this study were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Analyses

Both accuracy and RTs from the word-pseudohomophone discrimination task were examined. Working memory span and the Flankers congruency effect were initially included as covariates but were not significant and therefore not retained in the final models. Because the accuracy outcome was binary (correct/incorrect for each trial) a Generalized Estimating Equations (GEE) model with a binomial distribution and a logit link function was used to analyze the accuracy data[1]. Post-hoc comparisons with the Šidak correction for multiple comparisons were used to examine whether there was a difference in performance between items involving misspelled vowels versus misspelled consonants in each L1 group.

RTs were analyzed for correct trials only, and RTs more than three standard deviations from an individual's mean RT were excluded. These procedures resulted in the exclusion of 3.9% of the data. The distribution of RTs in each L1 approximated a normal distribution and

[1] A GEE is essentially a logistic regression, adjusted to account for a non-normal dependent variable distribution and the non-independence of repeated measures designs (multiple items nested within a single participant).

therefore a mixed ANOVA was used to analyze the RTs. Misspelling type was a within-subjects factor and L1 was a between-subjects factor. Because of the difference in means and standard deviations between the L1 English speakers and the non-native speakers, all main effects analyses included only data from the non-native speakers. This was done to avoid artificially inflating the variance between L1 groups and thus biasing the results toward finding a significant effect of L1(Keppel & Wickens, 2004; Tabachnick & Fidell, 2013). Descriptive statistics from the L1 English speakers are included for comparison purposes only and pairwise comparisons within the L1 English speakers were computed via a separate analysis.

Results

English Proficiency and General Cognitive Abilities. Means and standard deviations for the performance of each L1 group on the English proficiency, working memory, and executive control tests are given in Tables 1 and 2. Participants in the three non-native speaker groups were matched on all three English proficiency tests. However, there were differences among the L1 groups on the working memory ($F(3,180) = 5.37$, $p < .01$) and executive control ($F(3, 180) = 3.62$, $p < .05$) tests. Specifically, the L1 Hebrew and L1 Chinese speakers had significantly higher working memory spans than the L1 French and L1 English speakers (*p*s < .05), although the differences between the Hebrew and the Chinese speakers and the between the French and the English speakers were not significant. In addition, both the L1 Hebrew and L1 Chinese speakers showed a smaller congruency effect than the L1 English speakers (*p*s < .05). In order to control for these differences, participants' scores on these measures were included as covariates in the first analyses of the word-pseudohomophone test. However, the results indicated that working memory and executive control did not have a statistically significant impact on the results and they were thus excluded from the final models reported below.

Orthographic Knowledge. The raw means and standard deviations for accuracy and RTs, by misspelling type and L1, are presented in Table 3. For accuracy, the effect of misspelling type was significant, $\chi^2(df = 1) = 41.43$, $p < .001$, with responses to items with misspelled consonants (95%) more accurate than responses to items with misspelled vowels (92%). The overall effect of L1 was also significant, $\chi^2(df = 2) = 9.32$, $p < .01$. The L1 Chinese speakers had the highest overall accuracy among the non-native speaker groups (95.35%), followed by the L1 Hebrew speakers (92.99%) and the L1 French speakers (92.07%) (see Figure 1), although only the difference between the L1 Chinese and the L1 French speakers reached significance. These overall effects were qualified by a significant interaction between misspelling type and L1, $\chi^2(df = 2) = 8.96$, $p < .05$. To follow up on this interaction, the difference in accuracy to items with misspelled consonants versus misspelled vowels was examined individually for each L1 group. The accuracy difference for items with misspelled consonants versus misspelled vowels was not significant for the L1 English speakers ($p > .50$) or the L1 French speakers ($p > .30$). However, both the L1 Hebrew and the L1 Chinese speakers did show a significant difference: L1 Hebrew, $p < .001$; and L1 Chinese, $p < .05$. For all L1 groups participants had higher accuracy on items involving misspelled consonants than misspelled vowels, although the size of the effect differed substantially across groups. The L1 French speakers showed the smallest difference, a non-significant 1.67%, with a small effect size ($\eta_p^2 = .03$)[2]. The L1 Hebrew speakers showed the largest difference, 4.19%, two and a half times

[2] These effect sizes were calculated as part of a separate analysis of the accuracy data using the same ANOVA procedure as used for the RTs. Although the the GEE analyses reported here are the most appropriate for the binary (correct/incorrect) outcome, the overall pattern of results between the GEE and the ANOVA results was largely the same.

as large as the L1 French speakers and with a large effect size ($\eta_p^2 = .18$). The L1 Chinese speakers fell in between, with a difference of 2.37% and a medium effect size ($\eta_p^2 = .07$).

For RTs, there were no main effects of misspelling type or L1, *p*s > .10. The interaction between misspelling type and L1 was also not significant, $p > .10$.

These results reveal a difference between vowel and consonant items for some of the L1 groups. However, not all pseudohomophones involved the same modifications to correctly spelled words. Thus, it is possible that some specific types of misspelling modifications may have had different levels of impact on participants' ability to detect the misspellings. To explore this possibility, the 80 stimuli were classified into one of six specific types: those that involved the addition or deletion of a vowel segment (e.g., threat/thret, $n = 4$), the addition or deletion of a consonant segment (e.g., thumb/thum, $n = 5$), a change in a vowel segment without addition or deletion (e.g., works/werks, $n = 17$), a change in a consonant segment without addition or deletion (e.g., cloud/kloud, $n = 12$), a change in the vowel involving addition or deletion of a silent 'e' at the end of the word (e.g., soon/sune, $n = 17$), or a modification of both a consonant and a vowel (e.g., fade/phaid, $n = 25$).

A GEE analysis was again used. The effect of misspelling type was significant, χ^2 ($df = 5$) = 103.94, $p < .001$. The overall effect of L1 was marginally significant, χ^2 ($df = 2$) = 5.77, $p = .06$. These effects were qualified by a significant interaction between misspelling type and L1, χ^2 ($df = 10$) = 20.87, $p < .05$. To follow up on this interaction, Šidák-corrected pairwise comparisons were made among the misspelling types within each L1 group. In addition, the accuracy for each misspelling type in each group, with item types ordered from highest to lowest accuracy separately for each L1, are presented in Table 4. Although the actual accuracy percentages differed, the accuracy ordering of misspelling types was the same for the L1 Chinese and L1 Hebrew speakers, while somewhat different for the L1 French and L1 English speakers.

For the L1 English speakers only one difference was significant: participants were more accurate on items that changed a consonant than on those that changed a vowel ($p < .05$). Similarly, the L1 Chinese speakers were more accurate on items that changed a consonant than on items that changed a vowel ($p < .001$), and they were also marginally more accurate on items that added or deleted a vowel as opposed to just changed one. The L1 Hebrew and the L1 French speakers showed many more significant contrasts. Compared to items that just changed a vowel, the L1 Hebrew speakers were significantly more accurate on items that just changed a consonant ($p < .001$), added or deleted a vowel ($p < .001$), modified both a consonant and a vowel ($p < .001$), or modified a silent ‘e’ ($p < .01$). They were also marginally more accurate on items that changed a consonant rather than added or deleted one ($p = .09$). The L1 French speakers were significantly more accurate on items that changed a consonant compared to items that modified a silent ‘e’ ($p < .05$), modified both a consonant and a vowel ($p < .001$), changed a vowel ($p < .001$), or added or deleted a consonant ($p < .001$). Finally, the L1 French speakers were significantly more accurate on items that modified a silent ‘e’ compared to items that changed a (word-internal) vowel ($p < .05$).

Discussion

This study examined English whole-word spelling knowledge and sensitivity to different types of misspellings in L2 English speakers, to look for evidence of L1 influence on L2 orthographic knowledge. A word-pseudohomophone discrimination test was used to assess spelling knowledge and also to examine whether performance differed for misspellings involving vowels versus consonants. Data were collected from native speakers as well as three L2 English groups with L1s that use different writing systems: French, Hebrew, and Mandarin Chinese.

Two main findings inform our understanding of L2 orthographic knowledge. First, the L1 Chinese speakers had the highest accuracy among the L2 English participants. This is consistent with previous literature, which has consistently demonstrated stronger orthographic knowledge in native Chinese speakers (morphosyllabic L1) compared to native Korean speakers (alphabetic L1) (e.g., Hamada & Koda, 2008; McBride-Chang et al., 2005; Wang & Geva, 2003; Wang & Koda, 2005; Wang et al., 2003). The current study thus provides confirmation that literacy in a morphosyllabic L1 is associated with greater orthographic knowledge skills and that this ability can transfer to an L2 and beneficially impact L2 whole-word spelling knowledge. Including the L1 Hebrew speakers in this study also provided a crucial comparison with speakers of an L1 with a writing system that is not alphabetic but is still segmental (an abjad). The L1 Hebrew speakers had only a small and non-significant accuracy advantage over the L1 French speakers, suggesting that stronger orthographic knowledge skills are associated specifically with L1 literacy in a non-segmental (morphosyllabic) writing system, not just a non-alphabetic writing system.

The second main finding was the substantial variation across L1 groups regarding their relative accuracy on items involving misspelled vowels versus misspelled consonants. Although all L1 groups showed higher accuracy on items involving misspelled consonants, the difference was only significant for the L1 Hebrew and L1 Chinese speakers. The L1 Hebrew speakers were much less sensitive to misspellings that affected vowels only: a difference of 4.2% and a large effect size ($\eta_p^2 = .18$). The L1 French speakers showed the smallest difference, a non-significant 1.67%, with a small effect size ($\eta_p^2 = .03$). The L1 Chinese speakers fell in the middle, with a difference of 2.37% and a medium effect size ($\eta_p^2 = .07$). Thus, the participants with a segmental writing system that nevertheless does not typically include many vowel graphemes (Hebrew) had the least sensitivity to or awareness of misspelled vowels in English.

This finding is consistent with previous studies of L1 Arabic speakers, who often have difficulties with vowel awareness in general (Hayes-Harb, 2006; K. I. Martin & Juffs, 2011; Ryan & Meara, 1991, 1996) and with vowel spellings in particular (Fender, 2008; Saigh & Schmitt, 2012). There is substantial similarity between the Arabic and Hebrew writing systems: both use a non-linear morphology and only optionally include many written vowels as diacritics set off from the main line of text (Abu-Rabia & Siegel, 2003; Frost, 2012). Thus, the finding from this study of reduced awareness and knowledge of written vowels in L2 English by L1 Hebrew speakers extends this pattern to a different group of abjad L1 speakers. It also strengthens the argument that this pattern of behavior is (at least partially) a result of the characteristics of the L1 writing system and morphophonology and reconfirms that such processes can transfer from the L1 and affect the L2.

The present results suggest that vowels are more difficult to process than consonants for most L2 speakers (consistent with the idea that consonant processing is privileged in both L1 auditory and visual lexical processing, e.g., Bonatti, Peña, Nespor, & Mehler, 2005; New, Araújo, & Nazzi, 2008). However, the magnitude of this effect varies substantially across L1s. Learners with an alphabetic L1 (French) had only small vowel difficulties, while learners with a segmental but consonant-based L1 (Hebrew) had much greater difficulties. The fact that the L1 Chinese speakers fell between these two groups, and indeed showed a significant difference at all, is intriguing. Although Chinese does not have separate vowel graphemes, the character-based morphosyllabary also does not have separate consonant graphemes. At the same time, vowels are crucial for conveying word meanings in (spoken) Chinese because they carry lexical tone. This suggests that a lack of written vowels in a reader's L1 writing system, regardless of whether it is segmental or non-segmental, may increase those learners' difficulty with processing L2 vowel graphemes. The finding of a significant detriment to vowel processing in the L1 Chinese speakers is particularly striking given that these participants had the highest overall (L2) performance on the orthographic knowledge task, while the group with the lowest overall performance, the L1 French speakers, had the smallest difference between vowel and consonant misspellings. Thus, although a morphosyllabic L1 is typically associated with greater orthographic knowledge overall, performance may still vary noticeably for specific item types.

One possible complication in interpreting the results is that, although the vowel items had misspellings that exclusively affected vowel graphemes, some of the consonant items had misspellings that affected both consonant and vowel graphemes. Thus, some of these items involved multiple changes, possibly making them easier to identify as misspelled. Although this may have contributed to somewhat higher accuracy on these items, it cannot explain why the difference in accuracy between vowel and consonant items varied substantially across L1 groups. Further, the more detailed accuracy analysis demonstrated that the items with multiple spelling modifications were in fact *not* answered with the highest accuracy in any of the groups. Thus, the performance difference between vowel and consonant items cannot be attributed to the number of misspellings alone (the uneven number of items of each detailed type recommends some caution in interpreting these results).

Other limitations should also be acknowledged. First, additional research is needed to replicate the findings, especially with Chinese speakers, and to determine whether the pattern extends other non-alphabetic L1s as well (such as Japanese, a syllabary, and Marathi, an abugida). Data from these populations would also contribute further to our understanding of how specific components of orthographic knowledge can be impacted by L1 literacy. Second, it would be beneficial to obtain data from participants with varying levels of L2 proficiency. Although the current results suggest that challenges with processing written vowels may persist even after many years, more detailed cross-sectional or longitudinal work would help to clarify the development of orthographic knowledge. Additionally, future work could usefully target other types of orthographic knowledge. For example, learners may also differ on their sensitivity to sub-lexical orthographic information (letter frequency, letter sequence legality) and their knowledge of phoneme-grapheme correspondences[3] - all of these forms of orthographic knowledge have the potential to reveal important dimensions of language learners' skills. Finally, in the current study, differences were found among L1 groups on accuracy but not RTs. This may be due in part to the overall high accuracy on the word-pseudohomophone task and thus reduced variance in RTs. Although it is not appropriate to interpret this null finding, future research with a wider range of orthographic tasks, and more difficult items, may help to resolve this disparity.

To conclude, the current results broaden our understanding of the ways in which L1 literacy can shape L2 literacy skills visual text processing. The findings are consistent with previous reports of vowel processing deficits in L1 abjad speakers and also extend them in a nuanced way to other L2 English populations. The results also have implications for practical language skills. Specifically, they suggest that although most learners may struggle with English vowels more than consonants (e.g., Share, 2008), those coming from an L1 without commonly written vowel graphemes may face additional challenges with vowels in their L2 writing. These

[3] The author thanks an anonymous reviewer for this suggestion.

challenges may also be quite long-lasting, as highlighted by the fact that this study found them in learners who had studied English for over a decade. Language instructors and materials designers would thus do well to particularly emphasize vowels and vowel spellings with ESL students. This would likely benefit all learners, while particularly helping those who are predisposed to more challenges with vowels. More broadly, additional cross-linguistic research of this type is needed to continue developing a detailed understanding of the particular difficulties faced by L2 learners from different language backgrounds and what the root cause(s) of those difficulties may be.

Appendix

Consonant Items

bite/bight
blow/bloe
church/churtch
claim/klame
clay/klay
clock/klock
cloud/kloud
clue/klue
cop/kop
crew/krew
cut/kut
dog/dawg
doll/daul
eight/ait
fade/phaid
fight/fite
fly/fligh
grow/groe
horse/horce
more/mohr
nod/nodd
noise/noize
once/wunce
quote/kwote
raise/raize
roof/rooph
scare/skair
screw/skroo
should/shud
show/sho
sick/sikk
sigh/sye
small/smol
snow/snoe
stop/stawp
through/thrue
thumb/thum
tight/tite
toll/toal
wall/whall
wheat/weet
whole/hoal

Vowel Items

blade/blaid
born/boarn
cake/caik
cheek/cheke
cope/coap
deem/deam
dirt/durt
field/feeld
first/furst
floor/flore
free/frea
gaze/gaize
girl/gurl
goal/gole
gold/goald
great/grait
home/hoam
jail/jale
joke/joak
late/layt
load/lode
loop/lupe
main/mayn
mate/mait
pie/pye
rape/raip
shirt/shurt
smoke/smoak
sneak/sneek
soon/sune
suit/sute
sweep/sweap
tear/tair
third/thurd
threat/thret
word/wurd
works/werks
wound/woond

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Table 1 Participants' demographic and language proficiency data

	L1 English	L1 French	L1 Hebrew	L1 Chinese
Age	18.43 (0.89)	24.96 (9.13)	27.70 (5.60)	22.07 (2.79)
Number of years studying English	--[a]	11.77 (3.33)	12.75 (4.83)	12.87 (3.10)
% of time speaking English	--[a]	10.54 (12.86)	10.19 (11.19)	7.70 (9.15)
Self-rated English reading proficiency *(1 = not literate, 10 = very literate)*	--[a]	6.60 (1.61)	7.60 (1.33)	6.67 (1.45)
Self-rated English writing proficiency *(1 = not literate, 10 = very literate)*	--[a]	5.94 (1.49)	6.67 (1.71)	5.50 (1.60)
Self-rated English conversational proficiency *(1 = not fluent, 10 = very fluent)*	--[a]	6.15 (1.62)	7.07 (2.02)	5.70 (1.66)
Self-rated English spoken language comprehension *(1 = no comprehension, 10 = perfect comprehension)*	--[a]	6.90 (1.61)	7.33 (2.09)	5.76 (1.74)
Reading comprehension	98.85 (11.66)	101.28 (13.48)	105.98 (12.80)	105.20 (10.46)
Listening comprehension	--	21.07 (5.17)	22.46 (3.82)	22.07 (3.16)
Vocabulary	58.96 (6.08)	21.57 (15.02)	21.50 (15.44)	21.33 (9.50)

Note. [a]The L1 English speakers were not asked this question.

Table 2 Scores on the Flankers and working memory span tests

	L1 English	L1 French	L1 Hebrew	L1 Chinese
Operation span size	4.59 (1.26)	4.54 (1.24)	5.24 (1.10)	5.22 (0.84)
Flankers accuracy	99.00% (1.15)	98.84% (1.61)	96.85% (8.60)	99.09% (1.20)
Flankers standardized congruency RT difference	0.13	0.12	0.10	0.10

Table 3 Accuracy and RTs on the word-pseudohomophone discrimination task

L1 Group	Consonant Accuracy	Vowel Accuracy	Consonant RTs	Vowel RTs
English	99.07% (1.62)	98.51% (2.12)	-668.33 (218.56)	-686.67 (222.51)
French	92.86% (5.88)	91.19% (7.67)	26.86 (581.42)	23.35 (571.67)
Hebrew	94.98% (5.97)	90.79% (8.68)	-191.19 (362.81)	-181.80 (410.28)
Chinese	96.48% (4.37)	94.11% (5.64)	-80.21 (335.91)	-66.56 (339.86)

Note. Standard deviations are in parentheses. RTs were measured from the end of the sound file presenting the word aurally; a negative RT therefore indicates that participants responded before the end of the sound file.

Table 4 Percent correct on specific misspelling types

L1 English		L1 French		L1 Hebrew		L1 Chinese	
Changed C	99.82	Changed C	97.83	Changed C	96.74	Changed C	97.64
Modified Silent ‘e’	99.23	Modified Silent ‘e’	93.73	Added or Deleted V	96.20	Added or Deleted V	97.28
Added or Deleted C	99.10	Added or Deleted V	93.48	Modified C and V	94.96	Modified C and V	96.35
Modified C and V	98.70	Modified C and V	91.74	Modified Silent ‘e’	93.22	Modified Silent ‘e’	95.40
Added or Deleted V	98.37	Changed V	88.11	Added or Deleted C	90.90	Added or Deleted C	94.30
Changed V	97.83	Added or Deleted C	86.50	Changed V	87.08	Changed V	92.07

Note. C = Consonant, V = Vowel.