Journal of Neurolinguistics 50 (2019) 82–93

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Another look at the role of vowel letters in word reading in L2 English among native Korean readers

Hye K. Pae[a,*], Sun-A Kim[b], Quintino R. Mano[c], Min Wang[d]

[a] School of Education, University of Cincinnati, USA
[b] Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, Hong Kong
[c] Department of Psychology, University of Cincinnati, USA
[d] Department of Human Development and Quantitative Methodology, University of Maryland, USA

ARTICLE INFO

Keywords:
Consonant-vowel hypothesis
Vowel letters
The Korean script
L2 English

ABSTRACT

While evidence shows that consonants play a primary role over vowels in reading Roman script, it remains unclear whether this primacy extends to reading non-Roman script. This study investigated the role of vowels in L2 English word reading among native Korean readers. Seventy six Korean- and English-speaking adults read words in a naming test. Stimuli included four conditions: lowercase, uppercase, letter strings with no vowels (e.g., *cmmn* for *common*), and letter strings with randomly missing letters (e.g., *corct* for *correct*). Overall, the vowel deletion manipulation gave rise to higher accuracy and faster reading than the random omission condition for the two groups. When the baseline was controlled, the group and condition variables jointly affected accuracy, but the condition and L1 script are independent of each other for latency. Results suggest that the consonant letter primacy observed in Roman script may not fully extend to other alphabetic languages.

1. Introduction

Advanced inquires of reading have focused on the role of vowel and consonant letters in word recognition (Blythe, Johnson, Liversedge, & Rayner, 2014; Duñabeitia & Carreiras, 2011; Hochmann, Benavides-Varela, Nespor, & Mehler, 2011; New, Araujo, & Nazzi, 2008; Perea & Lupker, 2004). New insights can be gleaned from examining how readers process segmentals (i.e., consonants and vowels) in English as a second language (L2) or a foreign language (FL).[1] This study investigated whether vowel letters functioned differently in English word reading between two groups of readers whose written L1s were a shallow orthography (Korean) and a deep orthography (English).

1.1. Literature review

While they are the building block for the architecture of language, consonants and vowels seem to function differently in speech processing and reading. Accordingly, the Consonant-Vowel Hypothesis has been proposed (Bonatti, Pena, Nespor, & Mehler, 2005; Toro, Nespor, Mehler, & Bonatti, 2008) to address the difference in the role between the two types of segmentals. Bonatti et al. (2005) and Toro et al. (2008) examined the role of consonants and vowels in continuous speech streams to find that consonants facilitated word identification or lexical processing, while vowels are tied to prosodic, rule-based, and syntactic awareness. An ERP study also supports a different role of consonants and vowels in

* Corresponding author.
E-mail addresses: hye.pae@uc.edu (H.K. Pae), sun-a.kim@polyu.edu.hk (S.-A. Kim), quintino.mano@uc.edu (Q.R. Mano), minwang@umd.edu (M. Wang).

[1] L2 and FL are used interchangeably in this article when the reference has little to do with learning contexts.

https://doi.org/10.1016/j.jneuroling.2018.01.004
Received 18 April 2017; Received in revised form 15 August 2017; Accepted 23 January 2018
Available online 21 February 2018
0911-6044/

visual word recognition. Specifically, Carreiras, Vergara, and Perea (2008) have reported, using transposed or substituted two consonants or two vowels, that a modulation was found at an early window (150–250 ms) and at the N400 component for vowel transposed letter strings but not for consonant transposed one and that faster processing was found on transposed consonants than substituted consonants. They have concluded that a different role is played by consonants and vowels in the process of visual word recognition. In addition, utilizing reading aloud and lexical decision tasks, Carreiras and Price (2008) have found that brain activation for consonants and vowels differs such that consonants are associated with lexico-semantic processing, while vowels are related to prosodic processing. These are consistent with the findings of research by Bonatti et al. (2005) and Toro et al. (2008).

Research shows that consonants and vowels play an asymmetrical role in visual word recognition and naming. For example, results converge on shorter lexical decision time for words preceded by transposed consonant letters (e.g., *caniso* - *CASINO*) than substituted consonants (e.g, *carivo* - *CASINO*) in masked priming tasks. However, this effect has been documented only for consonant letters but not for vowel letters (e.g., *anamil* – *ANIMAL* or *anomel* – *ANIMAL*) in Roman orthographies such as Spanish and English (Lupker, Perea, & Davis, 2008; Perea & Lupker, 2004). New et al. (2008) demonstrated that consonants played a more dominant role than vowels in native French speakers' lexical processing. They used four different primes in a masked-priming lexical decision task, including identity (e.g., *joli* vs. *joli*), unrelated (e.g., *joli* vs. *vabu*), consonant-related (e.g., *joli* vs. *jalu*), and vowel-related (e.g., *joli* vs. *vobi*) conditions, and found that the identity and consonant-related conditions showed significant priming effects, but not the vowel-related condition. Research also highlights the saliency of consonants in lexical activation and processing found in both children and adults (Havy, Serres, & Nazzi, 2014) and even in infants (Hochmann et al., 2011). The same pattern has been found in both speech stream and reading in French (Bonatti et al., 2005). Collectively, results suggest that consonant and vowel letters make unique contributions to word reading and that consonant letters play a stronger role within deep orthographies.

The saliency of consonants has also been found in studies of letter positions in words. Letter position effects are dependent on whether the prime is a string of vowels or consonants. For example, Duñabeitia and Carreiras (2011) have investigated the relative position priming effects, using subset primes of vowel-only and consonant-only letter strings [e.g., *aeo-acero* (Spanish for *steel*) vs. *frl-farol* (Spanish for *lantern*)]. They have found that the priming effect is significant only with consonant string primes, not with vowel primes (Experiment 1) with no effect of letter frequency (Experiment 2) and no effect of phonology (Experiment 3). Their Experiments 4 and 5 showed consistent findings of the consonant primacy using both repeated vowel and consonant primes. They argue that consonants and vowels play a different functional role in word processing wherein consonants place orthographic constraints in the lexicon, while vowels facilitate the identification of the "properties of the syntactic structure and the rhythmic class" (Duñabeitia & Carreiras, 2011, p. 1145). Duñabeitia and Carreiras (2011) have concluded that the significant role of subset primes of consonants is attributable to the greater number of consonants than vowels in most alphabetic languages and scripts as well as the degree of the consonantal constraints placed on the lexicon.

Research has been expanded to scripts other than Roman alphabets in the role of segmentals in word recognition. For example, the processing asymmetry of consonants and vowels has been examined in Thai (Winskel & Perea, 2013), which is a tonal language with a complex deep orthography and relational markers. Specifically, Winskel and Perea (2013) conducted an eye movement study in Thai and found nonadjacent transposed-letter effects in gaze duration for consonants but not for vowels. They concluded that the distinction between consonants and vowels does not occur at the initial level of processing but at the later stage of processing.

Writing systems of Semitic languages (a.k.a., abjads) such as Arabic and Hebrew also provide a unique perspective on segmental processing due to their consonant-dominant scripts, which make use of a limited inventory of vowel diacritics. Frost (1995) found that the latency of lexical decision was unaffected by missing-vowel stimuli in words. It seems that vowel-absent strings in Hebrew are as legible as vowel-present Hebrew words in efficient reading. In Arabic, most words are written in consonants only in texts, while vowels are notated mainly in poetry, children's books, and liturgical texts as diacritical marks above, below, or within the body of the word (Ibrahim, 2013). Ibrahim (2013) has noted that vowelized scripts are orthographically shallow because the mapping between letters and sounds is consistent, whereas unvowelized scripts are considered to be orthographically deep because the relationship between graphemes and phonemes is inconsistent. These studies were in line with the notion of a less salient role of vowels than consonants in reading. Although Abu-Rabia (1997) has claimed that vowels play an important role in reading among poor and skilled native Arabic readers, other research indicates that unvowelized words may be processed quicker and more accurately than vowelized-words among Arabic speaking individuals (Ibrahim, 2013). Taken together, research suggests that consonants and vowels are processed differently across orthographies and that cross-linguistic investigations may be in need to corroborate the dominant role of consonants in reading in Roman script. In the extant literature, discussion on the role of vowels has been comparatively silent. It is unclear whether the asymmetry of consonants and vowels has something to do with the observed consonant dominancy.

L1 influences on L2 performance have been well documented in word recognition (Akamatsu, 2003; Hamada & Koda, 2008; Wang, Koda, & Perfetti, 2003), which is consistent with the idea that linguistic skills are fluid and transferable. Research has demonstrated that nonnative speakers with different L1 script backgrounds (i.e., alphabetic vs. nonalphabetic) make use of different constituents of words (i.e., phonology, orthography, and morphology). For example, Wang et al. (2003) show that Chinese adult readers are more likely to rely on orthographic information than phonological structures, while Korean counterparts exhibit the opposite preference. Such results may stem from the fact that Chinese is primarily a logography whereas Korean is a phonetic alphabetic language. Hamada and Koda (2008) have also shown the effect of L1 (Chinese and Korean) orthographic experience on L2 (English) decoding in a pseudoword naming task. They found Koreans' higher retention rate on overall recall tasks than Chinese counterparts but their more difficulties with irregular pseudowords than regular ones. They attributed the difference in performance between Chinese and Korean adult participants on accuracy and response time (RT) to the influence of L1 orthography on L2 reading. Akamatsu (2003) also found effects of L1 orthography on L2 English reading among different L1 groups of readers (i.e., Iranian, Chinese, and Japanese). These types of results strengthen an argument that cross-linguistic investigations may shed unique light on segmental processing.

1.2. The present study

To date, no study has examined the differential role of segmentals among Korean readers, although much attention has given to readers of other Roman scripts such as English (Cutler, Sebastian-Galles, Soler-Vilageliu, & van Ooijen, 2000), French (Bonatti et al., 2005; Havy et al., 2014), Dutch (Van Ooijen, 1996), Italian (Colombo, Zorzi, Cubelli, & Brivio, 2003), and Spanish (Cutler et al., 2000). A study with native Korean speakers bears significant implications due to the Korean script *Hangul*'s unique characteristics that it is alphabetic and shows a salient syllabic configuration. The Korean language and script have unique features in several ways.[2] Of those, three features are conspicuously related to this study: (1) the distribution of consonant and vowel letters, (2) clear mapping between graphemes and phonetic sounds, and (3) the dominance of a vowel in a syllable with no onset and medial consonant clusters in words.

Regarding the first feature, Korean has more vowel letters (21 vowels) than consonant letters (19 consonants) in its writing system. The greater number of vowels than consonants is different from that of most other writing systems (except Swedish that has 18 consonant phonemes and 18 vowel phonemes) that have more consonants than vowels in the inventories of both phonemes and letters. The larger number of vowel letters than consonant letters reinforces vowel centrality in a *Hangul* syllable in which vowels play a chief role in the formation of syllables. In written Korean, the shape of the vowel determines whether the format of the syllable is a top-down or left-to-right format (i.e., top-down, 무; left-to-right, 가). Therefore, the presence and place of the vowel are crucial in the syllabic structure of the Korean script.

Regarding the second feature, the full inventory of phonemes clearly accords with that of the letters in Korean[3]; consequently, there is no need to have phonetic symbols (e.g., IPA symbols) to represent phonemes or to look up the dictionary for correct pronunciation. This is different from English. In English, the phonetic inventory is larger than that of the letters; thus, some consonant and vowel sounds do not appear in the alphabet inventory (e.g., [tʃ, ʃ, ð, θ, dʒ, ʒ, ŋ] for consonantal sounds and [ə, æ, ə, ʌ, ɔ, etc.] for vowel sounds). Besides, there are letters that are not included in the phonetic inventory (i.e., *c, q*, and *x*).

Regarding the third feature, the Korean alphabet does not permit consonants to stand alone or to be clustered without vowels.[4] Consonants are literally called "the sound made by touching another" (닿소리; i.e., dependent sound), which means that consonants can make sounds only when the tongue makes direct contact with another vocal organ (e.g., teeth, palate, etc.) or that a consonant is required to be combined with a vowel so that the sound value of the consonant becomes robust. This is different from English in which consonant clusters are acceptable and each consonant within the cluster can be sounded out (e.g., *strong* →/s/ + /t/ + /r/ + /ɔ/ + /ŋ/). Given that vowels can make sounds without making contact with other vocal organs by relying on air flow with no contriction in the vocal track, such sounds are dubbed the "independent sound" (홀소리). In this sense, the Korean words for "consonants" and "vowels" not only literally reflect the articulatory characteristics of each segmental well,[5] but also signify *Hangul*'s syllabic feature.

The English writing system is governed by the graphotactic rule of legal or illegal consonant combinatorial chunks (e.g., *dhr*-is illegal, while *chr*-is legal); therefore, proficient native English readers intuitively know the legality of consonant chunks. One important question is whether L2 readers are able to make use of the graphotactic rules of consonants *psychologically* or *unconsciously* as a result of prolonged literacy experience when they read English as L2. If the answer is positive, it may support the universality of reading processes involved in L1 and L2. If not, we can conjecture that L1 has meaningful effects on L2 reading. Another question is related to the potential generalization of the consonant primacy to readers of a vowel-centered script. One way to test how readers make use of the English graphotactic rule is to have L2 readers whose L1 has a different orthography and syllabic format read English as L2 with various letter combinations. Because shallow orthographies do not generally allow for strings of multiple consonants or vowels within the word, readers with an orthography that does not subscribe to strings of multiple consonants or vowels within the word may experience greater disruption in letter strings with missing letters either systematically or randomly than individuals with a deep L1 orthography. Under this reasoning, a study that tests nonnative speakers' L2 English word processing with purposefully designed experimental items would be useful, drawing on the Consonant-Vowel Hypothesis (Hochmann et al., 2011) and L1 orthographic effects on L2 reading (Akamatsu, 2003; Hamada & Koda, 2008; Wang et al., 2003).

The aforementioned idiosyncracies of the Korean script warrant a cross-linguistic study in terms of the role of vowels because it is still unknown whether the effect of the large vowel repertoire and vowel centrality in L1 Korean is carried over to L2 English word reading. Hence, it would be important to compare performance patterns between native Korean and English readers whose L1s have different orthographies, vowel inventories, and vowel positions from each other.

Building upon the Vowel-Consonant Hypothesis (Bonatti et al., 2005; New et al., 2008; Toro et al., 2008), this study investigated how Korean- and English-speaking university students read words and manipulated letter strings in English that either lacked vowels altogether or consisted of randomly missing letters. Examining L2 reading will provide meaningful information as to whether the Vowel-Consonant Hypothesis is supported or other variables, such as word class and frequency, come into play in L2 reading. Lowercase words served as a comparison condition while the manipulated letter strings served as experimental conditions. The performance of native Korean readers on uppercase words would explain an unfamiliarity effect given that uppercase texts are rarely

[2] Because the characteristics of the Korean language and script have been extensively discussed elsewhere, general information about Korean is not provided in this article Pae (2011, in press).

[3] There are some sound variations, such as vowel harmony and palatalization between syllables, but these are beyond the scope of the given discussion.

[4] This is in part why Korean children are first taught with syllables, not with individual consonants and vowels, which is different from the way English is first earned by emergent readers.

[5] *Hangul* vowels were devised by King Sejong in the 15th century based on philosophical reasoning to represent heaven, earth, and human, while consonants were created to represent the manner and place of articulation (see Pae, in press).

used in Korea. Based on previous findings of L1 effects (Akamatsu, 2003; Hamada & Koda, 2008; Wang et al., 2003), we globally hypothesized that the two groups would perform differently on the experimental conditions (i.e., letter strings with no vowels and letter strings with randomly missing letters), while they perform similiarly on the reference condition (i.e., lowercases). Specific hypotheses are as follows:

Hypothesis 1. Native Korean students would read typically printed words similarly to native English readers, regardless of cases (i.e., lowercase or uppercase).

We hypothesized this because the stimuli were drawn from the list of sight words for third graders (Fry, 2004) to ensure that all words were to be read without laborious decoding efforts and because the Korean participants were university students who had made a cut in the enterance exam in Korea. In other words, this hypothesis was posed as an instrumental premise to further address the specific aims of this study (i.e., Hypothesis 2 and 3). Uppercase words were included to see whether or not the unfamiliar case format have an effect on reading.[6]

Hypothesis 2. Native Korean students would be more error-prone than English readers in letter strings that had missing vowels.

We hypothesized this because the Korean writing system has a very clear combinatorial rule in that a vowel is central in a *Hangul* syllable and that a consonant should be glued together with a vowel to the degree that consonant clusters are not permitted in a word. This strict syllabic principle (i.e., a consonant should be accompanied by a vowel which is different from English in which consonant strings are permissible) might lead Korean readers to develop a strong sensitivity to syllables in word identification. Hence, due to L1 effects, the absense of vowels in words might disrupt the "psychological" graphotactic rule in English for Korean readers more than native English readers. It should be noted that the group difference was of interest for this hypothesis. Given the essential difference betweent the two groups with one in L1 and the other in L2, accuracy was regarded as a primary index of reading skills to address this hypothesis. Latency was additionally examined.

Hypothesis 3. The disruption experienced by native Korean readers with randomly omitted letter strings would be comparable to that by native English readers, when the baseline is controlled.

The condition of random omission would break the graphotactic rule to the degree that it would disturb any reader's reading, regardless of L1 or L2 due to no predictability of letter neighborhood cohesion and the greater degree of freedom for possible letter combinations with the given stimulus. Therefore, we hypothesized that the difference in accuracy and latency between the two groups would be similar, when their L1 and L2 status was taken into consideration (i.e., controlling for the baseline). If this was true, the results would additionally support Hypothesis 2.

2. Methods

2.1. Participants

Seventy six college students were recruited from Pusan National University in South Korea and the University of Cincinnati in the U.S. The mean age of the Korean participants (N = 38) was 22.26 years (*SD* = 3.07; Male: *N* = 21, 55%; Female: *N* = 17, 45%), while that of the English-speaking group (*N* = 38) was 19.5 years (*SD* = 1.13; Male: *N* = 3, 8%; Female: *N* = 35, 92%). They had normal or corrected-to-normal vision. The Korean participants reported that they had studied English in the official school system for 12 years (*SD* = 2 years). Their self-reported reading skills[7] were at 5.6 (*SD* = 1.64) on a 10-point Likert scale with 10 to be native-like skills.

2.2. Procedure

Upon granting consent, the participant was individually administered a computer-based naming test in a quiet room. The student was asked to read out loud a *base word* of a letter string (i.e., missing vowels or missing random letters) as quickly and accurately as possible. After the participant completed six practice items, each target item was presented on the computer screen, following a fixation point (+) presented for 500 ms, until the participant read the word. All items were randomly scrambled for each presentation. The stimulus was set to time out after 4 s, but all participants read the target words within the time limit. Accuracy and reading time (RT) were the dependent variables. RT was measured by a tester's button press in the keyboard upon the participant's naming. This method has been used in the behavioral science literature (Lee & Hwang, 2015; Kumar et al., 2010). Moreover, measuring naming time upon the completion of the examinee's articulation is typical in timed tests, such as the Rapid Automatized Naming and Rapid Alternating Stimulus Tests (RAN/RAS; Wolf & Denckla, 2005) and rapid color, object, digit, and letter naming subtests of the Comprehensive Test of Phonological processing (Wagner, Torgesen, & Rashotte, 1999). Latency was operationalized as a time interval between the appearance of the stimulus on the computer screen and the end of response. A pilot study showed that L2 readers often made repetitions (e.g., *tra … travel, be … behind*) of syllables, dragging sounds (e.g., *beeeehind, cirrrrcle*), or self-corrections (e.g., *come on … common* for *cmmn*), which were considered correct if the final utterance was correct. In order to reflect these deviations in

[6] Uppercase-only texts in English are almost nonexistent and are rarely used in any circumstances in Korea.

[7] Given that (1) there is no standardized word reading test available for adult nonnative speakers of Korean and (2) the test materials are drawn from Fry's sight-word lists for third graders, it is safe to note that a lack of standardized proficiency test is not a critical issue for this study. Importantly, the baseline data (i.e., accuracy of lowercase) demonstrated the Korean participants' perfect accuracy in reading English words.

latency, the measurement of spoken onset times was not utilized in this study. If voicebox were used for onset-time measurement, it would have been prematurely triggered.

2.3. Measure

A computer-based naming test using E-Prime included 40 items and 20 distractors (see Appendix). All stimuli were drawn from Fry's third-grade sight words (Fry, 2004). The list of high frequency sight-words for third graders was used because the participant should easily read the target on the computer screen without difficulty. In order to confirm this, lexical frequency was obtained using the MCWord database (Medler & Binder, 2005) which provides orthographic information about English words, including lexical (word frequency and neighborhood counts) and sublexical (letter and letter combination) data.

Words drawn from the sight-word list for this study[8] were initially assigned into four conditions: (1) lowercase sight-words with no missing letters, (2) uppercase sight-words with no missing letters, (3) lowercase letter strings without vowels, and (4) lowercase letter strings that had randomly missing letters from the base word. The last two categories served as experimental conditions. The numbers of letters, vowels, and syllables were matched across the conditions. The condition with no vowels was constructed by simply deleting all vowels from the base word (e.g., the word "*common*" became "*cmmn*"). The condition with random letter omission was formed by deleting letters as the number of syllables within the base word. For example, given that the words "*correct*" and "*became*" have two syllables, two letters were randomly deleted, regardless of consonants or vowels, from the base word, resulting in "*corct*" and "*bcae*," respectively. In the construction of the random-ommision items, the first and last letters were kept intact given that (1) previous studies showed a more dominant role of the onset and ending letters in word recogntion than medial letters (Johnson & Eisler, 2012) and (2) the first and last letters provide the minimum phonotactic rule; hence only internal letters were subjected to be randomly deleted.

It was ensured that the four conditions had similar word length (i.e., the number of letters in the base word) by having four to nine letters in length in each base word. This decision was based on empirical evidence. Specifically, a meta-analysis shows that words that have five to eight letters have no word-length effects on RT in lexical decision (New, Ferrand, Pallier, & Brysbaert, 2006). New et al. (2006) note that a large corpus of data including the wide range of word lengths demonstrates a U-shaped curve of RTs when the effects of frequency and neighborhood size are controlled, showing that words of three to five letters have a facilitatory effect (i.e., shorter words associated with shorter RTs); words of five to eight letters have no effect (i.e., RTs are independent of lengths for words of five to eight letters); and words of eight to 13 letters have an inhibitory effect (i.e., longer words associated with longer RTs).

3. Results

3.1. Preliminary analysis

Scatter plots and outliers were visually examined to screen data. No atypical data points were found. The experimental condition was letter strings with no vowels as well as letter strings with randomly missing letters within the word, whereas the baseline condition was the lowercase stimuli. The participants' accuracy rate and reading time showed a wide variability, which allowed the dataset to be free from the problem of restricted ranges of data.

In order to ensure that the two groups' accuracy and reading latency were independent of spurious variables, word class (a.k.a., part-of-speech) and frequency among the baseline words across the conditions were first examined. The entire pool of the stimuli consisted of nouns (50%), verbs (17.5%; *travel* was considered a verb due to higher frequency of use than as a noun), adjectives (12.5%), prepositions (10%), adverbs (5%), pronouns (2.5%), and conjunction (1.5%; *until* was viewed as a conjunction due to higher frequency of use than as a preposition). For those with no vowels, nouns comprised the largest proportion (40%) in the pool, followed by verbs (20%), adjectives (20%), pronoun (10%), and prepositions (10%). For those with randomly missing letters, nouns comprised of 50% of the stimuli, followed by verbs (40%) and adjectives (10%).

Word frequency obtained from the MCWord database (Medler & Binder, 2005) showed no significant difference among the conditions ($p > .05$). The mean number of syllables in the base word for the entire set of the stimuli was 1.97 ($SD = .41$), while the mean of letters in the base word was 5.32 ($SD = 2.61$). The breakdown of the number of letters by condition was as follows: Lowercase: 6.5 ($SD = 1.58$), Uppercase: 6.1 ($SD = 1.66$), Vowel omission: 6.40 ($SD = .52$), and Random omission: 6.90 ($SD = .32$). As expected, the word length was not different among the four conditions ($p > .05$). The results of these analyses confirmed that the stimuli were well matched for the different conditions in terms of word frequency and length.

3.2. Hypothesis testing

Hypothesis 1 was to examine the comparability of performance of native Korean and English readers to further test Hypotheses 2 and 3. The means of accuracy rate and latency as well as standard deviations by group are presented in Table 1. With respect to a group difference in accuracy, the Korean- and English-speaking groups did not show a significant difference in naming words of lowercase and uppercase words. Importantly, both groups showed 100% accuracy[9] in the performance on the lowercases, as

[8] This study is part of a larger study and the items were selected to address the aim of this study.

[9] This confirmed that the Korean participants' word reading skills were on par with those of the native English speakers and that an English proficiency test was unnecessary for the Korean participants in this study.

Table 1
Means and standard deviations of accuracy (%) and latency (ms.).

Accuracy Rate (%)	Korean (N = 38)		t	English (N = 38)	
	Mean	SD		Mean	SD
Lowercase	100	0	N/A	100	0
Uppercase	99.47	3.24	ns	100	0
Vowel Omission	88.68	9.91	−4.23***	96.58	5.82
Random Omission	68.16	14.30	−4.99***	82.11	9.63
Vowel Omission Interference Effect	11.32	9.91	−4.23***	3.42	5.83
Random Omission Interference Effect	31.84	14.30	−4.99***	17.89	9.63

RT (ms)	Korean (N = 38)		t	English (N = 38)	
	Mean	SD		Mean	SD
Lowercase	1310.86	300.23	5.39***	987.56	203.20
Uppercase	1542.18	455.87	9.95***	955.31	198.44
Vowel Omission	1723.51	447.17	6.97***	1162.48	215.09
Random Omission	1920.39	477.34	5.53***	1362.63	399.17
Vowel Omission RT Effect	412.65	423.80	3.34**	174.92	151.66
Random Omission RT Effect	609.53	950.24	ns	375.07	724.35

Note: SD = standard deviation.
N/A = not available; t could not be computed because the SD of the both groups were 0.
ns = not significant.
*$p < .05$; **$p < .01$; ***$p < .001$.

expected. The accuracy performance on the uppercase words was close to perpection (99.47%) among the Korean readers, while the native English readers showed 100% accuracy in the uppercase words. Regarding performance difference within the group, there was no difference in accuracy between lowercases and uppercases for both groups of native Korean and English readers. This result demonstrated that unfamiliarity effects with the uppercase words were not found in the Korean participants in terms of accuracy.

With respect to a group difference in latency, the Korean- and English-speaking groups showed a significant difference in the lowercase and uppercase words (see Table 1), indicating that Koreans read both cases significantly slowly. Regarding the performance difference within the group, there was a significant difference in latency between lowercases and uppercases for the native Korean readers ($t(37) = -4.12$, $p < .001$), whereas there was no difference for the native English readers. The Korean participants might have read the uppercase words comparatively slowly simply due to the lack of exposure, despite the near-perfect accuracy of reading. A question may arise as to whether a difference in latency but not in accuracy should be considered a group difference or not. Given that standardized timed and untimed reading measures, such as the Test of Word Reading Efficiency, the Gray Oral Reading Test, and the Woodcock-Johnson Achievement Test, assess accuracy of reading and that reading fluency or skills are a confluence of accuracy and reading speed, accuracy can be considered one of major skills of reading. Furthermore, this study was focused more on observed performance than mental processes or operations, which is different from the point of interest in priming lexical decision tests.

Since both groups showed 100% accuarcy in reading the lowercase words, only performance on lowercases was used as a baseline for comparison. This result provided good baseline data for further comparisons to the results of the manipulated stimuli in which vowels or random letters were omitted. As globally hypothesized, while no significant group difference was found in reading accuracy in the lowercase and uppercase words, there was a significant difference between the two groups in accuracy of reading stimuli with no vowels ($t(74) = -4.23$, $p < .001$) and between the two groups in letters randomly missing within the word ($t(74) = -4.99$, $p < .001$). Notably, the group difference was of interest of analysis here rather than a comprarison between the vowel missing and random missing conditions because these two conditions had inherent differences in terms of the lack of predictability and impalusibility in the letter neighborhood within the stimuli in the random-missing condition. In other words, the vowel missing stimulus still preserves the graphotactic rule to the degree that readers take advantage of consonant strings of the stimulus. As a result, it might not be reasonable to directly compare the performance on the conditions without controlling for the baseline.

In order to have omnibus tests and contrasts and to avoid problems of multiple comparisons[10], Hypotheses 2 and 3 were examined simultaneously. A repeated measures ANOVA was run with a 2 (groups) x 3 (conditions) design as a way of testing significance among all

[10] The reason for not running separate analyses for subjects and items was due to the fact that the focus was placed on the group difference. There has been criticism raised on separate subject and item analyses because of drawbacks involved in separate analysis [e.g., statistical power can be reduced due in part to repeated observations within the subject; different levels of data points (i.e., continuous variables for RT and dichotomous for accuracy) are involved]. Raaijmakers, Schrijnemakers, and Gremmen (1999) has noted that it might be unnecessary to run separate analyses because the traditional F statistics tend to be adequate and sufficient in most cases, and that it is particularly unnecessary "when item variability is controlled by matching" (p. 416), which is the case of the current study.

variable means as well as equality of their variances with the two groups as the between-subject factor and the three conditions (i.e., lowercase words,[11] letter strings with no vowels, and letter strings with randomly missing letters) as the within-subject factors. With respect to accuracy, the result of the multivariate test was significant ($F(2, 73) = 157.04$, $p < .001$, $\eta_p^2 = .81$). The interaction between condition and group was also significant ($F(2, 73) = 15.57$, $p < .001$, $\eta_p^2 = .30$). Mauchly's test showed that the assumption of sphericity (i.e., the variances of the differences among all combinations of the three conditions are not different) was violated: χ^2 (2) = 16.18, p < .001, ε > .86. Hence, a degree-of-freedom corrected model was adopted using the Huynh-Feldt correction instead of Greenhouse-Geisser. The results with a Huynh-Feldt correction showed that there was a significant main effect of the three letter conditions on the accuracy: Corrected $F(1.73, 127.67) = 208.38$, $p < .001$, $\eta_p^2 = .74$. This meant that if all other variables were held constant, the accuracy rate was different for the three conditions. Post-hoc tests using a Bonferroni correction demonstrated that vowel-deleted and random-letter-deleted manipulations significantly reduced the accuracy of naming. There was a significant interaction effect ($F(1.73, 127.67) = 15.62$, $p < .001$, $\eta_p^2 = .17$), indicating that the two groups' accuracy rates were different for the three conditions. The between-subject results showed a significant difference ($F(1, 74) = 31.56$, $p < .001$, $\eta_p^2 = .30$), indicating that Korean readers made more errors in both vowel-deleted and random-letter-deleted conditions than native English speakers.

As for RT, a repeated measures ANOVA was also performed. The multivariate test for the main effect of the conditions was significant ($F(2, 73) = 58.55$, $p < .001$, $\eta_p^2 = .62$). The interaction effect between condition and group was also significant ($F(2, 73) = 6.12$, $p < .01$, $\eta_p^2 = .14$). The assumption of sphericity was not met, as showen by the Mauchly's test (χ^2 (2) = 7.02, $p < .05$), indicating the inequality of variances of the differences among the conditons. Therefore, a degree-of-freedom corrected model was adopted using the Huynh-Feldt F statistics for the test of within subjects effects because ε = .95. The test of within-subjects effects showed a significant main effect of conditions ($F(1.90, 140.73) = 64.23$, $p < .001$, $\eta_p^2 = .47$), indicating that reading time was significantly affected by the conditions and was different for typical, vowel-ommitted, and randomly-omitted letters, if all other variables were ignored. There was a significant interaction effect ($F(1.90, 140.73) = 5.18$, $p < .01$, $\eta_p^2 = .07$), indicating that reading time between the groups was different for the three conditions (i.e., lowercase, letter clusters with no vowels, and letter clusters with randomly missing letters). The pairwise comparison between-subject results based on the estimated maginal means showed a significant difference: $F(1, 74) = 54.57$, $p < .001$, $\eta_p^2 = .42$. All pairwise comparisons of the conditions (i.e., lowercase vs. vowel ommision; lowercase vs. random omission; vowel omission vs. random omission) were significant at the .001 level with the multivariate test statistics of $F(2, 73) = 58.55$, $p < .001$, $\eta_p^2 = .62$.

As indicated earlier, the two groups were fundamentally different with one with English as L1 and the other as L2. Therefore, an ANCOVA was performed as a way of controlling for an inherently possible response bias for the Korean group and reducing the effects of variables that might have changed the relationship with the dependent variables of accuracy and latency. In other words, the baseline data (i.e., performance on lowercases) were used as a covariate in the ANCOVA to control for initial group differences in reading latency in order to improve precision and to compensate for the lack of balance in performance between the two groups because the L2 status was expected to influence the dependent variable (i.e., latency) to be analyzed. Regarding accuracy, when the lowercase data were controlled, the multivariate tests and tests of within-subject effects showed a nonsignificant difference for the main effect and the interaction effect between condition and the covariate in terms of accuracy. However, there was a significant interaction between condition and group for accuracy: $F(1, 74) = 4.89$, $p < .05$, $\eta_p^2 = .06$, indicating that reading accuracy was affected by the manipulation and that the Korean group was more disrupted than the English group. Since two conditions were entered into the model with the covariate, sphericity was assumed to be met. The pairwise comparison between the two groups based on the estimated marginal means showed a significant effect of the group ($F(1, 74) = 31.56$, $p < .001$, $\eta_p^2 = .30$). The multivariate effects of condition through pairwise comparisons between the vowel deletion and random deletion conditions with the covraiate showed a significant difference ($F(1, 74) = 168.58$, $p < .001$, $\eta_p^2 = .69$), indicating that vowel deletion was easier to read than random deletion.

In order to visually examine the interaction between group and condition, the means for each condition by group were plotted, adjusting for the baseline. Fig. 1 shows that there were simple effects of the conditions on the two groups with the vowel omission leading to higher accuracy than the random omission. However, the change between the vowel deletion and random deletion was signifiantly greater for the Korean group than the English group ($F(1, 74) = 4.89$, $p < .05$, $\eta_p^2 = .06$) and the difference between the two conditions was slightly attenuated for the English group. We could conclude that the readers' accuracy was dependent on the deletion type and that the distance between vowel omission and random omission in accuracy was greater for the Korean group than the English group.

As for reading latency, when the lowercase latency was controlled, the multivariate test and within-subject tests showed a nonsignificant difference for the two groups. Specifically, the main effects and interaction effects were not significant in the multivariate tests, tests of within-subject effects, and tests of within-subject contrasts. The test of between-subject effects was significant for the covariate (i.e., lowercase latency) and for the group: $F(1, 73) = 22.89$, $p < .001$, $\eta_p^2 = .24$) for the covariate and $F(1, 73) = 18.17$, $p < .001$, $\eta_p^2 = .20$ for the group. The test of group effects based on the linearly independent pairwise comparisons among the estimated marginal means showed a significant difference, indicating that the English group read faster than the Korean group: $F(1, 73) = 18.17$, $p < .001$, $\eta_p^2 = .20$. For pairwise comparisons for the conditions also showed a significant difference: $F(1, 73) = 19.07$, $p < .001$, $\eta_p^2 = .21$, indicating that the random deletion manipulation was more disruptive for both groups.

In order to see whether the conditions had a differential effect depending on the L1 script, interactions were examined. Fig. 2 shows the plots of the interaction term using the means for each level of factors. This contrast showed a nonsignificant interaction effect. This means that, although the English readers read faster than the Korean readers and vowel deletion was read faster than random deletion, regardless of L1 scripts, the decrease in speed seen in the random manipulation was not different

[11] Because native Koreans were not accustomed to reading all uppercase texts because all uppercase texts are rarely used in Korea, the data of uppercases were not used for comparison.

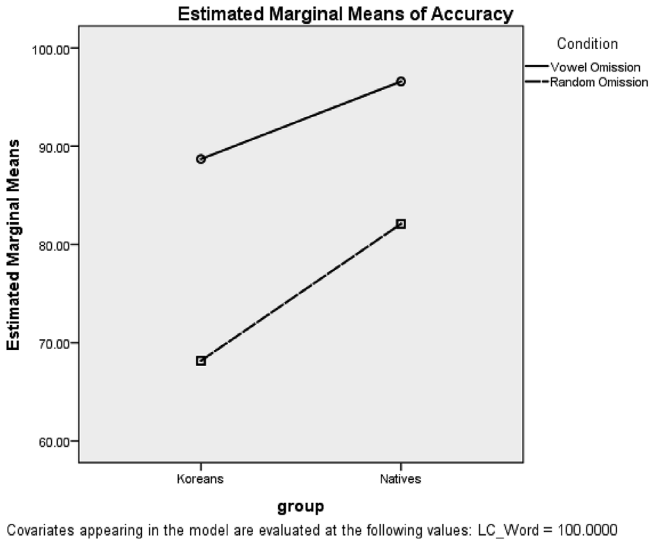

Fig. 1. Interaction graph for accuracy by group.

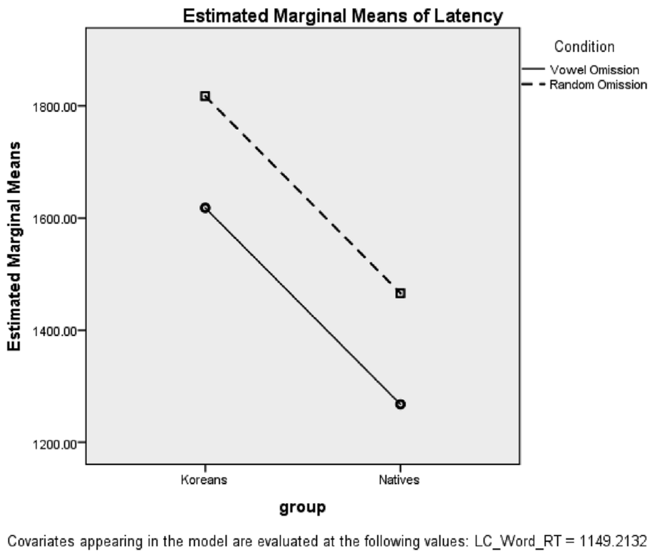

Fig. 2. Interaction graph for latency by group.

from that in the vowel manipulation. We could conclude that the reading speed due to the manipulation was not affected by the grouping variable.

4. Discussion

This study compared native Korean readers to native English readers on a task that involved reading aloud letter strings with no vowels and randomly deleted letters. The approach to vowel omission effects was an indirect way to cross-examine the role of consonants in reading. It was an indirect way because the deletion manipulation was different from methods used previously in the literature. However, it was worth the examination of the vowel importance in reading especially with Korean readers whose L1 had unique characteristics. Given that the participants were able to accurately read the letter strings that had missing vowels to a great extent, performance on the experimental items appeared to be affected by knowledge of the base word. These results suggest that knowledge of whole words seem to be critical in efficient reading. In general, our hypotheses were partially supported and are discussed briefly below.

Our first hypothesis was that native Korean students would read typically printed words similarly to native English readers. The two groups performed similarly on the typically printed words (e.g., lowercases and uppercases) in terms of accuracy. This indicates that once a threshold for L2 reading is reached, nonnative speakers' efficiency of word identification in L2 may be comparable to that of native speakers with respect to accuracy. This allowed us to rule out the possibility that the Korean participants' English proficiency could have an artificial effect. The reading latency was different between the two groups without taking L1 and L2 status into consideration. Reading latency could be considered less crucial to address Hypothesis 1 due to the inherently different L1 versus L2 performance of the readers. Although the strength of L1 linguistic skills is likely to be denser than that of L2, it is still unclear whether the difference in latency between the two groups was resulted from the readers' L1 and L2. No difference in accuracy found in the result for Hypothesis 1 provided at least the feasibility of the comparisons of the two groups' performance on accuracy for the specific aims addressed in Hypotheses 2 and 3.

The second hypothesis, which was that native Korean students would be more error-prone than English readers in naming letter strings that lacked vowels, was largely supported. Of interest was a group difference for this hypothesis given that the primary objective of this study was to find the presence of L1 script effects for the Korean readers. A significant difference in both accuracy and latency was found between the two groups in the vowel-deleted stimuli with the Korean participants to be more error-prone than their English-speaking counterpart. The results of an ANCOVA in accuracy with the baseline as a covariate showed a significant interaction effect indicating the distance between the vowel and random manipulation conditions was significantly greater for the Korean group than the English group. The ANCOVA showed that a significant between-subject effect in latency, meaning that the two groups read the stimuli significantly differently, when the lowercase reading latency was controlled.

This finding may paint a little different picture than the Consonant-Vowel Hypothesis (Hochmann et al., 2011). Although the approach of this study was different from the standard method used in the existing literature, the manipulation of vowel deletion yielded consonant-only strings. Accordingly, the results open up a discussion on whether the consonant primacy is script-universal or script-specific. Previous research has converged on the consonant primacy in alphabetic languages such as Spanish, French, and English (Blythe et al., 2014; Duñabeitia & Carreiras, 2011; Hochmann et al., 2011; New et al., 2008; Perea & Lupker, 2004). In English, the consonant advantage may be attributable to the linguistic feature that consonant letter clusters are permitted. With consonant clusters, native English speakers might have developed an implicit understanding that a consonant does not have to couple with a vowel; consequently, readers become tolerant of consonant strings. Conversely, the Korean writing system does not subscribe to consonant clusters except the limited number of ending digraphs. Moreover, vowels are the key ingredient of a syllable in written Korean. Furthermore, as vowels dictate the way syllables are formed (i.e., top-down or left-to-right), the absence of vowels in the word makes the print illegible because of too many degrees of freedom involved in the permissible vowels to form a plausible syllable. Although it has not been pointed out in the literature, another explanation of the consonant primacy in reading English words would be the visual characteristics of consonants, such as ascenders and descenders. There are eight ascenders (i.e., *b, d, f, h, i, k, l,* and *t*), four descenders (i.e., *g, p, q,* and *y)*, and one ascender-descender (i.e., *j*) in the inventory of the English alphabets. These visual characteristics may be closely related to more distinctive legibility of consonant strings (e.g., *vsl chrctrstics*; key: *visual characteristics*) than vowel strings (e.g., *iua aaeii*; key: *visual characteristics*). However, this feature is nonexistent in Korean.

The third hypothesis was that letter strings with randomly missing letters would disrupt both native Korean and English speakers similarly. A contrast between the experimental vowel and random manipulations was of more interest to address this hypothesis. This hypothesis was posed in order to supplement the result of Hypothesis 2. If randomly missing letters are equally difficult to read for both groups because of the lack of graphotactic properties in the manipulation, the significant difference found in reading vowel missing letters could be highlighted. Due to the essential difference between the two groups in terms of L1 and L2, the baseline was controlled in an ANCOVA. When the lowercase was covaried, there were no significant main effects for the condition and the covariate. Only significant interaction effect was found in accuracy. Notably, the interaction term of accuracy showed that the distance between random deletion and vowel deletion was smaller for the English group than the Korean group. In contrast, the interaction with the condition was not significant in latency. There was only a significant difference in the between-subject effects in latency, although not only did the English readers consistently read more accurately and faster than the counterpart, but also vowel deletion was easier to read regardless of the L1 script. This hypothesis was partially supported insofar as the condition and L1 scripts are dependent of each other in accuracy but are independent of each other in latency.

Taken together, readers with English as L1 and L2 are more efficient in reading more systematically manipulated vowels than randomly manipulated letter strings. In vowel-absent letter strings consonants are still present with retained relative positions within the word (i.e., the letter string *prblm* preserves each consonant's relative position of *pr-bl-m* for *problem* to a great extent; see Duñabeitia & Carreiras, 2011, for a review of the relative-position effects). This indicates that consonants-only letter strings are easier than randomly arranged letters because readers can take advantage of the graphotactic rules. This was the basic assumption for Hypothesis 2. The consequences of L1 literacy experience were also factored in to address Hypothesis 2 because the Korean script does not subscribe to consonant strings. The data appeared to support Hypothesis 2 based on the group difference found. The last hypothesis was formulated to supplement the findings of the second hypothesis. Overall, the hypotheses were partially supported.

An overall interpretation of these results requires an explanation of differences in printing conventions. Because of the chief role of vowels in the Korean printing system, it is possible that Korean readers are not likely to decompose a word according to consonants and vowels, but instead process the syllabic unit more holistically. Korean consonants are dependent on vowels, as the Korean word for consonants literally suggests (i.e., dependent sound), whereas vowels themselves make sounds independently (i.e., independent sound). Following this principle,[12] the Korean writing system neither allows consonants to stand alone without vowels in the syllable

[12] This distinctive trait in the Korean script is well manifested in practical usage. For example, Koreans rarely invent shortened forms of text messages by using an array of consonants or vowels for the sake of efficiency, when text messaging, but they use contractions at the *syllable* level for a compound word or a phrase (e.g., "여친" for "여자 친구"). This is particularly notable given that Korean is an alphabetic language like English, in which the minimal grain size is a grapheme/phoneme, not a syllable. Due to the vowel centrality in Korean, practical use takes place at the syllable level, not the grapheme level. In other words, although the grain size is graphemes/phonemes, Korean graphemes do not allow for stand-alone usage as in English. To the contrary, English users use contractions to a more micro-level of segmentals by using consonants only (e.g., "*ppl*" for "*people,*" "*msg*" for "*message,*") or a mixture of consonants and vowels for phrasal contractions (e.g., "*lol*" for "*laugh out loud*").

nor permits consonant clusters except the case of ending digraphs in the word,[13] while some vowels can form syllables by themselves (e.g., 아, 어, 오, and우[14]). In contrast, English shows a drastic difference. English permits multiple consonants in the beginning, middle, and at the end of words as clusters in which each consonant has a unique sound value (e.g., *strong, machine, thoughts*, respectively). Even vowel strings are permissible in English (e.g., *early, liaison, beautiful, queue*).

Although this study did not directly test the specific role of consonants, the contribution of this paper to the current understanding of word reading is three-fold. First, the present findings expand the Consonant-Vowel Hypothesis (Hochmann et al., 2011) with new evidence of vowel importance in Korean. The importance of vowel letters seems to be hinged upon the greater vowel inventory of *Hangul* than that of consonants as well as the syllabic configuration. The present results suggest variability among alphabetic languages such that some scripts have a different role of segmentals depending on the syllabic structure and the vowel inventory in the given language.

Second, the results highlight L1 effects on L2 reading. Although L1 effects have been discussed, the angle from segmentals has hardly been taken. The acquired mechanism or strategy from L1 reading may come into play in the way that L2 words are processed, identified, or read. Given the unique characteristics of Korean, the findings suggest that L1 effects of native Korean readers are observable in L2 English word reading.

Last, the findings may point to language- and script-specific processing in word reading. These findings indirectly support the notion that the property of the L1 linguistic or writing system makes the minimal grapheme unit (i.e., consonants and vowels) behave differently in reading (Bonatti et al., 2005). The Korean readers' difficulties shown in reading consonant-only stimuli, compared to the English readers, may be attributable to the Korean script which has a vowel-centered system. This suggests that the robust role of consonants found in Roman script may not be fully applied to reading non-Roman alphabetic script.

4.1. Limitations and future directions

This study bears several limitations, which are closely related to future directions. First, this study showed that the Korean group read the stimuli slowly in all conditions, compared to the English group. It is still unclear whether the performance difference stemmed from the difference in L1 and L2 or the nature of oral reading wherein the Korean group's delay in articulation was observed due to their lack of opportunities to speak English in Korea. The use of visual recognition measures such as lexical decision tasks with or without a priming paradigm would address this issue better. In addition, task effects can also be examined with different types of tasks. Further studies that directly tackle the strength of linguistic skills in L1 and L2 and task effects would better explain the different pattern of the group-condition interaction effects found in accuracy and latency. Further research will also explain whether L2 learners' reading accuracy can be on a par with native speakers as proficiency improves, although reading latency tend to be slower than L1 readers. Second, the experimental study sample was only Koreans who read English as L2, along with native English speakers as a comparison group. An inclusion of other L1 groups, such as Chinese and Japanese, with different writing systems in follow-up studies would lead to a better understanding of L2 English word processing and L1 script effects. Relatedly, the inclusion of other L1 groups in a study will overcome the shortcoming of this study. Specifically, direct comparisons made in this study between the English group and the Korean group entail an inherent limitation for contrasts due to their L1 versus L2 status. Direct contrasts between L2 groups with a reference group of native English speakers will provide a better explanation of group differences. Third, although the vowel deletion affected consonants (i.e., the byproduct of the vowel deletion was consonants only), this study did not include consonant manipulations in the measure because consonant omission would result in illegible strings in the deletion manipulation due to a more relevance of the graphotactic rule to consonants than vowels (e.g., *cnsnnts* vs. *ooa* for *consonants; vwls* vs. *oe* for *vowels*). Further studies using different types of manipulations with consonants and vowels or the standard approach that has been used in the literature are in need. Fourth, more test items that allow for a subgroup analysis of items may be useful. An inclusion of more test items will enable us to run more in-depth or sub-group analyses to understand onset-body position effects and graphotactic frequency effects. Next, this study did not counterbalance the test items as a way to control for order effects due in part to the exploratory nature of the study as well as a comparatively short test (in which fatigue effects were not a concern). Follow-up studies using a counterbalanced design may validate the results of this study. Last, a comparison between children and adults may provide a better understanding of L2 English word processing. With multiple age bands, a developmental trajectory or age-related factors in the role of segmentals would be identified. Follow-up studies including more diverse L1 groups, a wider range of items, and more age groups may extend the present findings.

Acknowledgements

This study was supported by a research grant awarded to Sun-A Kim and Hye K. Pae (4-ZZEP) from The Hong Kong Polytechnic University as well as a research grant awarded to Hye K. Pae from the Arts, Humanities, and Social Sciences division of the University Research Council at the University of Cincinnati.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jneuroling.2018.01.004.

[13] Two consonants are allowed to appear at the end of syllable (e.g., 삶, 닭), but these diagraphs has only one sound value as a representative sound when they are sounded out. Therefore, they should be considered differently from consonant clusters found in English.

[14] The vowel notation per se is "ㅏ, ㅓ, ㅗ, and ㅜ" for the given syllables where the consonant "ㅇ" is used as a place holder.

Appendix

Lowercase	Uppercase	Vowel Omission		Random Omission		Vowel Omission Distractors		Random Omission Distractors	
		Baseword	Target	Baseword	Target	Base	Target*	Base	Target*
light	THOUGHT	travel	trvl	explain	expa	Write it down	Wrt t dwn	My new place	M ne plae
under	HEAD	strong/string†	strng	correct	corct	Come and get it	Cm nd gt t	Live and play	Liv an pla
important	STORY	behind	bhnd	science	scince	Now and then	Nw nd thn	I work too much	I wok to mch
children	UNTIL	common	cmmn	became	bcae	She likes to write	Sh lks t wrt	Mother means it	Mohr mens t
feet	SIDE	circle/crucial†	crcl	minutes	mintes	Behind the river	Bhnd th rvr	We came home	W cae hoe
across	CAREFULLY	cannot	cnnt	contain	cotan	Give it back	Gv t bck	It turned out well	I tured ot wel
during	ISLAND	problem	prblm	surface	surae	Write two sentences	Wrt tw sntncs	After the game	Ate th gae
happened	LANGUAGE	himself	hmslf	nothing	nohig	Study and learn	Stdy nd lrn	Change your clothes	Chage yor clohes
usually	SPECIAL	pattern	pttrn	machine	mchne	Turn the page	Trn th pg	Answer the phone	Aner te pone
hundred	SCHOOL	morning	mrnng	brought	broght	Tell the truth	Tll th trth	He called me	H called e

Note: † This word was considered correct as well.
*These two conditions were used as distractors in the experiment.

References

Abu-Rabia, S. (1997). Reading in Arabic orthography: The effect of vowels and context on reading accuracy of poor and skilled native Arabic readers in reading paragraphs, sentences, and isolated words. *Journal of Psycholinguistic Research, 26*, 465–482.

Akamatsu, N. (2003). The effects of first language orthographic features on second language reading in text. *Language Learning, 53*, 207–231.

Blythe, H. I., Johnson, R. L., Liversedge, S. P., & Rayner, K. (2014). Reading transposed text: Effects of transposed letter distance and consonant-vowel status on eye movements. *Attention, Perception, & Psychophysics, 76*, 2424–2440.

Bonatti, L. L., Pena, M., Nespor, M., & Mehler, J. (2005). Linguistic constraints on statistical computations: The role of consonants and vowels in continuous speech processing. *Psychological Science, 16*, 451–459.

Carreiras, M., & Price, C. J. (2008). Brain activation for consonants and vowels. *Cerebral Cortex, 18*, 1727–1735.

Carreiras, M., Vergara, M., & Perea, M. (2008). ERP correlates of transposed-letter priming effects: The role of vowels versus consonants. *Psychophysiology, 46*, 34–42.

Colombo, L., Zorzi, M., Cubelli, R., & Brivio, C. (2003). The status of consonants and vowels in phonological assembly: Testing the two-cycles model with Italian. *European Journal of Cognitive Psychology, 15*, 405–433.

Cutler, A., Sebastian-Galles, M., Soler-Vilageliu, O., & van Ooijen, B. (2000). Constraints of vowels and consonants on lexical selection: Cross-linguistic comparisons. *Memory & Cognition, 28*, 746–755.

Duñabeitia, J. A., & Carreiras, M. (2011). The relative position priming effect depends on whether letters are vowels or consonants. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*, 1143–1163.

Frost, R. (1995). Phonological computation and missing vowels: Mapping lexical involvement in reading. *Journal of Experimental Psychology, 21*, 398–408.

Fry, E. B. (2004). *1000 instant words: The most common words for teaching reading, writing, and spelling.* Westminster, CA: Teacher Created Resources.

Hamada, M., & Koda, K. (2008). Influence of first language orthographic experience on second language decoding and word learning. *Language Learning, 58*, 1–31.

Havy, M., Serres, J., & Nazzi, T. (2014). A consonant/vowel asymmetry in word-form processing: Evidence in childhood and in adulthood. *Language and Speech, 57*, 254–281.

Hochmann, J.-R., Benavides-Varela, S., Nespor, M., & Mehler, J. (2011). *Consonants and vowels: Different roles in early language acquisition*.

Ibrahim, R. (2013). Reading in Arabic: New evidence for the role of vowel signs. *Creative Education, 4*, 248–253.

Johnson, R. L., & Eisler, M. E. (2012). The importance of the first and last letter in words during sentence reading. *Acta Psychologica, 141*, 336–351.

Kumar, U., Das, T., Bapi, R. S., Padakannaya, P., Joshi, R. M., & Singh, N. C. (2010). Reading different orthographies: An fMRI study of phrase reading in Hindi-English bilinguals. *Reading and Writing, 23*, 239–255.

Lee, S. H., & Hwang, M. (2015). Word and nonword processing without meaning support in Korean-speaking children with and without hyperlexia. *Reading and Writing: An Interdisciplinary Journal, 28*, 217–238.

Lupker, S. J., Perea, M., & Davis, C. J. (2008). Transposed letter priming effects: Consonants, vowels and letter frequency. *Language & Cognitive Processes, 23*, 93–116.

Medler, D. A., & Binder, J. R. (2005). *MCWord: An on-line orthographic database of the English language.* http://www.neuro.mcw.edu/mcword/.

New, B., Araujo, V., & Nazzi, T. (2008). Differential processing of consonants and vowels in lexical access through reading. *Psychological Science, 19*, 1223–1227.

New, B., Ferrand, L., Pallier, C., & Brysbaert, M. (2006). Rexamining the word length effect in visual word recognition: New evidence from the English lexicon project. *Psychonomic Bulletin & Review, 13*, 45–52.

Pae, H. K. (2011). Is Korean a syllabic alphabet or an alphabetic syllabary? *Writing Systems Research, 3*(2), 103–115.

Pae, H.K. (in press). The Korean language, script Hangul, and word reading.In H.K. Pae (Ed.), Writing systems, reading processes, and cross-linguistic influences: Reflections from the Chinese, Japanese and Korean languages. Philadelphia, PA: John Benjamins.

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51*, 231–246.

Raaijmakers, J. G., Schrijnemakers, J. M. C., & Gremmen, F. (1999). How to deal with “the language-as-fixed-effect fallacy”: Common misconceptions and alternative solutions. *Journal of Memory and Language, 41*, 416–426.

Toro, J. M., Nespor, M., Mehler, J., & Bonatti, L. L. (2008). Finding words and rules in a speech stream: Functional differences between vowels and consonants. *Psychological Science, 19*, 137–144.

Van Ooijen, B. (1996). Vowel mutability and lexical selection in English: Evidence from a word reconstruction task. *Memory & Cognition, 24*, 573–583.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *Comprehensive test of phonological processing (CTOPP).* Austin, TX: Pro-ed.

Wang, M., Koda, K., & Perfetti, C. A. (2003). Alphabetic and nonalphabetic L1 effects in English word identification: A comparison of Korean and Chinese English L2 learners. *Cognition, 87*, 129–149.

Winskel, H., & Perea, M. (2013). Consonant/vowel asymmetries in letter position coding during normal reading: Evidence from parafoveal previews in Thai. *Journal of Cognitive Psychology, 25*, 119–130.

Wolf, M., & Denckla, M. B. (2005). *Rapid automatized naming and rapid alternating stimulus tests (RAN/RAS).* Austin, TX: Pro-ed.