The Role of Subsyllabic Units in the Visual Word Recognition of Korean Monosyllabic Words: A Masked Priming Study

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Native speakers of Korean have been shown to prefer a left-branching body-coda subsyllabic structure over a right branching onset-rime structure when processing monosyllabic words in written language. However, counter-arguments have been made that the highly transparent nature of Korean \textit{hangul} provides no preference for larger subsyllabic units beyond the phoneme. A masked priming lexical decision experiment was conducted to determine whether this subsyllabic preference occurs for orthographic processing in Korean. C\textsubscript{1}VC\textsubscript{2} structured monosyllabic target words preceded by one of four different types of primes at a short prime duration (50 ms): body (C\textsubscript{1}VC), rime (CVC\textsubscript{2}), identical (C\textsubscript{1}VC\textsubscript{2}), and non-match (C\textsubscript{2}VC\textsubscript{1}). Both identical and body prime conditions elicited a significant priming effect as consistent with the left-branching model in Korean. The present study provides converging evidence for a left-branching model of subsyllabic structure in visual word recognition in Korean using a masked priming paradigm.

\textbf{Keywords:} orthographic priming, syllable structure, subsyllabic unit, Korean


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Introduction

In an alphabetic writing system, such as English, learning to read involves mapping scripts (e.g., graphemes) to their corresponding sounds (e.g., phonemes). It is widely accepted that phonological awareness is critically related to this process (Gillon, 2004; Goswami & Bryant, 1990). For instance, a monosyllabic word in English (e.g., CAT /kæt/) can be parsed into its phonemes as onset (initial consonant or consonant cluster, C /k/), nucleus (vowel, A /æ/), and coda (terminal consonant or consonant cluster, T /t/). However, one-to-one mappings of individual graphemes to phonemes may not be efficient for word recognition (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995), raising the question of whether skilled reading requires segmentation over a larger set of units that are more predictive of the phonological features (e.g., Goswami, Ziegler, Dalton, & Schneider, 2003; Prinzmetal, Treiman, & Rho, 1986; Rey, Jacobs, Schmidt-Weigand, & Ziegler, 1998). Whereas some have argued that orthography may be segmented in syllabic units (e.g. Alvarez, Carreiras, & Perea, 2003; Prinzmetal et al., 1986), evidence for this has been equivocal (Brand, Rey, & Peereman, 2003; Schiller, 1998). However, evidence suggesting that subsyllabic orthographic units, such as the rime, are formed early in reading acquisition (Bowey, 1990; Goswami & Bryant, 1990; Trieman, 1985; Trieman et al., 1995) as a function of the bidirectional feedback between orthography and phonology (Harm & Seidenberg, 2004; Stone, Vanhoy & Van Orden, 1997; Seidenberg, Plaut, Petersen, McClelland, J. L., & McRae, 1994). As such, characteristics of the spoken language (e.g., stress or phonotactic patterns) should arguably provide the subsyllabic structure (Venezky, 1979; Chomsky & Halle, 1968) upon which orthographic units are most readily mapped (Yoon, Bolger, Kwon, & Perfetti, 2002). Because languages vary greatly in the segmental and suprasegmental features inherent to their phonological systems, it follows that the subsyllabic phonological structures beyond the phoneme may differ across languages.

There are two commonly referred subsyllabic units, body and rime, based on whether the nucleus is combined with the onset (i.e., body, CA /kæ/) or is combined with the coda (i.e., rime, AT /æt/). The existence of such units has been investigated using metalinguistic tasks of spoken and written
word processing (e.g., phonological awareness, decoding, analogical word reading, and sound-similarity judgments). Indeed, it has been suggested that adult speakers of English have an onset-rime parsing preference (C-VC) during subsyllabic analysis of speech rather than alternative structures (CV-C) (Bowey, 1990; Treiman, 1983, 1995; Treiman & Kessler, 1995). For instance, Treiman (1983) showed evidence that English native speakers tend to keep initial consonant cluster when they were asked to insert a rime, VC (æz), into a nonword with CCVC structure. The vast majority of participants (over 95%) decomposed a nonword *skef* into *sk + ef*, not into *s + kef*, when asked to insert the given VC, /æz/. Thus, the fact that the participants choose to preserve the initial consonant cluster (*sk* in *sk-æzef*) supports the hypothesis for an onset-rime structure in English. This pattern reflecting the rime as a cohesive unit in English was confirmed by studies with children (Goswami, 1993; Treiman, 1985, 1995; Treiman & Kessler, 1995), which suggests that the onset-rime structure is a preferential structure for subsyllabic analysis in English.

The emergence of the onset-rime bias in visual word processing has led some to argue for an orthographic rime hypothesis (Bowey, 1990) in which the orthotactic distribution of the frequency of rime units in word spellings is predictive of the bias in English reading. An alternative orthographic account has argued that, as a unit, the orthographic rime more reliably predicts pronunciation relative to individual graphemes (Treiman et al., 1995), thus preference for the orthographic rime unit may arise from the reliance on more successful coding schemes. While these factors may account for specific stimulus effects, the literature generally supports the notion that the orthographic effects are largely a result of mapping onto phonological properties of the language (Yoon, et al., 2002). Evidence for the onset-rime structure is largely supported by the statistical distribution of onset and coda in monosyllabic words in spoken English (Kessler & Treiman, 1997; Treiman & Kessler, 1995). There are greater phonotactic restrictions between the nucleus and coda than between the nucleus and onset. In other words, a vowel in a syllable is more strongly connected to the subsequent consonant than to the preceding consonant (i.e., C-VC).

While the onset-rime bias was once postulated to be universal (Fudge, 1969, 1987), language-specific preference has been supported by evidence
from several languages including Dutch (Geudens & Sandra, 2003), Chinese (Wang & Cheng, 2008), Japanese (e.g., Katada, 1990), Hebrew (Share & Blum, 2005) and Korean (e.g., Baek, 2014; Derwing, Yoon, & Cho, 1990; Yoon, et al., 2002; Yoon & Derwing, 2001). For example, Yoon and Derwing (2001) showed, in a sound similarity judgment task, that English speakers perceive CVC words that share rimes (-VC) are more similar than those that share bodies (CV-), whereas Korean speakers showed the opposite pattern of preferences. Korean native speakers judged the pair /mot/ and /mop/ as more similar than the pair /mot/ and /pot/. This difference between English and Korean in subsyllabic parsing in spoken language holds even when employing the same monosyllabic and bisyllabic stimuli, judging both within-language and across-language speakers, and for lexical and pseudoword stimuli (Yoon et al., 2002). These findings again suggest a left-branching syllable structure in Korean (i.e., body-coda) which contrasts to the English (i.e., right-branching) that emerge from the structures of the spoken language.

Although there have been many theories postulating both specific structural (e.g., left-branching or right-branching) and non-structural models of syllable structure, a further hybrid model for syllable structure has been proposed (Lee & Goldrick, 2008; also see Lee, 2006, for more extensive review about syllable structure models). According to this emergent perspective (Lee & Goldrick, 2008), a language user is sensitive not only to language specific primitive segments in CVC words, but also to the particular phonotactic probability of a given sequences (e.g., CV or VC). In their short-term memory experiments (CVC monosyllabic nonword recall), each group of Korean and English speakers were found to be sensitive not only to the phonotactic probability of particular sequences in each language but also to each language’s general regularities (onset-rime structure for English speakers and body-coda structure for Korean speakers). Lee (2006) provides the statistical evidence of native Koreans’ preference for the body unit in Korean, which supports the notion that onset-vowel sequences are in general more constrained and cohesive unit in general (beyond specific patterns) than the vowel-coda sequences in Korean. In sum, this emergent perspective suggests that subsyllabic unit preference can be determined not just by the statistical constraints of particular co-occurrences but also by
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Another alternative model proposed by Geudens and colleagues (Geudens & Sandra, 2003, Geudens, Sandra, & Martensen, 2005) postulates that there is no clear-cut subsyllabic unit preference based on their findings from Dutch speaking children. The distributional properties in the phonological lexicon in Dutch are similar to those in English. Geudens and Sandra (2003) investigated whether onsets and rimes affect Dutch speaking children’s explicit phonological awareness using an auditory segmentation task and a phoneme substitution task. The results across these experiments were not consistent with a typical subsyllabic structure. Namely, Dutch Children in this study found it harder to segment two-phoneme syllables into the onset-rime boundary (CV) than within the rime (VC). In their follow-up experiments, Geudens et al. (2005) showed an effect in a task highlighting phonological similarity between items sharing the rimes, but this effect disappeared in tasks without repetition of rime units. Thus, the researchers concluded that children’s sensitivity to rimes depends on phonological similarity relations and might not reflect a fixed perceived structure of spoken syllables.

The present study examines whether recognition of Korean monosyllabic words is facilitated by priming of the body unit relative to other subsyllabic units (e.g. rime) in a Korean monosyllabic. Korean (hangul) orthography can be characterized by its transparent letter-sound correspondence and its syllable packaging (kulja). Namely, graphemic units for 14 primary consonants and 10 primary vowels are regularly mapped to the corresponding sounds (i.e., transparently), which is different from some the relatively opaque grapheme-to-phoneme conversion in other alphabetic languages such as English (Taylor, 1980). In addition to its transparent alphabet, the graphemes in Korean are written as a square-shaped package corresponding to a single syllable, which contrasts with the linear arrangement of alphabetic characters in English words. For instance, a single syllable word in Korean, 감 /kam/ is comprised of initial consonant /k/, nucleus vowel /a/ and coda /m/. Note that English and Korean are similar as both are alphabetic writing systems, but are different in their characters and the arrangement of characters. Whereas English allows the
linear arrangement of its characters, consonant(s) and vowel(s) in Korean are packaged into six different types of syllable blocks (e.g., 강 /kang/, river). However, categorizing syllable types in Korean by phonological components yield the syllable blocks V, VC, CV, CVC, and CVVC. This is because there could be the null consonant (ㅇ) can be positioned in the initial consonant location (e.g., ㅇㅏ is pronounced /a/ as a single phoneme, but it is presented with two graphemes as ㅇ + ㅏ). Due to this written form of syllable blocks, it is difficult to imagine that Korean letters are processed as a serial position function. Thus, it has been argued that the subsyllabic preferences which are exhibited in spoken word tasks of Korean may not contribute to orthographic word recognition considering the transparent nature of the orthography and the saliency of the syllabic packaging (Yoon et al., 2002).

As mentioned earlier, several previous studies provided evidence that the body-coda is a preferred unit in Korean over rime, unlike English. However, this conclusion was mostly based on the results of phonological awareness tasks in Korean (Baek, 2014; Derwing, et al., 1990; Yoon & Derwing, 2001) or correlational studies with children (e.g., Kim, 2007). While Yoon et al. (2002) found body-coda preferences in visual word reading using an analogy task, the participants were young children beginning to acquire literacy and may be more heavily constrained by the influence of subsyllabic phonology. Similarly, Lee and Goldrick (2008) showed a body-coda preference using lists of written Korean words in two short-term memory tasks with young adults which likely reflect the effects of phonological rehearsal. Presently, the effects of subsyllabic processing in Korean have been demonstrated in meta-phonological tasks, in which explicit awareness is brought to bear on the behavioral response to words. However, it has been argued that such effects may be task induced and require post-lexical stimulus decision-making and thus do not reflect obligatory activation in online word processing (Massaro & Jesse, 2005). There have been few if any studies that have examined how these subsyllabic units in orthography affect skilled, automatic visual word processing in Korean. Thus, we attempt to test whether the body (or other subsyllabic) unit influences on-line visual word recognition using an unconscious orthographic priming lexical decision task with Korean
monosyllabic words (CVC).

We began this investigation with the following research questions regarding the effect of subsyllabic units on the processing of Korean monosyllabic words: 1) Is the processing of Korean monosyllabic words susceptible to the effects subsyllabic priming or are the syllable packages \( (kulja) \) processed as holistic forms? 2) If a Korean visual word processing is influenced by subsyllabic units, is there a preference for the body-coda relative to onset-rime structure or is the effect of graphemic constituents additive (increases with the number of shared graphemes)? In order to examine the role of Korean syllables’ visually unique structure, the present study will use a masked priming paradigm, and will vary the primes as each subsyllabic unit (e.g., body or rime). We selected a short prime duration (50 ms) for the masked priming paradigm. This prime duration was successfully used in a recent study examining the masked onset priming effect using a nonword naming task in Korean (Witzel, Witzel, & Choi, 2013). In addition, previous studies using short prime durations (from 14 ms to 57 ms) in the masked priming lexical decision tasks found that orthographic redundancy between prime and target plays an independent role beyond that of the phonological overlap between prime and target (e.g., Ferrand & Grainger, 1994; Perfetti & Bell, 1991).

To summarize, we hypothesize that the body prime will induce a greater priming effect than the rime prime based on the previous studies (Lee, 2006; Lee & Goldrick, 2008; Yoon & Derwing, 2001). However, the uniqueness of the written form of a Korean syllable (i.e., square arrangement) compared to the linear arrangement of letters in English enable us to predict a different pattern of priming effects. Namely, an alternative hypothesis is that the body-coda parsing will be not preferred in rapid orthographic processing. If it is true, there will be no difference in the priming effects between the body and the rime primes.

### Method

This experiment was designed to examine whether subsyllabic structures play a significant role in the recognition of monosyllabic words in Korean
using a masked priming lexical decision. Therefore, the prime conditions were $C_1VC_2$ structured monosyllable that overlapped with the target in body ($C_1VC$), rime ($CVC_2$), identical ($C_1VC_2$) or non-matching ($C_2VC_1$) as control.

**Participants**

Thirty-six native Korean speakers (20 females and 16 males) in a state university in the United States participated in this experiment for monetary compensation. All of the participants had lived in Korean until they graduated a college (mean age = 30, $SD = 2.1$). All had normal or corrected-to-normal vision and did not suffer from any learning or reading problem. They were paid for their participation.

**Stimuli**

Six hundred forty prime and target pairs (4 prime conditions $\times$ 160 targets) were constructed. The four prime conditions included $C_1VC_2$ structured monosyllable that overlapped with the target (e.g., 감: 강), rime (CVC:악), identical ($C_1VC_2$: 감) or non-matching ($C_2VC_1$: 막). The non-matching condition served as a control. The log-transformed syllable frequency of the body ($M = 3.35$, $SD = .94$), rime ($M = 3.42$, $SD = .92$), identical ($M = 3.35$, $SD = .73$), and non-matching ($M= 2.69$, $SD = 1.12$) was not explicitly matched (Modern Korean Frequency Database 2, 2005).

In order to minimize the influence of visual overlap between primes and targets on the priming effect, the font sizes and types were manipulated. The font sizes for the primes and the targets were 17 points and 28 points, respectively. Primes and targets were presented in the different font types (i.e., Batang and Gulim fonts, respectively). Stimulus pairs were split into four lists within the Latin Square design. Each participants was presented all target words only once in one of the four prime conditions, with 40 items from each condition.
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Procedure

Participants were randomly assigned to perform the lexical decision task at one of the four lists individually in front of a computer screen in a quiet room. Before starting, they received oral instructions on how to perform the task. Participants were informed that they would see a series of letter strings on the screen, one string at a time, and they were asked to respond as quickly and as accurately as possible by pressing a key to indicate whether the letter string was a Korean word or not. The presence of masked primes was not mentioned at this time. Prior to an experimental session, participants were given 10 trials for practice.

A masked priming lexical decision task procedure similar to that used by Forster and Davis (1984) was employed. For each trial, a forward mask \(^1\) appeared in the center of the screen for 500 ms, followed by one of the four prime stimuli based on condition (e.g., body, rime, identical, or control), which was displayed for 50 ms, and then followed by a target (e.g., C\(_1\)VC\(_2\)). All of target words were C\(_1\)VC\(_2\) structured monosyllables (see an example list of stimuli in Table 1). Four different prime conditions were constructed: 1) body unit (C\(_1\)V), 2) rime unit (VC\(_2\)), 3) identical word (C\(_1\)VC\(_2\)), and 4) non-match (C\(_2\)VC\(_1\)). The non-match primes (NM) served

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1 The mask used in this study was designed for Korean words which based on its non-linear syllable packages (e.g., Kim, Wang, & Taft, 2015).

Table 1. An example list of stimuli in experiment 2

<table>
<thead>
<tr>
<th>Prime</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body (C(_1)VC)</td>
<td>강 &quot;kang&quot;</td>
</tr>
<tr>
<td>Rime (CVC(_2))</td>
<td>감 &quot;am&quot;</td>
</tr>
<tr>
<td>Identical (C(_1)VC(_2))</td>
<td>감 &quot;kam&quot;</td>
</tr>
<tr>
<td>Non-match (C(_2)VC(_1))</td>
<td>막 &quot;mak&quot;</td>
</tr>
</tbody>
</table>
as the baseline, which were generated by switching the onset (C₁) and coda (C₂). The target remained on the screen for 1500 ms or until the participant responded. Response time was measured from the onset of the target to the time point when the response was made. Primes and targets were displayed in black on a white background. The experiment was run on a desktop computer, using *E-Prime software 2.0* (Schneider, Eschman, & Zuccolotto, 2002) with a random trial presentation. Responses were given via keyboard (“z” key for the “YES” response, “m” key for the “NO” response). The total duration of the experiment was about 12 minutes for each participant.

**Results**

Participants were unaware of the mask between prime and target based on a post-experiment interview. Incorrect responses were removed for RT analysis (2.3%). RTs faster than 200 ms and slower than 1500 ms were also excluded (0.5%). The remaining RTs were inversely transformed (i.e., -1000/RT) to remove any skew in the data. In addition, a log transformation was applied to the two frequencies (syllable frequency and word frequency) to reduce the skewness in the distribution of the data and the measures.

RTs were analyzed using linear-mixed effects (LME) modeling (Baayen, Davidson, & Bates, 2008) in R (R Core Team, 2013), with the *lme4* (Bates, 2013) package.

### Table 2. Mean of reaction times and standard errors (msec), and error rates (%)

<table>
<thead>
<tr>
<th>Condition</th>
<th>RT</th>
<th>Error (%)</th>
<th>Priming Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body (C₁VC)</td>
<td>568 (22)</td>
<td>2.7</td>
<td>-10</td>
</tr>
<tr>
<td>Rime (CVC₂)</td>
<td>581 (23)</td>
<td>2.6</td>
<td>3</td>
</tr>
<tr>
<td>Identical (C₁VC₂)</td>
<td>559 (22)</td>
<td>1.3</td>
<td>-19</td>
</tr>
<tr>
<td>Non-match (C₂VC₁)</td>
<td>578 (22)</td>
<td>2.5</td>
<td>---</td>
</tr>
</tbody>
</table>

*Note.* The Non-match condition is the baseline condition.
Maechler, Bolker, & Walker, 2013) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2013) packages. Prime condition (Con), syllable frequency (SF), and word frequency (WF) were entered as fixed effects. Subjects and items were entered as crossed-random factors where the stimuli list (List) served as the intercept for subjects and items. Interaction terms removed one at a time until we obtained the model with the best goodness-of-fit using Chi-square test. The analysis of variance (ANOVA) approach to linear mixed effect model analysis of the data in Table 2 showed a significant main effect of prime condition \[ F (3, 5384.5) = 14.888, p < .0001 \] and syllable frequency \[ F (1, 157.5) = 50.974, p < .0001 \], respectively. For the prime condition, the RT in the identical condition was significantly faster \( (b = -0.007, SE = .001, t = 5.897, p < .0001) \) than that in the baseline condition (559 ms vs. 578 ms). More importantly, the RT in the body condition was significantly faster \( (b = -0.003, SE = .001, t = 2.799, p < .001) \) than that in the baseline (568 ms vs. 578 ms), whereas the difference in RT between the rime condition and the baseline (~3 ms) did not significantly differ. Importantly, the RT in the body condition was significantly faster \( (b = -0.003, SE = .001, t = 2.261, p = .024) \) than that in the rime condition (Table 2). As error rates were very low (below 3%), no statistical differences across the priming conditions were found \( (F < 1) \).

With respect to the effect of the subsyllabic unit in Korean monosyllabic words, the result showed that the body unit, but not the rime unit played a significant role in orthographic priming after the syllable and word frequency of the targets were considered. The fact that the body and rime units, even in the kulja packages would have the same general degree of orthographic feature overlap lends support for the notion of preferred direction of subsyllabic unit processing, body-coda, in Korean visual word processing.

**Discussion**

The present study provided evidence about subsyllabic processing in a Korean monosyllabic word recognition using masked priming paradigm. The significant priming effect of the body prime condition in the present study, but no priming effect of rime primes supported the left-branching
structural preference for online visual word processing of Korean which has typically been tested in meta-linguistic tasks. These findings suggest that the structural unit is not simply an effect of post-lexical processing, but is present during lexical access.

From a theoretical perspective, the evidence presented in the current study is consistent with a set of findings in Korean word processing (Derwing, et al., 1990; Lee, 2006; Lee & Goldrick, 2008; Yoon et al., 2002) dispelling the notion of the rime as a universal (Fudge, 1969). The notion that particular languages such as Dutch may have no preferential subsyllabic structure (Guedens & Sandra, 2003) has been offered in the case of Korean as well (Yoon et al., 2002) given the lack of lexical stress in the phonology and the relative transparency in the orthography, both lexical stress and weak orthographic transparency have been offered as explanations for the rime unit preference in English.

The analysis of Lee and Goldrick (2008) provides an alternative frame through which we can view the results of rime priming in Korean processing. Their emergentist perspective suggests that for particular structures, the frequency of the specific phonological patterns may be sufficiently high as to promote subsyllabic priming in the rime case. It is likely, as suggested for rimes in English (Bowey, 1990), that the orthotactics may play a particular role in orthographic rime formation in Korean as well. Unfortunately, we did not systematically invoke the use of subsyllabic units with varying distributions of co-occurrence to test this hypothesis. However, there was a significant effect for syllable frequency suggesting that we cannot rule out the impact of statistical frequency of orthography at the syllable level.

A fundamental argument has been that deeper alphabetic orthographies with less consistent grapheme-phoneme mappings, utilize larger grain size units such as the onset-rime that provide more information about pronunciation (Treiman et al., 1995; Goswami, 1999; Wimmer & Goswami, 1994). In contrast, more shallow alphabetic orthographies are suggested to rely on smaller grapheme-phoneme units (Goswami, Porpodas, & Wheelwright, 1997; Goswami, Leevers, Pressley, & Weelwright, 1998; Goswami et al., 2003). Findings from Yoon et al. (2002) suggest that pre-literate speakers of Korean, a very shallow alphabetic script, show the body-
coda effect on scale with the English onset-rime effects. However, some have argued that such effects occur beyond lexical access and are observed largely in meta-phonological tasks in which post-lexical processing of grapho-phonemic relationships are demanded of the task (Baek, 2014; Yoon & Derwing, 2001). The findings from our lexical decision task belie the argument that such effects are due to post-lexical, meta-phonological processing suggesting that these representations are available prior to lexical access. Such findings are consistent with models suggesting that orthographic processing may be shaped by feedback from phonological structures.

The results reported here lend further support to the notion of intermediate functional orthographic units that are at both sublexical and subsyllabic level (Bowey, 1990; Treiman, 1985). There has been much debate as to whether such units (such as an orthographic syllable effect) arise as a function of orthotactics (Bowey, 1990; Seidenberg & McClelland, 1989) or interactive phonological processing (Rapp, 1992; Taft, 1979; Alvarez et al., 2004; Treiman et al., 1995). Findings regarding orthographic syllable processing have been generally equivocal both within and between languages (see Schiller, 1998; Doignon & Zagar, 2005; Brand et al., 2003). However, findings regarding subsyllabic processing in alphabetic processing in reading tasks have been supported using the onset-rime in English (e.g., Treiman et al., 1995) and the body-coda in Korean (e.g., Yoon et al., 2002). The findings reported here further suggest that such units are involved in pre-lexical orthographic processing in a non-linear transparent writing system (where bigram frequencies may arguably drive such effects).

In conclusion, these findings are the first demonstration of subsyllabic priming in rapid visual word processing in Korean. They demonstrate, for one, that the priming effects in the specific arrangement of the Korean hangul syllable packages, the kulja, are susceptible to morpho-lexemic information, maybe even more so than English. Overall, we conclude that the left-branching structure in Korean word processing is a preferred unit of analysis beyond meta-phonological processing and is engaged in rapid visual word processing. Probing the nature of these effects with respect to the specific phonotactic and orthotactic properties will be imperative to a complete understanding of how these structures emerge.
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