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EFFECTS OF PHONOTACTIC PROBABILITIES ON SYLLABLE STRUCTURE[1]

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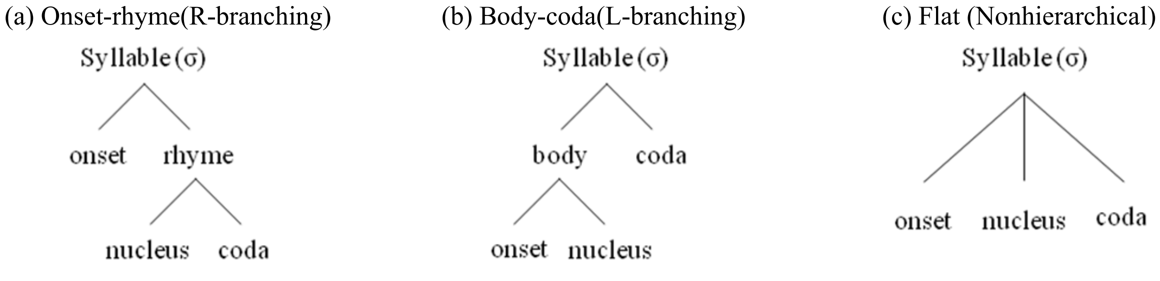
Korean is known for its onset-body structure or left-branching syllable structure. Experimental findings have shown that native speakers of Korean are better at processing the onset and nucleus of a CVC syllable as a constituent than the nucleus and coda, while English speakers prefer the nucleus and coda, the rhyme. This study investigates the nature of the different mental representations of a syllable across the two languages by testing if the processing rate of reduplicating CV and VC sequences is affected by phonotactic probabilities of the sequences. The effects of phonotactic probabilities are discussed at two levels. At the local level, a frequently occurring phoneme sequence in either of the two languages is predicted to lead to fast processing either at the CV or VC position because native speakers of each language are sensitive to the likelihood of having a particular sequence in their language. At the global level, the overall branching advantage of each language found in the literature is predicted to be the consequence of native speakers' sensitivity to the overall statistical distribution of phonotactic constraints put on the CV domain and the VC domain in their respective language.

1. INTRODUCTION. The onset-rhyme structure of a syllable has been traditionally proposed to be a phonological universal (Fudge 1987; Selkirk 1982). This syllable structure is also known as right-branching (R-branching), because the direction of the sub-branching hierarchy takes place in the right portion of the syllable, as illustrated in figure 1a. The claim for the universal R-branching structure is based on cross-linguistic observations where the rhyme, i.e., a subunit of the syllable composed of its nucleus and coda, plays a pivotal role in various phonological processes, such as stress-assignment rules, rhyming conventions in poetry, or phonotactic constraints (Ewen and Hulst 2000). Also in compensatory lengthening of historical sound changes of languages such as English and Ancient Greek, for example, a vowel is lengthened when a coda consonant of a closed syllable is lost, but not when an onset consonant is lost. This is because each nucleus and coda, but not the onset, comprises one moraic count, and the two moras in the rhyme are preserved after a segment in it has been deleted (Hayes 1989). Therefore, the rhyme is considered as a domain where moras exist.

FIGURE 1. Illustration of the three possible subsyllabic structures (Kim and Lee 2011)


(a) Onset-rhyme(R-branching)
(b) Body-coda(L-branching)
(c) Flat (Nonhierarchical)

Studies of Korean syllable structure, however, have been one of the strongest pieces of counterevidence for the claim that R-branching is universal. At an early stage of Korean syllable-structure study (Chun 1980; Kim 1984; Lee 2007), phonological processes observed in language-internal data have

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been suggested as supporting evidence for the L-branching structure (see figure 1b), also referred to as the body-coda structure. The L-branching structure posits a different subunit of a syllable, namely the body, composed of its onset and nucleus. As in (1) below, reduplication of the body unit is a common pattern found in mimetic words and onomatopoeia in Korean. The derived mimetic word /tu.tuŋ.sil/ in (1) has a form that reduplicates the onset and nucleus of the first syllable in the root word tuŋ.sil, intensifying the meaning of the root word. Other examples of body reduplication in onomatopoeia and mimesis include /ʧik/ - /ʧi.ʧik/ ‘sound of tearing’, /t’a.lɨŋ/ - /t’a.lɨ.lɨŋ/ ‘sound of bike bell’ (Berg and Koops 2010). Other types of language-internal observations also have been used to support the L-branching structure of the Korean syllable. Chun (1980) suggested that it is the body unit that speakers are more likely to retain when mispronunciation of a CVC syllable occurs in real speech data, as in (2), and so errors are more likely to occur outside the body.

(1) Reduplication in mimetic words and onomatopoeias (Kim 1984)
/tuŋ.sil/ → / tu.tuŋ.sil/
‘buoyantly’ ‘more buoyantly’
: reduplication of onset + nucleus in the first syllables (supporting L-branching)

(2) Mispronunciation (Chun 1980)
/pok.hap.cək/ → /pop.hak.cək/
‘complex’
: miscombination of onset + nucleus as a unit and coda as another (supporting L-branching)

However, there are also phonological processes where the rhyme plays a pivotal role, as in (3) and (4).

(3) Reduplication of mimetic words (Kim and Lee 2011)
/ul.tʰuŋ/→ /ul.tʰuŋ.pul.tʰuŋ/
‘bumpy’ ‘more bumpy’
: reduplication of nucleus + coda in the first syllable (supporting R-branching)

(4) Short-hand from computer-mediated communication (Lee 2007)
/t’ɛ.mun.ɛ/ → /t’ɛm.ɛ/
‘because’
: deletion of nucleus + coda in the second syllable (supporting R-branching)

By providing examples from the young generation’s speech, where the onset alone or the rhyme portion is deleted, Lee (2007) pointed out that the analysis on language-internal data had not been comprehensive enough to draw a conclusion. Depending on the kind of data, it can be either the rhyme or the body that is used as a key constituent of a Korean syllable. Because of conflicting evidence, some studies (Berg and Koops 2010; Kim 1984; Shin 2000) have alternatively suggested a representation of the Korean syllable with no inherently fixed subsyllabic hierarchy, the flat structure (see figure 1c above). What the coexistence of evidence for both R- and L-branching preference shows is that neither R- nor L-branching conclusively describes the mental representation of native speakers, if we limit the range of our observation to the language-internal data (see Lee 2007 and Kim and Lee 2011 for more discussion of this data discrepancy).

2. THEORETICAL BACKGROUND. Another approach to this issue is to look at the language-behavioral aspect with experimental methods in an effort to reveal psycholinguistic patterns of how the underlying subsyllabic structure representation is realized in speech processing. Various behavioral patterns of Korean and English native speakers have been compared in the literature, which consistently revealed that Korean native speakers perform L-branching processing better, while English native speakers do R-branching better. Yoon and Derwing (2001) showed the opposite preferences of the two languages clearly in a series of experiments, tasks of which include sound-similarity judgment, unit reduplication, concept formation, and recalling. In their unit-reduplication test, 40 Korean native children aged from 4 to 7 were tested to corroborate the L-branching preference that they found in a series of three other experiments with adult participants. The children heard 48 monosyllabic Korean words and verbally produced two types of reduplicated forms. All the materials were constructed on a C_1VC_2 closed-syllable structure, composed of a consonant at the onset, a monophthong vowel at the nucleus, and another different consonant at the coda position. In the L-branching task, participants were directed to derive a form of $C_1V.C_1VC_2$ from the given C_1VC_2 structure. That is, the body unit, i.e., the C_1V portion, was copied from the word and was attached to the left of the original syllable. For example, if /pam/ 'chestnut' was heard, the result was /pa.pam/. In the R-branching task, on the other hand, the given C_1VC_2 syllable became $C_1VC_2.VC_2$, where the rhyme unit, i.e., the VC_2 part, was copied and attached to the right of the original syllable. For example, /pam/ becomes /pam.am/. Accuracy rates indicated that participants performed significantly better in the L-branching than in the R-branching tasks. Also, other experimental studies using literacy skills (Y. Kim 2007), mispronunciation (M. Kim 2007), and short-term memory (Lee and Goldrick 2008) revealed the same pattern of L-branching preference of Korean native speakers.

Despite the data discrepancy, there has been another approach to the language-internal data with more statistical precision. Berg and Koops (2010) calculated phonotactic probabilities of all CV and VC sequences from 3,001 Korean monosyllabic words (using Fisher's Exact test) and found that there is no significant difference between the phonotactic constraints of CV sequence (L-branching) and VC sequence (R-branching). Rather than interpreting this result as insensitivity to a particular syllable structure, they proposed that there is interplay between language-specific L-branching and language-universal R-branching effects that leads Korean syllable structure to neutrality.

It is further argued by Berg and Koops that the L-branching effect of Korean syntax is expanded by a "cross-level harmony constraint" (Berg and Koops, 2010:46) to a different analytical unit of phonology, that is, syllable structure.[2] In addition, they assume the R-branching effect as a phonetic universal based on Marslen-Wilson and Tyler's (1980) cohort theory and Dell and colleagues' (1993) work that showed how the cohort is realized within the scope of the syllable onto English phonotactic constraints. The cohort model of speech perception posits that as the speech sound unfolds from the left to the right in a phoneme sequence, the number of candidates for successful word recognition decreases. This means that the hearer's certainty or the word's predictability increases as the speech signal unfolds. Likewise, it is hypothesized in the domain of the syllable that VC portion, which appears later than the CV, has higher predictability than the CV portion. Also, a hearer can profit less from phonotactic constraints at the beginning of a word (in the body domain) than towards the end of it (in the rhyme domain). Thus, it is expected that cross-linguistically, phonotactic constraints occur more at the end of the syllable. Although more empirical evidence is needed for the assumptions of Berg and Koops (2010) regarding each branching effect, it is a fair starting point to consider the overall pattern of phonotactic probabilities in the lexicon as one of the most reliable and comprehensive statistical factors of the language-internal aspect of subsyllabic structure.

Lee and Goldrick (2008) were the first to reveal the relation between the language-internal statistical distribution and behavioral patterns observed in an experimental method. Their short-term memory (STM) task tested whether CV sequences or VC sequences are recalled and repeated more accurately, after hearing stimuli composed of 6 CVC nonsense syllables. Before the STM test, phonotactic probabilities of Korean and English syllables were calculated with 939 Korean monosyllabic CVC words and 2,521 English monomorphemic CVC words (measured with r_ϕ correlation coefficient). It was found that Korean words have significantly higher correlation strengths in CV sequences than in VC sequences (unlike Berg and Koops 2010), while English words have significantly higher correlation strengths in VC sequences than in CV sequences. It is possible that the different results of the two studies are due to either the different criteria they used when sampling the lexical items or the use of different statistical models between the two studies (Fisher's Exact test versus r_ϕ correlation coefficient), though this issue is outside the scope of the present study.

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[2] Although it is a radical argument, "cross-level harmony'" refers to the idea that the internal structures of each language tend to be patterned consistently across different analytical levels, e.g., syntax and phonology, for the interest of easiness to "learn and use when the same decisions that are required at different analytical levels are taken once for all" (Berg and Koops 2010).

However, what is notable in Lee and Goldrick’s (2008) finding is that the memory processing of Korean and English speakers correlated with the phonotactic probabilities they calculated. When the participants reproduced the auditory stimuli, both Korean and English speakers were sensitive to the strength of correlation within CV and VC sequences in their own languages. Specifically, when phonotactic probabilities were varied between the CV sequence and VC sequence within a single CVC syllable (e.g., CV has high probability and VC has low probability, or vice versa), participants from both languages recalled the sequence that had higher probability within their respective languages more accurately than the sequence with lower probability. That is, when the CV sequence was highly correlated in their respective language, errors occurred more frequently on the coda consonant. Conversely, for the stimuli that contained highly correlated VC sequences, more errors occurred on the onset consonant for both languages. When phonotactic probabilities were controlled to be similar, however, the different preferences of the two languages emerged. Korean speakers recalled CV sequences significantly better than VC sequences while English speakers recalled VC sequences better. With these findings, Lee and Goldrick concluded, “Language users are not only sensitive to phonotactic probabilities that govern particular sequences of segments but also to the general statistical skew existing in the lexicon (2008:162). They thus argued that the mental representation of the syllable structure is not hierarchical, that is, neither L-nor R-branching, but is nonhierarchical, and that it is statistical information on the distributional patterns of phoneme sequences that affects which subunit (whether body or rhyme) is stored in and recalled from STM with more ease.

The aim of the current study is not only to replicate the overall behavioral difference between Korean and English speakers, but also to investigate how far the effect of phonotactic probabilities can reach in speakers’ linguistic processing of syllables. Considering that repeating syllables is only a limited domain of language processing, it is still questionable whether the effect can survive in a more complicated processing of subsyllabic units. Therefore, this study adopts a modified version of Yoon and Derwing’s (2001) unit reduplication task to test two different effects of phonotactic probabilities. First, the sensitivity to varied probabilities in Lee and Goldrick 2008 can be interpreted as a local effect of phonotactic probabilities because it shows that memory processing is affected by the phonotactic probabilities contained in a particular CVC syllable. Second, the sensitivity to controlled probabilities will be referred to as a global effect because it shows speakers are also sensitive to the overall statistical information of their native language. If the effect of phonotactic probabilities is strong enough, then both the local and global effects will appear in the unit reduplication test as well. That is, when the phonotactic probabilities are varied within a syllable, the sequence with a higher probability, whether it is L- or R-branching, will trigger faster processing regardless of the speaker group. On the other hand, when the phonotactic probabilities of CV and VC sequences are controlled, Korean speakers will reduplicate L-branching substructure better than R-branching, while English speakers will do better with R-branching.

3. METHOD. Although the logic of this experiment was borrowed from Yoon and Derwing’s (2001) unit-reduplication test, the current experiment was designed to be more difficult in multiple ways to obtain a sufficient number of errors from adult participants (as opposed to children) and to observe differences in reaction times (RTs). First, nonsense-word stimuli were used as often as possible to prevent the effects of frequency and familiarity that are associated with any particular real lexical item. Another difference is that participants were given not only monosyllabic stimuli to create bisyllabic responses (Test 1), but also bisyllabic stimuli, to which 4-syllable responses are made (Test 2). For example, a nonsense word stimulus /ʧʰip.ʧʌm/ in the Korean set becomes /ʧʰi.ʧʰip.ʧʌ.ʧʌm/ or /ʧʰip.ip.ʧʌm.ʌm/, upon the appearance of an L- or R-branching prompt, respectively. Also, participants were asked to keep switching between L- and R-branching processing in each experiment session, rather than consistently reproducing one of the two branching tasks in each session, which was the case in the original version.

3.1 PARTICIPANTS. For the Korean participant group (KOR group), 24 native speakers of Korean (20 females and 4 males, aged from 19 to 22) were recruited from a group of Korean nursing college students from a two-month exchange student program at the University of Hawai‘i. They were paid for their participation. None of them had lived longer than 6 months in English-speaking countries at the time of participation. The English participant group (ENG group), 25 native speakers of English (18 females and 7 males, aged from 19 to 26), were recruited from undergraduate students at the University of Hawai‘i. None of them had had any knowledge of or exposure to Korean at the time of participation. They were compensated with course credit. None of the 49 participants in either group reported that they had been diagnosed with any sort of language impairment or hearing problems.

3.2 MATERIALS. Two sets of stimuli were created for the English group and the Korean group, respectively. In each set, 40 C1VC2 syllables were created using segments in the respective language. With regard to phonotactic probabilities, the 40 syllables were contrasted under four conditions, based on Lee and Goldrick (2008)’s calculation of r_{ϕ} correlation coefficients in CV sequences and VC sequences. The four conditions are compared in table 1, where “H” stands for a sequence with a strong correlation, and “L” for a weakly correlated sequence in the leftmost column (see Appendix for the full set of stimuli).

TABLE 1. Four types of nonsense word syllables

Phonotactic probability type	Strength of correlation in CV	Strength of correlation in VC	Branching bias	Example stimuli	
				Korean	English
HH	High	High	Neutral	ʧʰip	ðæp
LL	Low	Low	Neutral	pʰʌt	gʊl
HL	High	Low	CV > VC	ʧʌk	maθ
LH	Low	High	CV < VC	sɨŋ	tɪg

Lee and Goldrick (2008) provided the full stimuli sets of CV and VC sequences of the Korean and English syllables that they used in the STM test. The strengths of correlation of Korean syllables were calculated into r_{ϕ} correlation coefficients by Lee and Goldrick, using 939 monosyllabic real words appearing in a corpus database, provided at the National Institute of the Korean Language (www.korean.go.kr). Phonotactic probabilities of English syllables were also obtained by Lee and Goldrick from 2,521 monomorphemic CVC words in the CELEX database consisting of English phonological word forms. In these analyses, homophones were treated as separate items and type frequencies of all items were assessed. To calculate the strength of correlation between two adjacent segments, they used the r_{ϕ} statistic, instead of the standard form of Pearson’s correlation coefficients (r value), treating the data as binary. This was because what they measured was, for example, “For the sequence /et/, to what extent does the presence of /e/ correlate with the presence of /t/?” (Lee and Goldrick 2008:158). The 40 syllables in the current experiment were created by combining the CV sequences and VC sequences into C_1VC_2 syllables, varying the strengths of correlation within the C_1V and VC_2 units. Each of the four phonotactic probability types (HH, LL, HL, and LH) contained 10 syllables, respectively.

Among the 40 syllables in each language, 20 appeared in Test 1 as the monosyllabic stimuli. These 20 syllables reappeared in Test 2 as the first syllable of the bisyllabic stimuli. The other 20 syllables were used as the second syllable of the bisyllabic stimuli in Test 2. All of the 20 bisyllabic stimuli in Test 2 were nonsense words in Korean and English, respectively. However, the 20 syllables used in Test 1 included two monosyllabic real words in the English set, /ʤæb/ as in *jab* and /zɪp/ as in *zip*. The Korean set had 8 real words, /ʧʌk/ ‘*enemy*’, /sɨŋ/ ‘*victory*’, /nɨp/ ‘*swamp*’, /kɨm/ ‘*gold*’, /pʰul/ ‘*grass*’, /ʧin/ ‘*camp*’ or ‘*sap*’, /pon/ ‘*model*’ or ‘*sample*’.

Reappearance of the 20 syllables and the inclusion of the real words were partly due to the restricted number of CV and VC sequences to combine. On top of that, there are reasons specific to the Korean lexicon. First, it is more difficult to find nonsense CVC syllables in Korean than in English, considering the massive neutralization of coda consonants in Korean, which will be discussed in more detail below as a phonemic constraint of the stimuli. Another reason is that Korean lexicon includes many words that are composed of only one Sino-Korean character, which corresponds to one syllable. These restrictions may have been the case for Lee and Goldrick (2008) as well, who noted that they were unable to include the

Korean HH condition (CV+VC condition in their own term) in the experiment, due to the structure of Korean lexicon. Most important of all reasons, however, the occurrences of each CV and VC sequence also had to be controlled to prevent priming effects as much as possible. Since the reduplication task required the participants not only to retain the whole syllable in memory but also to copy just the subsyllabic unit (either the body or the rhyme), it was as important to control the number of subsyllabic sequences as the number of both CVC syllables. For this reason, the 40 C_1VC_2 syllables in each language set were composed of 20 CV sequences and 20 VC sequences, and all of these 40 sequences (20 CVs and 20 VCs) were controlled to appear exactly three times throughout the whole experiment.

The unit reduplication task itself is branching-neutral with regard to the phonological structure of the output. Both the L- and R-branching tasks yield the identical sequence of CVCVC from a CVC input. To maintain neutrality, potential factors of processing interference were prevented as much as possible. For example, phonemes that may cause misanalysis, such as glides, which may be part of either the consonant or the vowel, were excluded from the stimuli. Several phonemic constraints like this were put on the stimuli syllables, excluding factors that might affect the weight of a particular subunit of the syllable. The constraints were uniformly applied to both languages.

As a phonemic constraint on consonants, only single consonants were used. Tense obstruents of the three-way distinction of Korean voiceless obstruents, also known as double consonants, were excluded. Because these stops are phonemically and orthographically treated as geminates, they might affect the weight of a particular subunit of the syllable. For the same reason, the English set did not utilize consonant clusters. Another constraint was to exclude coda consonants whose surface forms are impossible to distinguish in perception. For example, /t, t^{h}, t’, s, s’, ʧ, ʧ^{h}, ʧ’, h/ in Korean are all neutralized as the same surface form of the unreleased alveolar stop [t̚] in the coda (Berg and Koops 2010; Shin 2000). In English, by contrast, obstruents in codas are not phonetically neutralized as massively as in Korean: their phonetic realizations of coda obstruents can be distinguished from one another. Therefore, the English set had more obstruents in the coda, including those distinguished by voicing, than the Korean set.

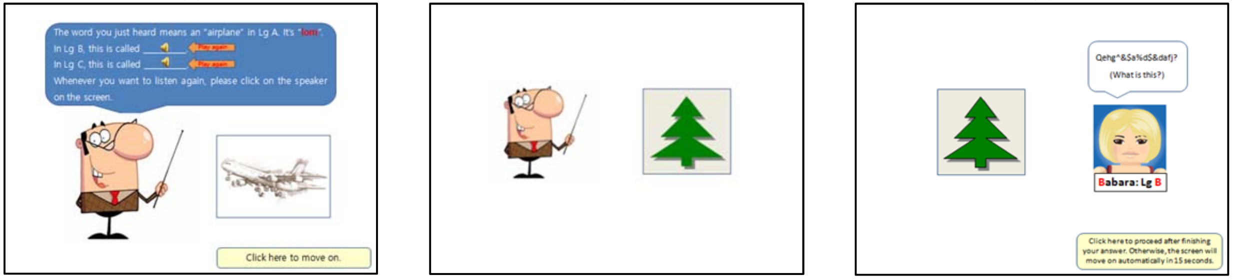
Vowels included /ʌ, i, o, u, ɨ/ in the Korean set and /a, ɪ, æ, ʊ, ə] in the English set. Using tense vowels of English was minimized, because tenseness affects the vowel length and thus, the RT. No diphthongs were used in either language set, because several vowels in Korean are controversial as to whether they should be categorized as diphthongs or a sequence of a glide and a vowel (Shin 2000). Also, /e/ and /ɛ/ (‘ㅔ’ and ‘ㅐ’ respectively in the orthography) in Korean were excluded because the distinction remains only in orthography; phonetically they merge into /ɛ/ both in perception and production of contemporary Korean speakers (Shin 2000).

All of these constraints taken together, the phoneme inventory of the Korean set included 12 consonants in onsets, 5 vowels in nuclei, and 7 consonants in codas. That of the English set included 16 consonants in onsets, 5 vowels in nuclei, and 15 consonants in codas (see the Appendix to examine the stimuli).

3.3 PROCEDURE. Experiment sessions were conducted in a sound-proof facility at the University of Hawai‘i. Participants completed four sessions, all of which were presented with Microsoft Office Power Point Presentation software on a computer monitor screen. Participants were told that they were going to translate words from an unknown language (Language A) to two different languages (Language B and C) that share word stems of Language A. Either Language A or B used the L-branching pattern to derive a word from Language A, while the other used the R-branching pattern, with Language B and C being counterbalanced across participants.

Session 1 was a training session which provided a demonstration of the two different derivation rules. As in figure 2a, a teacher appeared on the screen with a line-drawing image of an object and gave examples of how words in Language A can be translated into Language B and C, respectively. Rather than directly explaining the underlying rules, the teacher only gave five sets of examples, and participants were instructed to derive the rules from the examples by themselves. All example words were provided acoustically, i.e., to prevent any effect of visualizing characters, no written forms were used to represent the nonsense words. Participants were allowed to freely move forward and backward within the training session to reexamine the given examples. Session 1 took about 6–7 minutes on average.

FIGURE 2. Presentation of visual stimuli: (a) a slide in Session 1, providing the examples of word derivation from Language A to Language B and C, (b) the first slide of each trial in Session 2 and 3, presenting a nonsense word stimulus, (c) the second slide of each trial, where Barbara is asking what the word is in Language B.



(a) (b) (c)

The word you just heard means an "airplane" in Lg A. It's "lom".
In Lg B, this is called ______
In Lg C, this is called ______
Whenever you want to listen again, please click on the speaker on the screen.

Click here to move on.

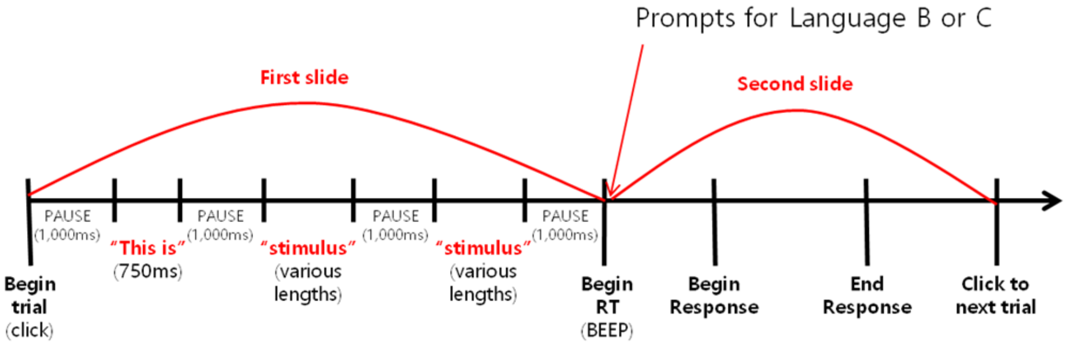
Qehg^&$a%d$&dafj?
(What is this?)

Babara: Lg B

Click here to proceed after finishing your answer. Otherwise, the screen will move on automatically in 15 seconds.

Session 2 was composed of four practice questions and answers. Participants were directed to verbally produce the answer loudly and compare their answer to the right answer. On the first slide (presented in figure 2b), the teacher appeared together with a line-drawing image of an object, and a carrier sentence was played, “This is …”, followed by a nonsense word spoken two times in succession. After the sound stimulus was played, there was a 1,000 ms pause, followed by the second slide. On the second slide, presented in figure 2c, the same object appeared with a foreigner asking what the object is in the foreigner’s language. Simultaneously with the appearance of the second slide, there was a 300ms beep. The foreign sentence was written in a speech balloon above the foreigner with a nonsense sequence of characters like “Qehg^&$a%d$&dafj?”, and its English translation, “What is this?” or a Korean translation for the Korean participants. The foreigner was either a woman introduced as Barbara, who speaks Language B, or a man named Carl, who speaks Language C (Language “B” as in “Barbara” and Language “C” as in “Carl”). Participants were told to translate the word in Language A to either B or C, depending on who pictured on the screen as asking. When they completed their response, participants either clicked the mouse to move onto the next trial or waited until the slide turned to the next trial automatically 15,000ms after the beginning of the second slide. Figure 3 below illustrates the entire procedure within a trial.

FIGURE 3. Illustration of the trial procedure

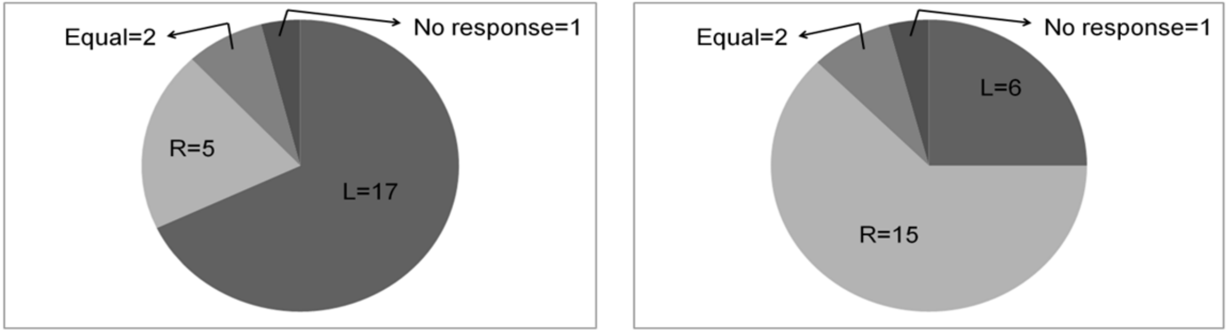


In Session 3, participants performed Test 1 (20 trials), the monosyllabic version. The display and prompts in a trial were the same as in the practice questions. Participants were directed to respond as quickly and correctly as possible, as soon as they heard the beep. Participants wore a headset through the entire experiment to minimize chances of misperception, and an external speaker was used to play the sounds simultaneously. This was in order for the digital recorder to record the beep and participant’s response, so that RTs could be measured by hand for the sake of precision. A portable Tascam DR-7 recorder, with a setting of stereo, 32-bit, 44,100 Hz sampling rate, was used to record the test sessions.

Session 4 provided instructions and practice trials of the bisyllabic version. And then, Test 2 (20 trials) was provided in Session 5. All procedures in Session 4 and 5 were the same as the previous sessions, except that the examples provided in Session 4 were bisyllabic nonsense words becoming tetra-syllabic. It took about 25 minutes on average to complete all of the five experiment sessions. After the experiment, participants answered an exit survey about their language background.

4. RESULTS. Participants' responses were coded with three categories of measurement: perceived difficulty, accuracy, and RTs. First, participants were asked which of the two languages (B or C) was "more difficult" at the end of the experiment. As in figure 4, 17 participants in the ENG group (N=25) answered that L-branching was harder than R-branching, while 15 participants in the KOR group (N=24) answered that R-branching was harder. A Pearson's Chi-square test was fit to the data. There was a significant association between the participant group and whether L- or R-branching was perceived more difficult, χ^2 (1) = 407.77, p < .001.

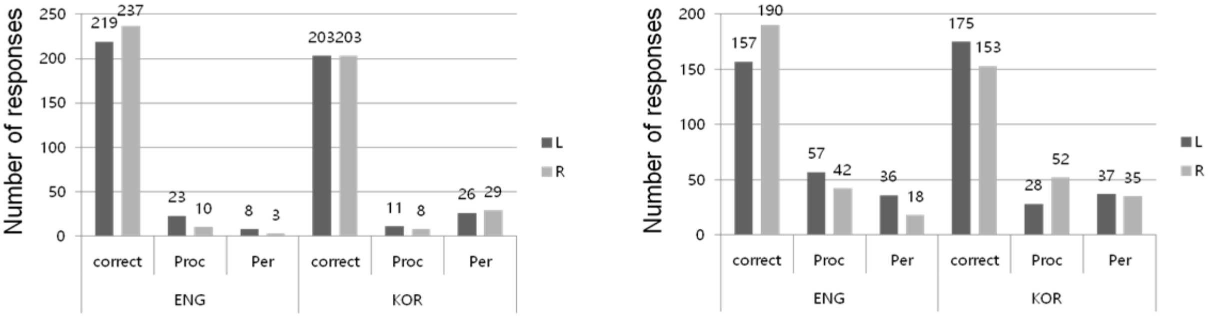
FIGURE 4. Perceived difficulty results with 25 ENG and 24 KOR participants


(a) ENG speakers

(b) KOR speakers

Second, accuracy was measured for each trial, based on the perception of the author, and coded as one of the three categories: correct, perception error, or processing error. Responses were coded as correct only when the participant unambiguously produced the correct form on the first try. Correct answers on the second or later try were not counted as correct. Perception errors refer to the errors caused solely by misperception of segments, where L- or R-branching template appears correct but segments are substituted. Examples of such cases include /tʰol/ → [pʰo.pʰol] in L-branching, and /kʰum/ → [kʰom.om] in R-branching. Processing errors were coded for all other cases where there were causes other than misperception, where the branching template is broken, as in /hun/ → [hu.un] (for [hun.un] in R-branching). Utterances with any sign of murmuring or stuttering before the end of the response were also counted as processing errors. Reponses containing both perception and processing errors were coded as processing errors, as in /lim/ → [bim.in] (for lim.im in R-branching). Graphs in figure 5 show the numbers of correct responses, perception errors, and processing errors for all participants, respectively, in Test 1 (monosyllabic) and Test 2 (bisyllabic).

FIGURE 5. Accuracy results: Test 1 and 2 respectively had 20 trials for 25 ENG participants and 24 KOR participants, thus 500 trials in total for ENG and 480 trials for KOR.



(a) Test1 (monosyllabic version)

(b) Test 2 (bisyllabic version)

To see whether there are significantly more correct answers in L-branching than in R-branching for KOR and more correct answers in R-branching than in L-branching for ENG, paired t-tests were fitted to the numbers of correct answers of each participant. When all the responses from Test 1 and 2 were fitted, only the ENG group showed significantly higher accuracy rate in R-branching than in L-branching, t[24] = -3.94, p < .001, whereas the KOR group did not show significant difference in the accuracy rates between L- and R-branching, t[23] = 1.64, p = .12. However, when only the data from the bisyllabic Test 2 were fitted, both KOR and ENG reached significant levels. ENG participants had significantly more correct answers in R-branching than in L-branching for Test 2, t[24] = -3.44, p < .01, and KOR had significantly more correct answers in L-branching than in R-branching for Test 2, t[23] = 2.16, p < .05.

According to the prediction of branching preferences of the two languages, ENG participants should have more processing errors (but not necessarily perception errors) in L-branching tasks than in R-branching, and KOR vice versa. To see whether this pattern appears statistically significant, paired t-tests were fit to the numbers of processing errors made by each participant. When all the responses from Test 1 and 2 were fitted, only the ENG group showed significantly more processing errors in L-branching than in R-branching, t[24] = 3.06, p < .01, whereas the difference in KOR's processing errors between L-branching and R-branching did not reach significance, t[23] = -1.61, p = .12. When only the data from Test 2 were fitted, however, processing errors occurred nearly significantly more in R-branching than in L-branching for the KOR group, t[23] = -2.04, p = .052.

The last category of measurement was RTs. Among the 1,960 responses (49 participants * 40 trials), RTs were measured for 1,536 correct responses. The open source analysis tool, PRAAT was used to measure two types of RTs in millisecond accuracy. RT1 was measured from the starting point of the beep, which accompanied the picture prompt (see fig.3 for the trial procedure), to the beginning of participant's verbal response. RT2 was measured from the starting point of the beep to the endpoint of participant's verbal response.

Following the norm of identifying outliers in RT analysis, all the individual responses above two standard deviation (SD) distance from the mean of either RT1 or RT2 were removed, as a priori screening.[3] Data from two participants (one from ENG and one from KOR) were also excluded by model criticism. These two participants had extremely high intercepts (over 1,000) when mixed effects models were fitted to RTs with "subject ID" as a random effect. This means that the two participants consistently took an unusually longer time to respond than other participants. In addition, data gained from four experimental items in the KOR bisyllabic test were removed from the RT analysis because of low accuracy rate (lower than 50%). Each of the four stimuli comes from one of the four phonotactic probability conditions: /lim.kɨŋ/ (HH), /sik.tʰon/ (HL), /hun.ʧʰop/ (LH), and /ʧʰot.mɨp/ (LL). For the four

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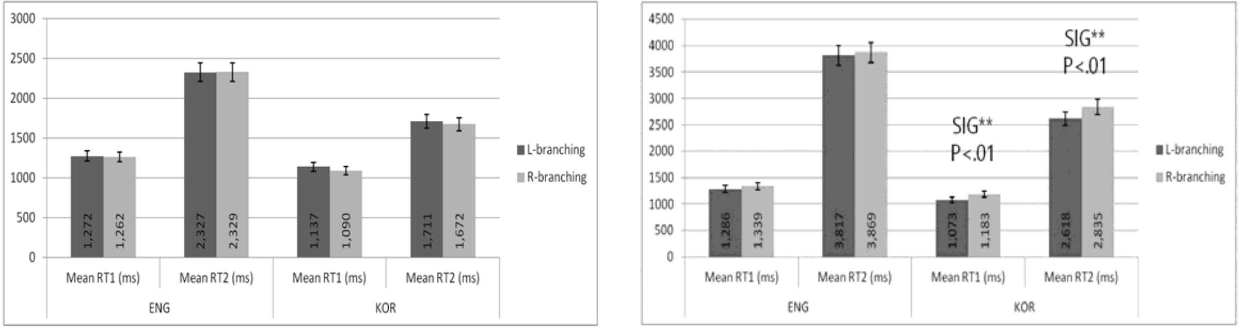
[3] "If the effect is not in the tail, then removing long RTs increases statistical power … Up to 15% of the data can be removed, but only if there is no thick right tail, in which case no more than 5% of the data should be excluded" (Baayen and Milin 2010:7).

items, there were 96 trials performed by 24 KOR participants, among which only 39 trials were correct. Among the 57 incorrect responses, 34 were perception errors. The fact that a large number of the incorrect responses consist of perception errors indicates that some segments included in these four items were difficult to identify, thus leading to poor RT data even when they are perceived correctly. Only the KOR group had any items below 50% accuracy rate. This seemed to be due partly to the perceptual obscurity of the stimuli, inherently caused by unreleased Korean stops in the coda position, i.e., [k̚] and [p̚]. Also, there were 16 participants who perceived [sik.pʰon] instead of [sik.tʰon], and 7 participants who perceived [lim.kɨm] instead of [lim.kɨŋ]. In total, 162 tokens out of the 1,536 correct responses were removed (41 monosyllabic and 27 bisyllabic for ENG, 30 monosyllabic and 64 bisyllabic for KOR). The final RT dataset contained 1,374 responses (414 monosyllabic and 320 bisyllabic for ENG, 376 monosyllabic and 264 bisyllabic for KOR) from 47 participants (KOR=23, ENG=24).

The predictions of the RT analysis are as follows. First, throughout all the four conditions of phonotactic probability (HH, LL, HL, LH), the KOR group will have shorter RTs in L-branching than in R-branching, and the ENG group will have shorter RTs in R-branching than in L-branching. Second, in controlled conditions (HH, LL), the same pattern will hold or even be strengthened. Last, in varied conditions (HL, LH), the HL condition will have shorter RTs in L-branching than in R-branching for both languages, while the LH condition will have shorter RTs in R-branching than in L-branching for both languages.

FIGURE 6. RTs in all conditions


(a) Test1 (monosyllabic)

(b) Test 2 (bisyllabic)

The means of RT1 and RT2 gained from all the four conditions are shown in figure 6 to see whether the overall pattern of language-specific branching preference appears in the RT data as well. Neither the L-branching advantage of KOR participants nor the R-branching advantage of ENG participants appeared uniformly across all RT measurements. Specifically, only the bisyllabic test for the KOR group supports the prediction. To see whether there is a statistically significant difference in each comparison between L- and R-branching, Mann-Whitney U-tests (a non-parametric test used for independently measured data, also known as Wilcoxon rank sum test) were fitted to each of the eight comparisons between L- and R-branching. The results of Mann-Whitney U-tests for each comparison are provided above the bars only when there was a significant difference between L-branching and R-branching. There were no significant differences between L- and R-branching either in ENG or in KOR when the monosyllabic test data were fitted to the model. However, in the bisyllabic data, KOR participants produced significantly faster RTs with L-branching than with R-branching both in RT1 ($W = 6839$, $p < .01$, $r = -.93$) and RT2 ($W = 6902.5$, $p < .01$, $r = -.89$).

Even though KOR participants responded significantly faster in L-branching tasks of bisyllabic stimuli, it is uncertain yet whether the L-branching advantage is due to the interaction of branching and participant group, because other comparisons do not show significant differences. To see whether the interaction appears when all the predictors are considered together, a linear mixed effects model was fitted by hand to RT1 and RT2 of the bisyllabic data, with branching, subject group (Group), and phonotactic probability type (Type) as fixed effects. Individual subject, item number, exposure level to either English (for KOR) or Korean (for ENG), whether or not a real-word syllable is contained in the stimulus, and whether Language B or Language C was used as L-branching were tested in the model, but only individual subject and item number, which reached significance, were included as random effects. As shown in table 2, the interaction between R-branching and KOR group (Branching = R: Group = KOR) significantly slowed RT1 and RT2 in the bisyllabic test. That is, RTs of the bisyllabic test were significantly longer when Korean speakers performed the R-branching tasks.

Table 2. Coefficients of fixed effects: higher estimated coefficients indicate a greater likelihood of a longer RT1 (above) and RT2 (below).

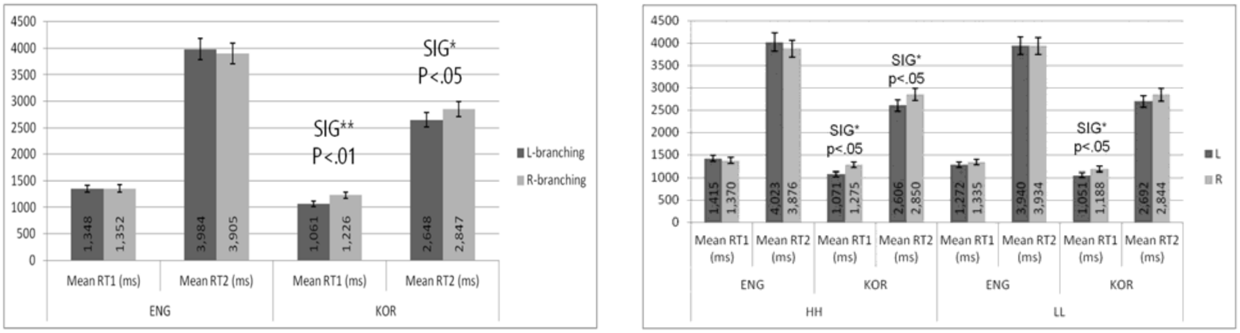
	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	1459.285	84.922	17.184	p<.001***
Group = KOR	-351.889	122.444	-2.874	p<.01**
Type = HL	-223.272	94.938	-2.352	p<.05*
Branching = R: Group = KOR	224.960	110.142	2.042	p<.05*
Branching = R: Type = HL	182.253	103.133	1.767	p=.077
Branching = R: Group = KOR: Type = HL	-312.027	155.407	-2.008	p<.05*

	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	4052.478	144.673	28.011	p<.001***
Group = KOR	-1494.517	208.919	-7.154	p<.001***
Type = HL	-283.844	149.274	-1.901	p=.057
Type = LH	-311.476	149.987	-2.077	p<.05*
Branching = R: Group = KOR	447.658	161.284	2.776	p<.01**
Branching = R: Type = HL	253.032	150.856	1.678	p=.093

Next, when we look only at the graphs of controlled conditions (HH and LL) to examine the global effect of phonotactic probabilities, we see that figure 7a indicates an L-branching advantage of KOR in the bisyllabic data. That is, KOR participants' responses were significantly faster with L-branching task than R-branching in RT1 (W = 1752, p < .01, r = -.94) and in RT2 (W = 1996, p < .05, r = -.63). Although it did not reach significance, the R-branching advantage of ENG can also be observed when compared to the all-condition data in figure 6, because RTs of ENG's R-branching are slightly lower than L-branching, which was not the case in figure 6.

Within the controlled conditions, it is rather the HH condition than the LL condition that leads to the branching preferences of KOR and ENG speakers. In figure 7b, which shows the HH and LL conditions separately, the HH condition looks similar to figure 7a in that KOR shows significant L-branching advantage, while ENG only shows a hint of R-branching. However, the LL condition in figure 7b does not show the ENG's R-branching preference as clearly as in the HH condition. The effect of syllables only with higher phonotactic probability (HH), compared to those with any lower probability (HL, LH, LL) on the unit reduplication test, will be discussed in §4.3.

FIGURE 7. RTs for bisyllabic controlled conditions


(a) Both controlled conditions (HH and LL)

(b) Comparison of HH and LL

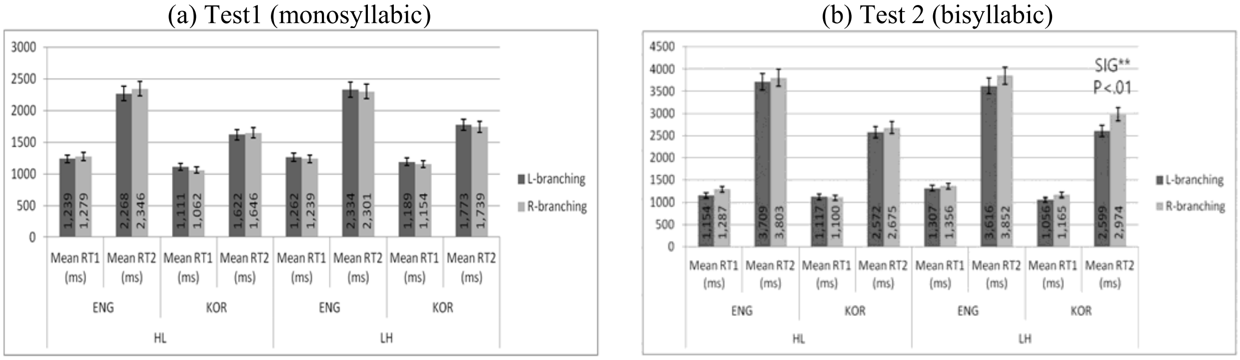
A linear mixed-effects model was fitted by hand to RT1 and RT2 of the bisyllabic controlled conditions, with the branching, subject group (Group), and phonotactic probability type (Type) as fixed effects. Individual subject and item numbers, which reached significance, were included as random effects. As shown in table 3, the interaction between R-branching and KOR group significantly slowed down RT1 and RT2. Note that the estimated coefficients of the interaction (246.820 for RT1 and 487.406 for RT2) are higher than those of the all-condition data in table 2 (224.960 for RT1 and 447.658 for RT2). Therefore, the L-branching advantage for KOR is slightly strengthened in controlled conditions, which indicates the global effect.

TABLE 3. Coefficients of fixed effects in bisyllabic controlled conditions for RT1 (above) and RT2 (below)

	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	1451.046	89.417	16.228	p<.001***
Group = KOR	-360.378	129.418	-2.783	p<.01**
Branching = R: Group = KOR	246.820	115.849	2.131	p<.05*
	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	4059.300	142.655	28.455	p<.001***
Group = KOR	-1521.174	206.018	-7.384	p<.001***
Branching = R: Group = KOR	487.406	164.780	2.958	p<.01**

In varied conditions, a hint of the predicted local effect—that the HL condition leads to L-branching advantage and LH leads to R-branching advantage in both languages—appears only in the monosyllabic data (shown in figure 8a below), but not in the bisyllabic data in figure 8b. That is, even though none of the eight comparisons between L- and R-branching in the monosyllabic data were significantly different in Mann-Whitney tests, L-branching was slightly faster than R-branching in the HL conditions except the RT1 of KOR data. In addition, it was always R-branching that was faster in LH conditions of monosyllabic data. However, this pattern was not observed in the bisyllabic data, where L-branching was almost invariably faster than R-branching.

FIGURE. 8. Mean RTs in varied conditions


(a) Test1 (monosyllabic)

(b) Test 2 (bisyllabic)

A linear mixed-effects model was fit to RT1 and RT2 of the monosyllabic varied conditions, with branching, subject group (Group), and phonotactic probability type (Type) as fixed effects. Individual subject was included as a random effect. All predictors that reached significance are shown in table 4. The interaction between R-branching and KOR group did not appear significant in varied conditions. This result is compatible with the hypotheses, because the HL and LH conditions are predicted to show the local effects of phonotactic probabilities, but not necessarily the global effect. It is more important, however, that the local effect did not appear significant either. That is, although the estimated coefficients of the main effect of the interaction between Branching and Type (Branching=R: Type=LH) were negative values, which indicates a slight decrease for both RTs (-116.854 for RT1 and -101.727 for RT2) when participants performed the R-branching task for the LH items, these values did not reach significance either in RT1 or in RT2 analysis.

TABLE 4. Coefficients of fixed effects in monosyllabic varied conditions for RT1 (above) and RT2 (below)

	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	1244.201	62.847	19.797	p<.001***
Group = KOR	-142.287	78.661	-1.809	p=.07
Branching = R: Type = LH	-116.854	67.586	-1.211	p=.199
	ESTIMATE	STD.ERROR	T.VALUE	PVALS
(Intercept)	2282.898	82.205	27.771	p<.001***
Group = KOR	-640.178	90.169	-7.100	p<.001***
Branching = R: Type = LH	-101.727	74.190	-1.371	p=.170

4. DISCUSSION.

4.1 OVERALL BRANCHING PREFERENCES. Results from this study corroborate the experimental findings in the literature that Korean speakers are better at processing the body (L-branching structure) than the rhyme (R-branching structure), while English speakers are better with the rhyme (M. Kim 2007; Y. Kim 2007; Lee and Goldrick 2008; Yoon and Derwing 2001). First, in the perceived difficulty results (figure 4), most of the ENG participants replied that L-branching was harder, whereas most of the KOR participants replied that R-branching was harder. Second, in the accuracy analysis, the KOR group showed more correct answers and fewer processing errors in L-branching, and the ENG group showed the opposite result. Last, the mixed effects model analysis on the overall RT data showed that RTs were significantly longer when the KOR group performed the R-branching tasks.

However, RTs of the ENG group were not slowed down for L-branching compared to R-branching (figure 6a and 6b). This may be because the reduplication task in general, regardless of whether L- or R-branching was tested, was more difficult particularly for the ENG group than for the KOR group. Results show that the task the ENG participants had more difficulty with the task than the KOR participants. In all analyses for both RT1 and RT2 (table 2 through 4), there was a main effect of participant group across the boards. That is, both RTs were significantly shorter in the KOR group than in the ENG group. Moreover, the difference between RT1 and RT2, which is equivalent to the time spent after participants initiated their responses, was always greater in English than it was in Korean. These findings clearly indicate that the ENG participants took a longer processing time, not only in the planning stage but also during articulation.

There are two reasons why English speakers have more difficulty in the reduplication task. First, one of the crucial elements in this task is the ability to recognize syllable boundaries. This may cause relatively less difficulty for Korean speakers due to the effect of the writing system. In the Korean writing system, Hangul, characters are put together in a block to represent phonemic syllable boundaries. However, the English writing system lacks such representation. This can cause relative insensitivity to syllable boundaries, in tandem with the fact that the English syllable structure allows a number of consonant clusters either in the onset and coda position, while Korean does not. Second, as noted in §3.2, English coda obstruents in this experiment were differentiated by voicing distinction while those of Korean were massively neutralized into unreleased surface forms. Because the ENG participants were able to hear the oral release of obstruents in the auditory stimuli, most of the participants produced the obstruents with audible release. Articulating obstruent release can increase especially RT2 in the R-branching condition, but not as much in the L-branching condition because coda consonants are produced twice for R-branching but only once for L-branching. In fact, the main effect of participant group was much larger in RT2 (coefficient = -1494.517, p<.001) than in RT1 (coefficient = -351.889, p<.01). Therefore, the use of released obstruents in the coda position seems to have reduced the predicted R-branching advantage for English speakers.

4.2 GLOBAL EFFECT. Even though the predicted branching advantage appeared only in Korean bisyllabic data, the results can still support the global effect of phonotactic probabilities on the mental representation of syllable structure that Lee and Goldrick (2008) found. The different processing advantages between the KOR and ENG group were strengthened when the phonotactic probabilities of

CV sequence and VC sequence within a syllable were controlled (figure 7a), and the estimated coefficient of the interaction between R-branching and KOR group for controlled conditions (table 3) were higher than that of the overall dataset (table 2). Also, the difference between subject groups was larger in the HH condition than in LL condition (figure 7b). Although the exact mechanism is unknown, this may indicate that the branching preferences of each language are most clearly observed when participants process the most frequently occurring sequences.[4]

4.3 LOCAL EFFECT AND PROCESSING OF UNIT REDUPLICATION. The monosyllabic test showed a slight tendency that the sequences of higher probabilities led to faster processing when the phonotactic probabilities of CV sequence and VC sequence are asymmetric (figure 8a), but the local effect did not appear statistically significant either in the accuracy analysis or in the RT analysis. There are a few factors to take into account about the processing of unit reduplication. While Lee and Goldrick's STM method tested whether participants retained the memory of each segment in CVC syllables, the unit reduplication requires not only memory retention but also subsequent processing, copy-and-pasting either of the two subsyllabic units. Note that reduplication in this experiment occurs only after intact retention in memory, and that RTs are measured only for correct responses. If it is the memory processing, but not necessarily the reduplication processing, that is essentially susceptible to the effects of phonotactic probabilities, then it is possible that the effects will be reduced when RTs are measured throughout the memory processing and reduplication processing. However, the reduced effects, i.e. smaller difference in RTs between L- and R-branching, may still show the global effect because the global effect is triggered by speaker's sensitivity to the general skew of statistical information existing in the native language, which is a more stable tendency of speakers than the local effect. The local effect, on the other hand, is much more variable depending on the manipulation of phonotactic probabilities and presupposes more precise association between the cause (phonotactic probabilities) and the effect (RTs), in that it should override the global effect when the phonotctic probabilities have been manipulated to conflict with the general tendency of branching in the native language.

In addition, participants may have set a "default" setting of L-branching. With respect to the three conditions that contain low probability sequence (HL, LH, and LL) in the bisyllabic test, it is almost invariably L-branching that was relatively faster across the two languages (see figure 7b and figure 8b). However, this was not the case in the monosyllabic test. Although this difference was not statistically significant, it may indicate that participants generally relied on a strategy that sets L-branching as default, just because onset consonants are more perceptually salient and thus more memorable than codas. Participants might have needed an alternative strategy for three conditions in the bisyllabic task due to the greater number of segments and the less frequently used sequence in their memory.

5. CONCLUSION. In sum, this study demonstrates that the global effect of phonotactic probabilities on syllable structure can be also observed in a unit reduplication processing, a process that is more complicated than short-term memory retention. That is, native speakers of Korean were more correct and faster in processing the reduplication of CV sequences than VC sequences and English speakers were better with VC sequences than with CV sequences, only when the phonotactic probabilities were controlled to be similar between the CV sequence and the VC sequence within a CVC syllable. Additionally, results from varied conditions indicate that it may be at the memory-processing stage but not necessarily at the subsequent stage of reduplication, where the local effect of phonotactic probabilities takes place. In other words, the influence of native speaker's subconscious knowledge about phonotactic probabilities on particular phoneme sequences is not as strong as their sensitivity to the overall statistical distribution of phonotactic constraints in their language.

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[4] Note that syllables in the HH condition are not necessarily frequently occurring syllables in each language. Even though the CV and VC sequences of a syllable are frequent, it is still possible that the combination of the two sequences do not occur frequently.

APPENDIX

Stimuli for KOR group						Stimuli for ENG group					
Monosyllabic test			Bisyllabic test			Monosyllabic test			Bisyllabic test		
#	Type	Stimuli	#	Type	Stimuli	#	Type	Stimuli	#	Type	Stimuli
1	HH	ʧʰip	1	HH	kʰɨm.lip	1	HH	naŋ	1	HH	bʊd.maŋ
2	HL	ʧʌk	2	HL	sik.tʰon	2	HL	ʤæb	2	HL	gək.zɪt
3	LH	sɨŋ	3	LH	kʰum.nul	3	LH	hʊʃ	3	LH	ʧab.gʊʃ
4	LL	pʰʌt	4	LL	pʰʌt.pol	4	LL	dɪt	4	LL	dɪt.kæn
5	HH	lim	5	HH	ʧʰip.ʧʌm	5	HH	ðæp	5	HH	naŋ.sɪg
6	HL	nɨp	6	HL	tʰol.ʧik	6	HL	maθ	6	HL	ʤæb.θəs
7	LH	kʰum	7	LH	nut.sɨm	7	LH	tɪg	7	LH	bəʧ.hæp
8	LL	ʧʰot	8	LL	kʰʌŋ.lot	8	LL	gʊl	8	LL	ʃaʤ.bək
9	HH	kɨm	9	HH	lim.kɨŋ	9	HH	zɪp	9	HH	zɪp.ʤæŋ
10	HL	sik	10	HL	ʧʌk.sin	10	HL	gək	10	HL	pʊʧ.naθ
11	LH	hun	11	LH	lop.hum	11	LH	ʧab	11	LH	kæŋ.nəg
12	LL	kʰʌŋ	12	LL	pon.kʰʌt	12	LL	nəs	12	LL	nəs.hʊl
13	HH	pʰul	13	HH	ʧʰʌm.pʰut	13	HH	bʊd	13	HH	ðæp.gəʧ
14	HL	ʧin	14	HL	nɨp.ʧʰʌk	14	HL	sɪm	14	HL	sɪm.bʊʧ
15	LH	lop	15	LH	hun.ʧʰop	15	LH	bəʧ	15	LH	tɪg.ʃab
16	LL	mɨt	16	LL	mɨt.pʰʌŋ	16	LL	hæn	16	LL	gʊl.tɪm
17	HH	ʧʰʌm	17	HH	pʰul.ʧʰim	17	HH	θəg	17	HH	θəg.pʊd
18	HL	tʰol	18	HL	ʧin.nɨt	18	HL	pʊʧ	18	HL	maθ.ðæb
19	LH	nut	19	LH	sɨŋ.kʰun	19	LH	kæŋ	19	LH	hʊʃ.dɪp
20	LL	pon	20	LL	ʧʰot.mɨp	20	LL	ʃaʤ	20	LL	hæn.ʧaʤ

REFERENCES

BAAYEN, R. HARALD, and PETAR MILIN. 2010. Analyzing reaction times. *International Journal of Psychological Research* 3:12–28.

BERG, THOMAS, and CHRISTIAN KOOPS. 2010. The interplay of left- and right-branching effects: A phonotactic analysis of Korean syllable structure. *Lingua* 120:35–49.

CHUN, SANGBEOM. 1980. A phonological interpretation of Lapsus Linguae. *Korean Journal of Linguistics* 5:15–32.

DELL, GARY; CORNELL JULIANO; and ANITA GOVINDJEE. 1993. Structure and content in language production: A theory of frame constraints in phonological speech errors. *Cognitive Science* 17:149–95.

EWEN, COLIN J., and HARRY VAN DER HULST. 2000. *The phonological structure of words: An introduction*. Cambridge: Cambridge University Press.

FUDGE, ERIC. 1987. Branching structure within the syllable. *Journal of Linguistics* 23:359–77.

HAYES, BRUCE. 1989. Compensatory lengthening in moraic phonology. *Linguistic Inquiry* 20:253–306.

KIM, MYOYOUNG. 2007. A study of slips of the tongue by monolingual speakers and bilingual speakers. University of Buffalo dissertation.

KIM, YOUNG-SEOK. 1984. Aspects of Korean morphology. University of Texas dissertation.

KIM, YOUNG-SUK. 2007. Phonological awareness and literacy skills in Korean: An examination of the unique role of body-coda units. *Applied Psycholinguistics* 28:69–94.

KIM, JUNG-YOON, and YONGEUN LEE. 2011. A study of Korean syllable structure: Evidence from rhyming patterns in Korean contemporary rap-songs. *Sociolinguistics Journal of Korea* 19:1–22.

LEE, JUHEE. 2007. Issues on the syllable structure in Korean. *Korean Language and Literature* 61:57–81.

LEE, YONGEUN, and MATHEW GOLDRICK. 2008. The emergence of sub-syllabic representations. *Journal of Memory and Language* 59:155–68.

MARSLEN-WILSON, WILLIAM, and LORRAINE TYLER. 1980. The temporal structure of spoken language understanding. *Cognition* 8:1–71.

SELKIRK, ELISABETH O. 1982. Syllables. In *The structure of phonological representations (part II)*, ed. by Harry van der Hulst and Norval Smith, 337–83. Dordrecht: Foris.

SHIN, JIYOUNG. 2000. *Malsoliui ihay,* “Understanding of speech sound.” Seoul: Hankukmunhwasa.

YOON, YEO BOM, and BRUCE DERWING. 2001. A language without a rhyme: Syllable structure experiments in Korean. *Canadian Journal of Linguistics* 46:187–237.

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