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Spoken-word production in Korean: A non-word masked priming and phonological Stroop task investigation

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Abstract

Speech production studies have shown that phonological unit initially used to fill the metrical frame during phonological encoding is language specific, that is, a phoneme for English and Dutch, an atonal syllable for Mandarin Chinese, and a mora for Japanese. However, only a few studies chronometrically investigated speech production in Korean, and they obtained mixed results. Korean is particularly interesting as there might be both phonemic and syllabic influences during phonological encoding. The purpose of this study is to further examine the initial phonological preparation unit in Korean, employing a masked priming task (Experiment 1) and a phonological Stroop task (Experiment 2). The results showed that significant onset (and onset-plus, that is, consonant–vowel [CV]) effects were found in both experiments, but there was no compelling evidence for a prominent role for the syllable. When the prime words were presented in three different forms related to the targets, namely, without any change, with re-syllabified codas, and with nasalised codas, there were no significant differences in facilitation among the three forms. Alternatively, it is also possible that participants may not have had sufficient time to process the primes up to the point that re-syllabification or nasalisation could have been carried out. In addition, the results of a Stroop task demonstrated that the onset phoneme effect was not driven by any orthographic influence. These findings suggest that the onset segment and not the syllable is the initial (or proximate) phonological unit used in the segment-to-frame encoding process during speech planning in Korean.

Keywords

Psycholinguistics; speech production; Korean; phonology

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Language production involves several successive stages: first, conceptual preparation commences, which is followed by a stage of grammatical and lexical selection, during which lexical items are retrieved from the mental lexicon and given their abstract phonological content. This content is eventually mapped onto articulatory movements during speaking. According to the word production model by Levelt, Roelofs, and Meyer (1999), the phonological content selected at the beginning of word-form encoding contains *phoneme-sized segments*. Previous research mainly based on data from Germanic languages such as Dutch and English have provided support for this view (e.g., Meyer, 1991; Rapp & Goldrick, 2000). However, recent research has shown that the view depicting a key role of phonemic segments during phonological encoding may not apply to all languages. For example, studies have shown that the syllable serves as the phonological preparation unit in Mandarin Chinese (T.-M. Chen & Chen, 2013; J.-Y. Chen, Chen, & Dell, 2002; O'Seaghdha, Chen, & Chen, 2010), and the mora is the unit for Japanese (Kureta, Fushimi, & Tatsumi, 2006; Verdonschot et al., 2011).

Given the large cross-linguistic differences in the preparation unit in spoken-word production, this study further investigates the unit in a relatively understudied language, namely, Korean. It is of considerable interest to examine the phonological preparation unit of Korean further, as there are many phonological, morphological, and/or orthographic differences between Korean and European

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languages on one hand and between Mandarin and Japanese on the other.

First, the syllable structure of Korean is more complex than Mandarin but far less complex than many European languages in several respects. It has been established that in English and Dutch, syllable onsets and codas have as many as three consonants, which may lead to 12,000 syllable types for Dutch (Schiller, 1998). The syllable boundaries of these languages are not clear, allowing re-syllabification and ambi-syllabicity. In contrast, Mandarin syllables allow only a single consonant in onset as well as coda, and only nasals are permissible in the coda position. Consequently, Mandarin has approximately 400 syllable types, not counting tones (J.-Y. Chen, Lin, & Ferrand, 2003). Also, Mandarin has no re-syllabification and ambi-syllabicity. In Korean syllables, the onset and the coda are maximally single consonants. The consonant clusters are allowable underlyingly (e.g., /talk/ "chicken"), but they are realised phonetically only when the immediately following segment is a vowel through re-syllabification (e.g., /talk + i/ > [tal.ki] "chicken is"), whereas one of the clusters is deleted when the following segment is a consonant or when they are used as an isolated form (e.g., /talk + to/ > [tak.to] "chicken also"; /talk/ > [tak]). Thus, the number of possible syllable types in Korean is 1,832, which is derived from the subtraction of the unattested types from all possible combinations from 19 consonant onsets, 21 vowels, and 8 coda consonants (Won, 1987). As mentioned above, the coda of the first syllable in disyllabic words is re-syllabified to the onset of the second syllable when the second syllable begins with a vowel (e.g., /hak.u/ "buddy" → [ha.gu]). There are numerous phonological processes in Korean which cross the syllable boundary. For example, the coda /k/ in /hak.mun/ "learning" is changed to [ŋ] ([haŋ.mun]) due to the assimilation to the onset nasal in the second syllable.

Second, the precise speech rhythm of Korean has provoked a heated debate; it has been said to be stress-timed as in English, German, or Dutch; syllable-timed as in Mandarin, Italian, or French (Abercrombie, 1967); or an intermediate form between the two (M. S. Han, 1964; H. B. Lee, Jin, Seong, Jung, & Lee, 1994). Recently, Mok and Lee (2008) investigated Korean speech rhythm using recently developed various durational rhythm measures such as %V (the percentage of vocalic intervals[1] in speech; the sum of vocalic intervals divided by the total duration of the sentence), ΔC (the standard deviation of the duration of consonantal intervals within each sentence), and other measures such as PVIs (which are pairwise comparisons of successive vocalic and intervocalic intervals; see Dellwo, 2006; Grabe & Low, 2002; Ramus et al., 1999) and compared it with typical stress-timed languages (English and German) as well as syllable-timed languages (Cantonese, Mandarin, French, and Italian). In their results, the durational measures of rhythm elicited a mixed picture of the Korean speech rhythm. For example, the %V, raw and normalised PVI parameters classify Korean as syllable-timed, although for other measures, Korean lies between syllable-timed and stress-timed languages (ΔC) or unclassifiable with less clear values.

The timing of a language is an important aspect to consider when investigating Korean as earlier work has shown that, in French, a syllable-timed language, the exact syllabic overlap between prime and target seems to influence the amount of priming observed in a masked priming naming task. For example, Ferrand, Segui, and Grainger (1996) showed that two target words sharing the identical three onset phonemes, that is, /b/, /a/, /l/ in "BAL.CON" ("balcony") and "BA.LADE" ("balad") when preceded by a syllable-matching prime (e.g., *ba* for BA.LADE and *bal* for BAL.CON) compared with when they were not (e.g., *bal* for BA.LADE and *ba* for BAL.CON) always elicited larger priming compared with when the syllabic structure was an exact match (see also Ferrand, Segui, & Humphreys, 1997 for similar results in English). Note that this means that *ba* would prime BA.LADE more than *bal* even though the latter has more phonological overlap with the target. However, in later studies, these French and English results could not be replicated (see Brand, Rey, & Peereman, 2003; Schiller, 1999). In addition, Grainger and Ferrand (1996) as well as Carreiras et al. (2006) have shown onset priming effects using the masked priming task in French, therefore the proximate unit during the early phonological encoding steps in French is still likely to be the phoneme. However, using the same task, more consistent results have been obtained in Chinese and show that the syllable is the fundamental phonological unit across the board (e.g., J.-Y. Chen et al., 2003; Verdonschot, Lai, Feng, Tamaoka, & Schiller, 2015; You, Zhang, & Verdonschot, 2012; though see Verdonschot et al., 2013 for onset priming in L1-Chinese when participants were also highly proficient in L2-English). A recent noteworthy example from the production literature is a study by J.-Y. Chen, O'Seaghdha, and Chen (2016) who used masked primes in combination with *picture* targets (i.e., thereby avoiding any reading processes on the target). They found that pictures (e.g., 玫瑰 /mei2gui1/ "rose") were named faster when preceded by a syllable-related prime (e.g., 妹 /mei4/) compared with control (e.g., 傻 /sha3/), whereas significant priming was not obtained for onset-related primes (e.g., 目 /mu4/ vs 手 /shou3/).

Despite mixed results in the production literature, syllabic consistency patterns have been found using Indo-European languages within the comprehension literature. For example, an influential study by Mehler, Dommergues, Frauenfelder, and Segui (1981) showed that the *ba* syllable was detected faster in words like BA.LADE compared to BAL.CON and vice versa for the *bal* syllable. Similarly,

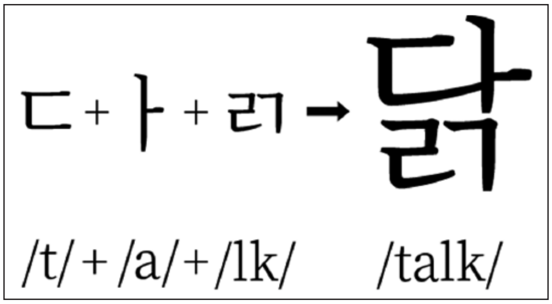

Figure 1. Illustration of the syllabic block for /talk/ “chicken” in the Korean writing system.

other studies have shown that phonemes in re-syllabified words are detected with more difficulty than those in non-re-syllabified words (e.g., Cutler & Norris, 1988; Vroomen & De Gelder, 1999).

Third, the Korean orthographic system (Hangul) shows both phonemic and syllabic characteristics at the same time, and it has been aptly described as an “alphabetic syllabary” (Taylor, 1980; Taylor & Taylor, 2014). Hangul is a relatively transparent orthography where grapheme-to-phoneme correspondence is consistent and thus, each phoneme is represented by a Hangul letter. These letters are, however, not linearly ordered but grouped into a block, which exactly corresponds to a syllable, according to a set of strict rules. The vowel strokes are either horizontal or vertical. The horizontal stroke is placed under the letter for an onset consonant (e.g., <소> “cow”), while the vertical stroke is placed on the right side of the onset letter (e.g., <나> “me”). The letter for a coda consonant is placed under the letter for a vowel (e.g., /손/ “hand”; <난> “nan bread”). Each orthographic syllable is composed of (C)V(C)(C), for example, <ㄷ> (/t/), <ㅏ> (/a/), and <ㄺ> (/lk/) = <닭> /talk/ “chicken.”

For a syllable with no onset, the letter <ㅇ> with no sound value takes the position of the initial consonant (e.g., <아이> “kid”). These blocks are then arranged horizontally from left to right or vertically from top to bottom. Thus, Hangul maps graphemes onto phonemes just as European languages do, but the composition of its graphemes is shaped into a square-like block, which leads it to its overall shape to be more like Mandarin Chinese than to alphabetic orthographies. The syllabic block of /talk/ “chicken,” for example, is illustrated in Figure 1.

Importantly, it has been shown that the specific script used in psycholinguistic experiments may play a significant role in phonological processing. For example, in Japanese, a study by Inagaki, Hatano, and Otake (2000) administered a vocal motor task (i.e., involving production) in which children of different Japanese kana proficiency levels had to play a game. In this game, they would have to “jump” a doll (which they controlled) across several circles according to the sound of a word depicted as a picture on a card (e.g., when seeing a picture of a “crab” or /ka.ni/ the child was supposed to jump two circles). Inagaki and colleagues found that children who were better at (or who had fully mastered) kana (a moraic script) switched from a syllable based to a mora-based jumping strategy. For example, a less literate child might have jumped three circles (i.e., following a syllabic pattern with the second syllable /ko.u/ consisting of two morae) with the doll instead of four for /hi.ko.u.ki/ (“airplane” in Japanese) following a moraic pattern. In addition, Kureta et al. (2015) used the *implicit priming paradigm* to investigate the role of script in Japanese. In this paradigm, participants first need to learn prompt-response pairs (e.g., 火山 /ka.zan/ “volcano” would be associated with マグマ /ma.gu.ma/ “magma” such that later when seeing the word 火山, one needed to reply with /ma.gu.ma/ in Japanese). Next, prompt words are presented, and groups would be formed overlapping in a certain phonological feature, thereby speeding up reaction times (RTs) or not. In Japanese, it has earlier been shown (e.g., Kureta et al., 2006) that mora overlap (e.g., the initial consonant–vowel [CV] /ma/ in マグマ /ma.gu.ma/; マンガ /ma.N.ga/ or 祭り /ma.tsu.ri/) facilitates naming latencies compared with a heterogeneous group (e.g., マグマ /ma.gu.ma/, 机 /tsu.ku.e/, さそり /sa.so.ri/). This effect is absent for phoneme overlap (see Kureta et al., 2006). However, Kureta et al. (2015) revealed that when participants were shown Japanese prompt-response pairs using Romanised Japanese (romaji), *they became aware of the phonological relationship of the target stimuli* (i.e., an onset overlap; e.g., maguma, menkyo, moppu). This effect was again absent when prompt-response pairs were presented in commonly used Japanese orthographies (such as kanji and kana, e.g., マグマ, 免許, モップ; see also Verdonschot et al., 2011). A recent paper by Yoshihara, Nakayama, Verdonschot, and Hino (2017) used two-kanji compound words for which the first character consisted of more than one mora. Here, the onset mora overlap was manipulated (e.g., prime: 発案 /ha.tsu.a.N/ “suggestion”—target: 博物 /ha.ku.bu.tsu/ “natural history” vs control primes such as 立案 /ri.tsu.a.N/ “planning” for the 博物 target). Surprisingly, they found that a moraic overlap alone was *not* sufficient to produce priming; significant priming was only obtained when the pronunciation of the *whole character* overlapped (e.g., /ha.ku/ in 迫害 /ha.ku.ga.i/ “persecution” for the 博物 target). When, in a subsequent experiment, the stimuli were transcribed to kana (a moraic script), *mora* priming once again emerged. However, another study by Verdonschot and Kinoshita (2017) recently showed, using the phonological Stroop task (see Experiment 2 for more details), that mora effects can appear even with *kanji* (e.g., RTs are faster when 右 /mi.gi/ “ear” is written in green, which is /mi.do.ri/ in Japanese, than when its written in red, or /a.ka/ in Japanese). This contrasts Yoshihara et al.’s (2017) findings and suggests that the Stroop task constitutes a more valid production task as the colour names are cued perceptually without any necessary involvement of script.

Fourth, many word games in Korean respect either a syllabic or phonemic structure. There is a word-chain game played by children named *kketmaliski* (i.e., the Korean version of Japanese shiritori; see Katada, 1990), in which players are required to say a word which begins with the final part of the previously heard word. In Korean, the final part is the orthographical syllable of the previous word. For instance, when /han.kuk/ "Korea" is heard, /kuk.min/ "people" would be a valid answer; however, /kjo.min/ "overseas Korean" or /ku.min/ "inhabitants of a certain area" cannot be a good continuation because only onset or onset plus a vowel, but not the entire syllable, is overlapped. However, Sohn (1987) points out another language game in which vowels of two consecutive syllables are switched around without affecting other parts of the syllable. For instance, a non-word /ha.pok/ is derived from /ho.pak/ "pumpkin" or /ba.ci/, from /bi.ca/ "Visa." In these two examples, only the two vowels in the first and the second syllables are switched without any change in the quality of the surrounding consonants, suggesting the phoneme as a functional unit.

Speech error analyses based on a spontaneous speech corpus also showed evidence for a key role of both onset phonemes and syllables in spoken production of Korean. Speech error data are particularly informative as speech errors are sensitive to the phonological characteristics of the language. In English, errors from sound exchanges are observed in segments as well as whole words or morphemes, but errors involving whole syllables are rare (Bock, 1991; Dell, 1995). In contrast, both syllable and segment errors are observed in Mandarin (J.-Y. Chen, 1993), and errors mostly adhere to a moraic structure in Japanese (Kubozono, 1989). J.-I. Han, Oh, Kim, and Kim (2017) examined the errors in the Seoul Naturalistic Speech Corpus (Yun et al., 2015) which contains audio recording of the interviews from 40 standard Korean speakers and classified them following Garnham, Shillcock, Brown, Mill, and Cutler (1981). Across various slips-of-the-tongue examples, both syllable and segment errors were observed even though syllable types of errors were far less frequent than those of phoneme segments. More crucially, even though the sound exchange errors were rare, 8 cases of segmental exchanges were observed (e.g., /cik.cʌp/ → [cip.cʌk] "direct"; /ka.mjən/ → [kan.mjə] "if (she or her) goes"), while syllable exchanges were only one case (e.g., /ol.ljə.cjə.sə/ → [ol.ljə.sə.cjə] "be put in"). The latter finding resonates with the error patterns of English and Dutch where syllables errors are rare or nonexistent but contrasts those found in Mandarin Chinese where both syllable and segment errors are prevalent.

In addition, considering previously mentioned studies indicating diverging evidence concerning the role script plays in Japanese (e.g., Verdonschot & Kinoshita, 2017; Yoshihara et al., 2017), it seems to be essential to point out that several psycholinguistic studies using Korean have shown that either a syllable or a phoneme segment to serve as a phonologically relevant unit when processing Hangul words. For instance, Simpson and Kang (2004) examined whether the syllable had a special status when naming Korean words. They found that participants showed a strong effect of syllable frequency compared with minimal effects of word and sub-syllabic frequencies on naming latencies. Similarly, Cho and McBride-Chang (2005a, 2005b) examined the relationship between CV syllable identification, or consonant/vowel letter knowledge of Korean, and performance when processing Hangul words. In a 6-month longitudinal study, Korean kindergarteners showed that identification of CV syllables rather than consonant/vowel letter knowledge contributed to Hangul reading abilities. The results of these studies suggest that syllables serve as a functional phonological unit when reading Hangul words.

On the contrary, visual word recognition findings on transposed-letter (TL) effects in Hangul words indicate that Korean speakers fully decomposed the words when they were asked to judge whether the target words were real words or non-words (C. H. Lee & Taft, 2009). For example, when a non-word <납묵> (/nap.muk/) was generated from the word <남북> (/nam.puk/ "south and north") through the transposition of the coda of the first syllable and the onset of the second syllable, native Korean speakers experienced little difficulty in making lexical decisions. This contrasts with findings obtained through native English speakers who showed considerable difficulty responding to non-words of the same structure in English (e.g., *nakpin* from *napkin*). C. H. Lee and Taft (2009) explained the lack of TL effects in Korean based on the orthographic structure of Korean such that graphemes are assigned to an orthographic onset, nucleus, or coda position at an early stage of processing and that such assignment is unambiguous in Korean Hangul, unlike English. Although this is visual word recognition study (and not spoken word production), it could still disclose important information for the functional unit of production as reading is often a component of the experimental tasks typically carried out in this domain (though it can be argued whether tasks involving reading constitute valid tools for studying the functional unit of language production).

To briefly summarise, there is mixed theoretical and experimental evidence for both phonemic and syllabic influences during the initial stages of phonological encoding in Korean. As far as we know, there have been only two studies which investigated priming effects in Korean, and they have showed mixed results.

Kim and Davis (2002) employed a masked priming naming task (as well as a lexical decision task). They had five prime-target manipulations, that is, identity prime (<결>—<결>, both /kjʌl/), onset prime (<개>—<결>, /kæ/, /kjʌl/), onset-plus or onset plus a vowel prime <겨>—<결>, /kjʌ/, /kjʌl/), form prime, in which the vowel and coda of the prime matched with the target (<멸>—<결>, /mjʌl/, /kjʌl/), and an all letter different prime serving as control (e.g., <돈> /don/). Kim and Davis (2002) did *not* obtain a significant onset effect (7 ms) but they obtained a significant identity priming effect of 17 ms as well as a significant onset-plus effect (i.e., the initial CV syllable) of 19 ms in their naming task. The form-priming condition was also not significant (–4 ms). Their lexical decision task only showed significant identity priming.

More recently, however, Witzel, Witzel, and Choi (2013) did find a significant effect for onset priming. They employed the same masked priming paradigm using Korean non-words, which were all bi-syllabic, preceded by one of three conditions (all of which were also disyllabic Hangul nonwords), namely, CV syllable overlap (e.g., <피추> <피토> /pʰi.cʰu/, /pʰi.tʰo/), onset phoneme overlap (e.g., <페추> <피토> /pʰɛ.cʰu/, /pʰi.tʰo/), and an all-letter-different prime (e.g., <카추> <피토> /kʰa.cʰu/, /pʰi.tʰo/). Their results revealed facilitative naming latencies when primes and target shared an initial onset phoneme as well as a CV syllable, even though there was greater priming at the CV syllable level (16 ms) than at the phoneme level (9 ms). Taken together, given the size of the onset effect and the incongruity between the two studies, it remains unclear whether there is any reliable onset effect in Korean.

In this study, we aim to further investigate Korean spoken word production using Hangul script. Specifically, three questions are raised in this study: (1) Is the onset effect as obtained by Witzel et al. (2013) reliable? (2) Is there any benefit of syllabic overlap between prime and target as observed in French (Ferrand et al., 1996; Mehler et al., 1981 but see Brand et al., 2003) and Chinese (J.-Y. Chen et al., 2003; J.-Y. Chen et al., 2016; You et al., 2012)? and (3) What pattern does Korean Hangul, through its unique "alphabetic syllabary" nature, show if a task is used which does not necessitate reading of the target word (see Verdonschot & Kinoshita, 2017)?

As for the first two questions, in Experiment 1, we employ a masked priming task (in line with two previous studies on the Korean preparation unit), but with extended experimental procedures and stimuli using non-word targets (to make a direct comparison to Witzel et al., 2013 possible). Specifically, Experiment 1 could be preceded by one of five different conditions (four experimental and one control). We include the onset condition to ascertain the robustness of the onset effect in Korean, but we also include three other conditions in which targets are preceded by primes which had a consistent syllabic orthography while the underlying phonological relationship to the target is syllabically manipulated (i.e., identical to target, re-syllabified, and with a phonological change [nasalised]). If the syllable has indeed a special status in Korean language production, we expect the largest priming effect when the syllable is an exact match between prime and target and less priming if it does not exactly match (e.g., re-syllabification, nasalisation). If the syllable does not have a special status in Korean language production, that is, if an exact syllable match between prime and target does not exert a profound influence, we expect these conditions to elicit similar priming (though still larger than onset priming, following Kim & Davis, 2002; Witzel et al., 2013).

To answer the third question, we employ the phonological Stroop task (PST) in Experiment 2. As stated earlier, recently, Verdonschot and Kinoshita (2017) used this task to shed more light on production versus reading effects during phonological encoding. Specifically, we investigate which latency patterns are found in a task that does not necessitate any direct orthographic processing on Hangul targets, thereby validating the robustness of onset or onset-plus (i.e., CV) effects without a direct influence of script. The PST is a variation on the classic Stroop colour-word naming task (i.e., Stroop, 1935) in which one must name the colour of the ink colour that the word is written in (e.g., RED). When the ink colour matches the written colour, word's pronunciation, naming latencies are faster compared to when they differ. In the PST variant used here (see Mousikou, Rastle, Besner, & Coltheart, 2015; Verdonschot and Kinoshita, 2017), the typical finding is that colour naming is faster when the sound of the word (or non-word) target overlaps with the response colour in the onset (e.g., the word POT or the pseudoword POZ when saying "pink") compared with when it does not (e.g., the word COD or the pseudoword GOZ when saying "pink"). If the masked priming results reported in the literature are consistent and indeed part of the production process, we expect to substantiate any onset and syllable/onset-plus effects using the PST task as well. As such, this study tries to undertake a thorough investigation of spoken word production planning in Korean (and not only focuses on the presence or absence of onset effects).

Experiment 1—masked priming using Korean Hangul

Method

Participants. In total, 32 students (20 males aged 20-30 years, mean [M] = 22.9) from Konkuk University in Seoul (South Korea) participated in the experiment in return for 10,000 won (approximately US$9).

Materials and design. All prime and target items were two-syllable Korean non-words adhering to a CVC.C(G)V structure which were fully in agreement with Korean

Table 1. Naming latencies and percentage errors of Experiment 1 (masked priming task).

Prime type	Example		RT	*SD*	Effect	% error
	Hangul	IPA				
Same syllable	독가—독쇠	[tok.ka]—[tok.swɛ]	466	80	30	0.6
Re-syllabify	독가—독유	[tok.ka]—[to.gju]	465	81	31	0.8
Coda change	독가—독머	[tok.ka]—[toŋ.mə]	469	82	27	0.7
Same onset	독가—댄소	[tok.ka]—[tæn.so]	477	79	19	1.1
Control	독가—남무	[tok.ka]—[nam.mu]	496	75	0	1.3

IPA: International Phonetic Alphabet; RT: reaction times, *SD*: standard deviation.

phonotactic constraints. A total of 80 non-word targets were constructed (e.g., 독가—[tok.ka] /tok.ka/) which were preceded by one of five prime conditions, specifically, (1) same initial character with a preserved first syllable pronunciation, for example, 독쇠—[tok.swɛ] /tok.swɛ/, (2) same initial character, but the coda of the first syllable was re-syllabified to the onset of the second syllable, for example, 독유 [to.gju] /tok.ju/, (3) same character, but the coda of the first syllable underwent a phonological change, for example, 독머 [toŋ.mə] /tok.mə/, (4) different character, but the same onset with the target, for example, 댄소—[tæn.so] /tæn.so/ (see Kim & Davis, 2002; Witzel et al., 2013), and (5) a control condition (all different), for example, 남무—[nam.mu]. Except for some control primes, no prime shared the vowel in the second syllable to prohibit any possible facilitation effects even though priming effects should not occur when the onset does not match (e.g., Forster & Davis, 1991). See the "Supplementary material" for a complete overview of the stimuli.

In total, participants were subjected to 400 items (80 targets × 5 conditions). Five lists of items were constructed such that each target appeared in all conditions across lists. These lists were counterbalanced over participants using a latin-square design. Therefore, this study employed a 5 × 5 design, with List as a non-repeated measure and prime type (same syllable, re-syllabification, phonological coda change, onset overlap, and control) as a repeated measure.

Apparatus and procedure. E-Prime 2.0 was used to administer the experiment. Primes were presented in Korean Courier New font (23 pt), and targets were presented in Korean Typo Crayon M font (23 pt) font using a Samsung S24E450F monitor. A typical masked priming procedure was used (see Forster & Davis, 1984), in which each trial comprised of a 1,000 ms fixation, followed by a 500 ms forward mask (###), a 50 ms prime, and a target (maximally presented for 2,500 ms). Participants read each target aloud as quickly and accurately as possible. All instructions were given in Korean. Before starting the experimental items, there were 10 practice trials, which were not included in the actual experiment.

Results. About 1.1% of all RTs were discarded due to (1) a failure to respond, (2) stuttering or repairing a response, (3) triggering the voice key using a non-verbal response (e.g., coughing), (4) or a failure to trigger the voice key. In addition, there were 0.9% errors across the board which were roughly equally distributed over conditions and therefore not further analysed.

The initial treatment of RT data for this analysis was as follows. First, we examined the shape of the RT distribution for the correct trials and excluded 15 data points faster than 200 ms (approximately 0.1% of the data) as outliers to meet the distributional assumption of the linear mixed effects model. This left 12,529 data points for further analysis, see Table 1 for the RTs. Response latencies were then analysed with a linear mixed effects model with subject and items as crossed random effects (e.g., Baayen et al., 2008) using the "lme4" package (Bates, Maechler, & Bolker, 2013) implemented in R 3.0.3 (R Core Team, 2016) to analyse RT for correct trials and error rates. The "lmerTest" package in R was used to calculate the p-values using Satterthwaite's approximation for the degrees of freedom (Kuznetsova, Brockhoff, & Christensen, 2014).

In our analysis, we opted not to use the maximum model method (Barr, Levy, Scheepers, & Tily, 2013; see also Baayen, Vasishth, Kliegl, & Bates, 2017), but instead we use an incremental approach to construct the optimal statistical model (see Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). The final model formula was [RT ~ Trial + List + Condition + (1 + Trial + Condition | Participant) + (1 | Item)]. We found there was a main effect of Trial (t = 2.0; $p < .05$) in the final model which indicated that people got slightly faster during the experiment, as well as a main effect of List (indicating that people got faster with each progressing block (t = 4.5, p < .001). We used the "multcomp" package (Hothorn, Bretz, & Westfall, 2009) for post hoc Tukey comparisons of Condition, and we found that there were no differences between the syllable, re-syllabify, and phonological change conditions themselves (all p's > .8), but these three conditions all differed significantly from the onset condition (z = 5.2, $p < .001$; z = 5.5, $p < .001$; z = 3.9, $p < .001$, respectively) as well as from the control condition (z = 8.9, $p < .001$, z = 10.2, $p < .001$; z =

8.9, $p < .001$, respectively). In addition, the onset condition also differed from the control condition ($z = 6.5$, $p < .001$).

Discussion. The main result of this experiment was that the same syllable condition, re-syllabification condition, and the coda change condition did not differ significantly. In addition, we found significant onset priming (in line with Witzel et al., 2013). The syllable result contrasts with findings in French (Ferrand et al., 1996; but see Brand et al., 2003) and Chinese (J.-Y. Chen et al., 2003; You et al., 2012) in which the syllable overlap played a more prominent role. One alternative account, however, for this effect, is that additional overlap beyond CV does not evoke additional priming. This would be similar to the "onset-plus" effect shown in Kim and Davis (2002) and is also consistent with results such as reported in Kinoshita (2000) who showed that additional overlap while naming English nonwords (e.g., suf—SIB vs sif—SIB) did not provide additional priming. We discuss this, and other alternatives, further in the "General discussion" section.

As Yoshihara et al. (2017) have shown that in the masked priming task the specific script employed (Japanese kanji vs kana) may influence the observed priming patterns, we ran an experiment in which reading the word is not necessary for the task at hand (see Verdonschot & Kinoshita, 2017). That is, in the masked priming task, participants must inevitably read the word as part of the task. In the phonological Stroop task, though people can read the word, there is no direct task involving necessary processing of the orthography, as participants must simply name the colour of the ink the word is written in.

Experiment 2—phonological Stroop task

Method

Participants. In total, 24 students (10 males aged 19-27 years, $M = 22.6$) from Konkuk University in Seoul (South Korea) participated in the experiment in return for 10,000 won.

Materials and design. See "Supplementary material B" for a complete overview of the stimuli.

In total, participants were shown 180 items (45 targets × 4 conditions). Four lists of items were constructed such that each target appeared in all conditions across lists. These lists were counterbalanced over participants using a latin-square design. Therefore, this study employed a 4 × 4 design, with List as a non-repeated measure and overlap (onset, onset control, onset-plus, and control) as a repeated measure.

Apparatus and procedure. E-Prime 2.0 was used to administer the experiment. Targets were presented in Korean Courier New font (32 pt) font using a Samsung S24E450F monitor. A typical Stroop colour naming procedure was used, in which each trial comprised of a fixation (+) for 100 ms, followed by the target (maximally 2500 ms) and an inter trial interval of 500 ms. Participants read each colour aloud as quickly and accurately as possible. All instructions were given in Korean. Before starting the experimental items, there were 10 practice trials, which were not included in the actual experiment.

Table 2. Naming latencies and percentage errors of Experiment 2 (phonological Stroop task).

Target colour (e.g., yellow; 노랑; /no.laŋ/)	Example		RT	*SD*	Effect	% error
Overlap	Hangul	IPA				
Onset C	낙문	/nak.mun/	503	76	14	0.1
Onset control	각문	/kak.mun/	517	75		0.2
CV	녹니	/nok.ni/	494	72	22	0.2
CV control	악니	/ak.ni/	516	78		0.2

IPA: International Phonetic Alphabet; CV: consonant–vowel; RT: reaction times, *SD*: standard deviation.

Results. About 0.8% of all RTs were discarded due to (1) a failure to respond, stuttering or repairing a response, (2) triggering the voice key using a non-verbal response (e.g., coughing), or (3) a failure to trigger the voice key. In addition, there were 0.2% errors across the board which were roughly equally distributed over conditions and therefore not further analysed.

The same treatment of RT data as in Experiment 1 was used. First, we examined the shape of the RT distribution for the correct trials and excluded 121 data points slower than 700 ms (approximately 2.8% of the data) as outliers to meet the distributional assumption of the linear mixed effects model. This left 4,159 data points for further analysis. Response latencies were then analysed in the same way as Experiment 1 (Table 2).

Again, we used an incremental approach attempting to construct the optimal statistical model (see Matuschek et al., 2017). The final model formula was [RT ~ Trial + List + Condition + (1 | Participant) + (1 | Item)]. We found there was a main effect of Trial ($t = 5.5$; $p < .001$) which indicated that people got slightly slower during the experiment, as well as a main effect of List ($t = 5.0$, $p < .001$). We used the "multcomp" package (Hothorn et al., 2009) for post hoc Tukey comparisons of Condition, and we found that the onset overlap was slower than its control condition ($z = 3.8$, $p < .001$), that the CV overlap condition was also slower than its control condition ($z = 6.5$, $p < .001$), and, in line with Kim and Davis (2002) and Witzel et al. (2013), that CV overlap with the colour name was faster than C overlap with the colour name ($z = 3.8$, $p < .001$). That is, when saying *yellow* (i.e., 노랑; /no.laŋ/) to 녹니 (/nok.ni/) was quicker than saying yellow to 낙문 (/nak.mun/) by means of increased overlap of the target colour and the underlying word's phonology.

Discussion. The main result of this experiment was that both onset and CV priming were obtained using a Stroop colour naming task. The CV syllable priming effect was greater than the onset priming effect. This substantiates earlier findings by Witzel et al. (2013) using a different (Stroop colour naming) task which has no direct orthographic involvement from naming a target word (such as the masked priming naming task). We will discuss the implications of these findings in the subsequent section.

General discussion

There is currently an ongoing debate concerning the phonological preparation unit of spoken word production. Specifically, this unit has been shown to be the phoneme in most European languages (e.g., Forster & Davis, 1991; Schiller, 2004), the syllable in Mandarin (J.-Y. Chen et al., 2002; J.-Y. Chen et al., 2016; O'Seaghdha et al., 2010), and the mora in Japanese (Kureta et al., 2006; Verdonschot et al., 2011). However, its standing in Korean is still unclear given that only two papers have investigated this topic using the Korean language (Kim & Davis, 2002; Witzel et al., 2013), and their results were not congruent even though both studies used a masked priming paradigm.

The purpose of this study was to further investigate Korean spoken word production using Hangul script (an alphabetic syllabary). To this end, we employed one of the two tasks that have been frequently used to investigate this matter, namely, the masked priming paradigm, in Experiment 1. In addition, we conducted a phonological Stroop task in Experiment 2. In both experiments, significant facilitation effects relative to control were observed when target and prime shared onset phonemes as well as when they (minimally) shared the initial CV.

First, with respect to the results of Experiment 1 (masked priming), native speakers of Korean showed preparation of the initial phoneme consonant of disyllabic non-words. We used a different set of stimuli to Witzel et al. (2013) but corroborated their findings, thereby positively attesting to the onset effect in Korean non-word naming (i.e., the first question of this article). The second result of Experiment 1 was the absence of a benefit for a complete syllable overlap. There were no signs of extra preparation benefits when sharing the whole syllable between prime and the target words (compared with the case where only part of the syllable was shared). That is, there were no differences between the identical syllable condition (e.g., prime: <독쇠>—[tok.swɛ]; target: <독가>—[tok.ka]), the re-syllabification condition (e.g., <독유> [to.gju]—<독가>—[tok.ka]) and the condition including the coda change due to nasalisation (e.g., <독머> [toŋ.mə]—<독가>—[tok.ka]). Our results show that all these three conditions elicited a similar amount of facilitation. These results favour the hypothesis that the syllable is not used as the initial unit of phonological planning in Korean in the segment-to-frame association process (Levelt et al., 1999) and that the extra benefit for the syllable may be simply due to more segments overlapping. In the example mentioned, the overlapping segment /to/ is shared by all three primes and may provide some extra benefit over only the onset [t] but the extra shared [k] with the target in [tok] compared with [to] or [toŋ] does not provide any additional benefit. Although some researchers obtained a different pattern for English native speakers (Kinoshita, 2000; Nakayama, Kinoshita, & Verdonschot, 2016), that is, they showed that native English language speakers did not show any increased advantage (facilitation) for CV priming over C priming, our Korean data suggest incremental insertion of phonemic segments into a metrical frame for Korean. An alternative explanation for our findings[2] is that our participants may not have had sufficient time to process the primes up to the point that re-syllabification or nasalisation could have been carried out. Thus, the reason for the equivalence of the first three conditions may have simply been that the first component/syllable was identical up to that point and is a match to the first character of the target nonword. Therefore, it remains unclear whether there is a syllable effect or just an onset-plus effect, and additional investigations, for example using a PWI task, should be undertaken to address this issue.

Although we did not find evidence for the role of the syllable in Korean, this does not necessarily mean that the syllable is not part of *any* phonological representation in this language. Syllable units are involved in spoken word production, but they may simply not be the ones selected *first* in the planning of the spoken word production. Therefore, we simply suggest that the first selectable phonological units during phonological encoding are likely to be phonemes, but not syllables in Korean. Note that even in many Indo-European language like English and Dutch, the syllable functions as an important unit in the spoken word production. Hence, the present results do not contradict the linguistic, orthographic, and/or psycholinguistic evidence as well as the data from speech errors, supporting the syllable as an important unit in the spoken word production. Although the direction is opposite to English/Dutch, a good (reversed) illustration of this issue can be found in J.-Y. Chen et al. (2016; especially their Figure 1) in which they propose that the existence and activation of onset segments in Mandarin (or Japanese) is possible, but it would have to be indirect through a syllable unit (or mora unit in Japanese). Therefore, this activation would potentially be weaker. In addition, it may be that after proximate unit selection, subsequent processing may be highly automatic (J.-Y. Chen et al., 2016) and therefore less susceptible to priming. Finally, Yoshihara et al. (2017) and Verdonschot and Kinoshita (2017) have shown in Japanese that script type may influence phonological activation depending on the task. That is, using masked priming, even when prime and target were overlapping in the first mora, this proved not to be enough. If one uses kanji in the masked priming task, the full pronunciation of the first kanji must be overlapping to show any priming effect. Conversely, this was not the case when the phonological Stroop task was used (then a mora was enough even with kanji).

Given the alphabetic syllabary status of Korean Hangul, one might wonder here if the presence of an onset priming effect in Experiment 1 may have been due to any possible influence of orthographic cues provided to the participants, which show alphabetic characteristics within a letter block corresponding to a syllable. To preclude this possibility, we conducted a phonological Stroop task in Experiment 2. Since the Stroop task does not include any prompts, the presence of segment preparation should not be influenced by them. Rather it should reflect a more intrinsic property of the Korean production planning. As expected, it was shown in the results of the Stroop task that there was a significant onset priming effect. These results suggest that the onset priming effect obtained in the masked priming task was not due to the influence of orthographic activation, if any. Consider the findings of Yoshihara et al. (2017) that in the masked priming task in Japanese, priming patterns could change depending on the script type. That is, Japanese targets showed mora priming when primes were written in kana, but only morphemic (full kanji overlap) priming when the same prime words were written in kanji. This is particularly interesting as Korean Hangul is an alphabetic syllabary (Taylor & Taylor, 2014) which means that one Hangul character represents both a syllable as well as discrete phonemes. Our results showed that significant onset and onset-plus effects were readily obtained by this task and confirm the vital role the phoneme plays within the speech production system in Korean.

Overall this study offers a novel example of how language-specific properties may influence the production of spoken words. These language-specific units of phonological preparation support the "proximate unit principle," whereby "the initial transition to phonological form in production is enacted by different types of explicitly selectable phonological units across languages" (cf. J.-Y. Chen et al., 2016). The idea of "proximate units" was proposed by O'Séaghdha and his colleagues in 2010 and is defined as "the first selectable phonological units below the level of the word or morpheme." As these units are basically acquired and stabilised with the exposure to the productive vocabulary of the native language, proximate units could vary in form across languages and could change from one to other units. The original model of speech production by Levelt et al. (1999) cannot easily explain the language-specific implementation in that it needs to specify different versions for each language (see Roelofs, 2015). O'Séaghdha proposes that theories of language production are explained by principles rather than stipulated roles for particular units. Without changing the basic processing scheme of the current models of speech production (e.g., developed by Levelt et al., 1999), the proximate unit principle can handle cross-linguistic differences as it assumes that the principle (e.g., prosodification) is the same between languages. In other words, English/Chinese/Japanese all have the prosodification step (see Roelofs, 2015) which is the principle of operation; however, the initial (or proximate) unit to be used in this step depends on the language (e.g., phonemes in English, syllables in Chinese, and moras in Japanese).

Before we reach any conclusion, it should be noted that we have not (yet) offered a straightforward explanation for the disparity between the two previous studies (as well as this study). The present results and those of Witzel et al. (2013) do not seem to concur with those of Kim and Davis (2002) where the onset priming effect was not significant. It is unclear what causes such discrepancy between the studies, but there might be task differences between Kim and Davis (2002) on one hand and Witzel et al. (2013) and this study on the other, such that real words were used in the former, eliciting no significant effect of onset priming, while the latter two studies used non-words, with a significant onset priming effect. This speculation awaits further investigation of how the lexicality effect might involve preparation of the spoken word production in Korean. It is also unclear whether Korean speakers are as firmly locked into a phoneme as English or Dutch speakers are (as Korean showed mixed theoretical and experimental evidence for both phonemic and syllabic influences during the initial stages of phonological encoding in Korean). Hence, it remains to be seen whether the preparation unit of spoken word production in Korean is always locked onto a phoneme or it could be varied depending on experimental context (Yoshihara et al., 2017). To determine the precise nature of the production planning effect, additional research making use of more extensive experimental procedures is needed to see whether there are distinct syllabic effects in Korean. For our future research, we will employ the standard implicit priming (Meyer, 1990, 1991) and the picture-naming (T.-M. Chen & Chen, 2013; J.-Y. Chen et al., 2016) tasks and investigate whether using these tasks we observe a similar pattern of results to what we found in this study.

To summarise, the results of this study shed more light on the Korean preparation unit of spoken word production investigating both the role of Hangul script as well as the role of linguistic features of the Korean language (e.g., nasalisation, re-syllabification) which may affect spoken word production processes. We believe that based on the present results, although there is mixed theoretical and experimental evidence in the literature, the Korean proximate unit is essentially phonemic, and there seems to be no additional benefit for the syllable in the early stages of speech planning.

Declaration of conflicting interests

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Supplementary material

The Supplementary material is available at qjep.sagepub.com

Notes

1. A vocalic interval is the total speech signal between the onset and the offset of a vowel (or vowel cluster). Likewise, a consonantal interval is the total speech signal between the onset and the offset of a consonant (or consonant cluster). For example, the word "text" has the following vocalic and consonantal intervals, /t/ /ɛ/ and /kst/.
2. Pointed out to us by an anonymous reviewer.

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