# The Syllable Frequency Effect in Semantic Categorization Tasks in Korean

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## Abstract

Previous studies of syllable frequency effects have proposed that inhibitory effects due to high first syllable frequency were the products of competitions between activated lexical candidates within a lexical level. However, these studies have primarily used lexical decision tasks to examine the nature of syllable frequency effects. This study investigates whether a syllable frequency effect can arise in semantic categorization tasks and whether phonologically or orthographically defined syllables interact with semantically related variables such as morphological family size. If the syllable frequency effect was created by activations and competitions on a lexical level, it is highly possible that the effect was related to semantic categorization tasks. To test this hypothesis, we conducted two experiments. In Experiment 1, morphological family size and phonological syllable frequency were factorially manipulated. In Experiment 2, morphological family size and orthographic syllable frequency were factorially manipulated. The results demonstrate that morphemes have no relationship with phonological syllables but do with orthographic syllables. This suggests that phonological syllables and orthographic syllables have different roles in the syllable frequency effect on visual word recognition process.

***Keywords:*** Syllable, syllable frequency effect, phonological syllable, orthographic syllable, morphological family size

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## 1. Introduction

In the area of visual word recognition, one of the foremost topics is whether sublexical units such as syllables play a critical role in activating whole-word candidates in mental lexicon. There already exists evidence that syllables are reliable sublexical units; previous research has shown that participants performing a lexical decision task had longer response times for words with high-frequency first syllables than for words with low-frequency first syllables.

According to studies that have supported the role of syllable units, a given multi-syllable word is automatically decomposed into syllables; if the word has a high-frequency first syllable, then it activates more lexical candidates than does the word with a low-frequency first syllable [1]. For example, in the Spanish language, the syllable "de" has a higher frequency in the first syllable than does "ci." Correspondingly, when participants are asked to decide whether a presented word is real, a word with "de" requires a longer time than one with "ci" [2].

Such results have been consistently shown in syllable-based languages such as Spanish, French, and German [1][3], a phenomenon known as the syllable frequency effect. However, these results raise important issues. First, most studies on the syllable frequency effect have been conducted only in Western languages [4]. Second, although syllables are composed of phonological, orthographic, and morphological representations, researchers have focused on the role of phonological representation and evidence thereof. Third, the syllable frequency effect has mostly been observed in lexical decision tasks.

Most evidence of the syllable frequency effect has been demonstrated in Spanish language studies [1]. According to these studies, Spanish, which is characterized by clear syllable boundaries and a very close grapheme-phoneme correspondence, has a regular syllabic structure that is resistant to stress movement; moreover, there is almost no ambisyllabicity compared to the syllabic structures of English. Therefore, they inferred that languages having similar characteristics would exhibit the syllable frequency effect, a hypothesis supported by subsequent studies in the French and German languages. However, the role of the syllable frequency effect in East Asian languages remains unclear. This study, therefore, aims to investigate whether Korean, a representative East Asian language, will demonstrate the syllable frequency effect, given its clear syllable boundaries and very close grapheme-phoneme correspondence. The Korean language has a very different syllable structure compared to Romance and non-Romance languages. The biggest difference can be found in the Korean writing system. Although the Korean language is basically alphabetical like the Western languages, several alphabetical units are written in a same space but in different locations to express one syllable. For instance, 말/mal/ is a single-syllable word with two consonants (ㅁ/m/ and ㄹ/l/) and one vowel (ㅏ/a/). This form difference may produce results contrary to those from studies previously conducted in Western languages [5]. The fact that a different syllable frequency effect could result from form difference shows that the syllable frequency effect could be divided into phonological and orthographic representations.

In addition, although the syllable frequency effect may be confounded by orthographic and morphological representations, most studies tend to emphasize phonological syllables. A word presented visually has to be influenced by visual representations such as letters [6], basic orthographic syllabic structure (BOSS) [7], and the body of the BOSS [8]. It may also be affected by morphological representations such as morphemes [9]. A study by Conrad, Grainger, and Jacobs (2007) on the French language found the syllable frequency effect to be a positively related interaction between letter order (bigram frequency) and syllable frequency [4]. In contrast, there was no evidence indicating a direct or indirect relationship between morphemes and the syllable frequency effect, although it is highly possible that these two linguistic representations have a relationship. This is because most studies that examined the critical role of syllables used multisyllabic words, and it is highly possible that multisyllabic words contain more than one morpheme. However, those studies overlooked the possibility that morphemes may influence the syllable frequency effect. A study by Alvarez, Carreiras, and Taft [2] employed several lexical decision tasks in order to find the relationship between syllables and morphemes in the Spanish language. This study, in contrast, did not compare the high- and low-syllable frequency effects while keeping the root morpheme frequency constant, although it demonstrates that the root morpheme plays an important role in the BOSS effect.

This study explores whether morphological representations such as morphological family size are involved in the syllable frequency effect. In particular, we investigate the role of morphemes in phonological and orthographic syllables. Some words in Korean appear differently as phonologically and orthographically defined syllables; for instance, 국민(people) consists of two syllables, 국/민, and each syllable is pronounced as /kuk/ and /min/. However, the pronunciation in everyday usage is /kung-min/. This characteristic allows words to have different syllable frequencies in orthographic /kuk-/ and phonological usage /kung-/. Moreover, the morpheme /kuk-/ means "people" but the morpheme /kung-/ means "palace" in the Korean language. Thus, the word 국민 can have a different orthographic syllable frequency based on /kuk-/, a phonological syllable frequency based on /kung-/, and morphological family size based on its meanings.

Thus, in this study, we examine the different roles of morphemes in phonological syllables and orthographic syllables using an orthogonal experimental design that can yield more information on how these three factors influence one another.

Lastly, many previous studies used lexical decision tasks to uncover the syllable frequency effect. This study, on the other hand, utilizes semantic categorization tasks, as morphological representation is more sensitive to semantic activation than to lexical activation. Semantic activation refers to the number of semantically related words in the mental lexicon that are activated by a presented target word, and lexical activation is defined by how many orthographically or phonologically similar words are activated on a given lexical entry, such as the index of a dictionary. For these reasons, we rely on semantic categorization tasks. In addition, these tasks can provide more information on which representation is more dependent on the semantic level. If there is an interaction between morphological family size and phonological syllable frequency, then phonological syllables may be an index of semantic knowledge. On the contrary, if orthographic syllable frequency interacts with morphological family size, then orthographic syllables may play a role in activating semantic knowledge.

To investigate these aforementioned issues pertaining to the syllable frequency effect, we conducted two semantic categorization tasks. In Experiment 1, we tested the difference in response time between the modulation of phonological syllable frequency and morphological family size. In Experiment 2, we tested the difference between orthographic syllable frequency and morphological family size.

## 2. Experiment 1

To investigate the relationship between morphemes and phonological syllables, we tested whether the phonological syllable frequency, while controlling orthographic syllable frequency, was modulated by the morphological family size. We defined the morphological family size as the number of words sharing a morpheme of an initial syllable of a target word.

When we asked participants whether a presented word was a regular or irregular word, the representative effect of the morphological family size was known as the facilitatory effect, characterized by rapid response and low error rate. Schreuder and Baayen (2007) showed that the feedback effect at the semantic level contributed to the facilitatory effect of the large morphological family size [10]. Their model assumed two pathways: one from the lexical entry level to the semantic level (feedforward) and one from the semantic level to the lexical entry level (feedbackward). The feedforward pathway activates lexical candidates that are similar to a target, and the feedbackward pathway sends activations to activated lexical candidates that share the same meaning. This feedbackward activation facilitates a faster lexical decision process. Therefore, if a target activates multiple similar lexical candidates and has many semantically related concepts at the semantic level, the response latency of the target is faster than that which has few lexical candidates and semantically related concepts. For instance, in English, because *dog* has many semantically related items, such as *doghouse*, *dogfight*, *doggy*, and *dogcart*, the response of *dog* is faster than that of *table*. In contrast, the phonological syllable size effect is likely to be affected by the number of words activated by the first syllable of a presented target word.

In this context, it is expected that morphemes will be related to phonological syllables and the response latency and error rate will be reliably modulated by the morphological family size and phonological syllable frequency. For example, words with a high phonological syllable frequency and high family size effect will produce faster response times and lower error rates than words with high phonological syllable frequencies and low family size effects.

### 2.1 Methods

#### Participants

Twenty-eight students at Korea University participated in the experiment. They were all native Korean speakers with normal or corrected-to-normal vision.

#### Design and Materials

Sixty-four bisyllabic words were selected from the *Sejong* corpus[1] database composed of 3,000,000 *eo-jeols*. The words selected matched those used in previous studies such as those by Kwon (2009) and Kim (2010) [11, 12]. Sixteen bisyllabic words were assigned to each condition. For this study, phonological syllable frequency was defined by the number of words sharing the first phonological syllable of a target, and morphological family size was computed on the basis of the number of words sharing the morpheme of a target's first syllable.

[1] *Sejong* corpus was constructed by the Ministry of Culture and Tourism and the National Institute of the Korean Language in Republic of Korea in 1998. This corpus is composed of approximately 200 million *eo-jeols*, which are the basic unit of phrases in Korean. Only 3 million *eo-jeols* can be digitized and thus were the ones used in the present study(http://www.sejong.or.kr).

Within-subjects two-way ANOVA served as the experimental design. Each of the factors has two levels: (1) morphological family size and high vs. low (H-MFS vs L-MFS) and (2) phonological syllable frequency and high vs. low (H-PSF vs. L-PSF). From this, we derived four possible conditions: (1) morphological family size is high and phonological syllable frequency is high; (2) morphological family size is high and phonological syllable frequency is low; (3) morphological family size is low and phonological syllable frequency is high; and (4) morphological family size is low and phonological syllable frequency is low. All materials were controlled by word frequency and other frequencies that were known to affect word recognition except phonological syllable frequency and morphological family size (**Table 1**). To conduct the semantic categorization task, we selected animate words because all the targets were inanimate words. These animate words, as they were insertion materials, were excluded from the actual analysis.

**Table 1**. Features of conditional words in Experiment 1

| Features of the stimuli | H-MFS | | L-MFS | |
|---|---|---|---|---|
| | H-PSF | L-PSF | H-PSF | L-PSF |
| Orthographic syllable frequency | 53.5 | 41.5 | 51.0 | 43.5 |
| Phonological syllable frequency | 37.0 | 5.0 | 39.0 | 10.0 |
| Morphological family size | 31.0 | 22.0 | 4.0 | 3.0 |
| Word frequency | 39.0 | 34.5 | 27.5 | 30.5 |
| Phonemes and graphemes | 6.0 | 6.0 | 6.0 | 5.5 |
| Orthographic neighborhood size | 13.7 | 11.8 | 12.6 | 11.4 |
| Log of bigram frequency | 3.3 | 3.3 | 3.3 | 3.3 |
| Higher-frequency orthographic neighborhood size | 39.0 | 21.1 | 37.0 | 31.4 |

*Note*: 1. All figures, except those for phonemes and graphemes, refer to the average occurrence in the *Sejong* corpus. For instance, the figure “39” at the word frequency row indicates that words in the condition occurred 36 times within the 3 million *eo-jeols* in the corpus.
2. Orthographic syllable frequency refers to the number of words sharing the first orthographic syllable of target words.
3. Phonological syllable frequency refers to the number of words sharing the first phonological syllable of target words.
4. Morphological family size refers to the number of words sharing the first morpheme of target words.
5. Word frequency refers to the frequency of occurrence of target words.
6. Phonemes and graphemes refer to the phonemes and graphemes of target words.
7. Orthographic neighborhood size refers to the number of word neighborhoods sharing all but one letter with target words. Some examples are the neighborhoods of 친구 are 친가, 인구, and 침구.
8. Log of bigram frequency refers to the logalism value of the frequency of occurrence of two letters.
9. Higher-frequency orthographic neighborhood size refers to the number of more frequently occurring words in word neighborhoods than the target words.
10. H-MFS refers to high morphological family size; L-MFS refers to low morphological family size; H-PSF refers to high phonological syllable frequency; and L-PSF refers to low phonological syllable frequency.

## Apparatus

The experiment was conducted using an IBM compatible 586 PC that was installed with E-prime version 2.0. A word was presented on the center of the 17" CRT monitor and the participant entered his response on the keyboard.

## Procedure

The participants were informed that they would be shown a series of words. After seeing each word, they need to respond on whether it was animate or inanimate. They were instructed to press number 1 if the given word was an animate, such as 참새 (bird), and number 2 if the word was inanimate, such as 반란 (revolution). Additionally, they were instructed to respond as quickly as possible to the word in order to minimize errors. Each trial started with a fixation point (+) on the center of the screen that lasts for 1,000 ms. Immediately after the fixation, a word was presented on the center of the screen. The stimulus remained on the screen until the participant responded by pressing number 1 or 2. If the participant did not respond before 1,500 ms has elapsed, the next trial began. All stimuli were randomly presented to participants. **Fig. 1** depicts the sequence of presenting the stimuli and intervals.

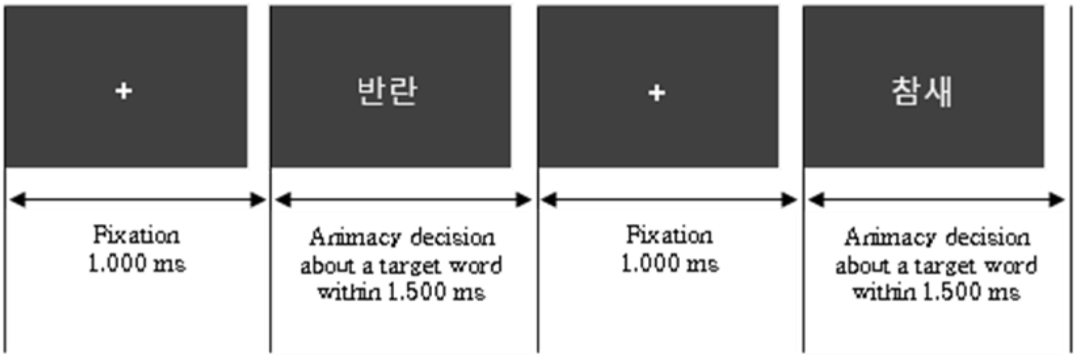


**Fig. 1**. Sequence of presenting stimuli

This figure describes the sequence of presenting the stimuli in Experiment 1. Participants had to decide whether a given word was an animate noun or an inanimate noun as soon as possible before 1,500 ms elapse. Otherwise, the fixation disappears and the next trial begins.

## 2.1 Results

Representative values were defined by means. A wrong response, such as animate words being misidentified as inanimate words and vice versa, resulted in the removal of fewer than 1% of the total words. However, if the errors made on a certain word was not significant, then it was not removed from the analysis. The minimum and the maximum values are the lowest and highest extreme values, which can be easily obtained by sorting the order of the values. Outliers always include the sample maximum, sample minimum, or both, depending on whether they are extremely high or low. However, the sample maximum and minimum are not necessarily outliers, especially if they are not unusually far from the other observations. In this study, extreme values were defined as those responses that exhibited lesser or greater than mean ± 2 standard deviation from each condition. A 2 × 2 repeated measures ANOVA (analysis of variance) was conducted on the participants' response times. In statistics, ANOVA is an omnibus test, which means that it tests for an experiment's overall effect. The associated procedure involves the observed variance in a particular variable being partitioned into components attributable to different sources of variation. ANOVA is useful in comparing two, three, or more means. The descriptive statistics are shown in **Table 2**.

Results from Experiment 1 showed that morphological family size had no significant effect on either participants or items [$F_1$ (1,27) = 1.04, $p > .05$; $F_2$ (1,15) = .05, $p > .05$]. Phonological syllable frequency, however, had significant effects. Words with high phonological syllable frequency had slower responses than words with low phonological syllable frequency [$F_1$ (1,27) = 8.88, $p < .05$; $F_2$ (1,15) = .06, $p > .05$]. There was no interaction found between the participants or items [$F_1$ (1,27) = .46, $p > .05$; $F_2$ (1,15) = .16, $p > .05$].

**Table 2**. Mean reaction times (M; in milliseconds), standard deviation of mean reaction times (SD; in milliseconds), and error rates (E; in percentage) from Experiment 1

| | H-PSF | | | L-PSF | | |
|---|---|---|---|---|---|---|
| | **M** | **SD** | **E** | **M** | **SD** | **E** |
| **H-MFS** | 632 | 65 | 6 | 613 | 66 | 4 |
| **L-MFS** | 634 | 61 | 6 | 622 | 71 | 9 |

*Note*: M denotes the mean reaction times of 'yes' button presses from participants; SD denotes the standard deviations of participants' mean reaction times; E denotes the error rates of target words.
H-MFS refers to high morphological family size; L-MFS refers to low morphological family size; H-PSF refers to high phonological syllable frequency; and L-PSF refers to low phonological syllable frequency.

In the analysis of error rate, morphological family size had a significant effect on participants [$F_1$ (1,27) = 4.83, $p$ < .05; $F_2$ (1,15) = .28, $p$ > .05], with more errors made for words with a low morphological family size than those with a high morphological family size. The phonological syllable frequency on error rates was not significant for either participants or items [$F_1$ (1,27) = 1.45, $p$ > .05; $F_2$ (1,15) = .28, $p$ > .05].

According to the results, the inhibitory effect of high phonological syllable frequency was consistent with previous research using a lexical decision task, i.e., words with a high phonological syllable frequency were recognized more slowly than words with a low phonological syllable frequency. Moreover, the inhibitory effect found in the present study tended to be reduced by the morphological family size particularly among targets with a low phonological syllable frequency for which the interaction between the two factors was not significant. This indicates that the inhibitory effect induced by phonological syllables was constant regardless of which tasks were used. It also suggests that morphemes might not be responsible for the phonological syllable frequency effect.

## 3. Experiment 2

The results of Experiment 1 demonstrated the role of morphemes and phonological syllables in the syllable frequency effect. In Experiment 2, we examined the relationship between morphemes and orthographic syllables while controlling phonological syllable frequency. We hypothesized that if the relationship between morphemes and orthographic syllables is similar to the relationship between morphemes and phonological syllables in the syllable frequency effect, the results of Experiment 2 should coincide with those of Experiment 1.

### 3.1 Methods

#### Participants

Twenty-eight Korea University students with normal or corrected-to-normal vision participated in the experiment. None had participated in the previous experiment.

#### Design and materials

As with Experiment 1, sixty-four bisyllabic words were selected from the *Sejong* corpus database. Sixteen bisyllabic words were assigned to four conditions. Orthographic syllable frequency was defined as the number of words sharing the first orthographic syllable of a target. Morphological family size was defined as it was in Experiment 1.

The experimental design in Experiment 2 was identical to that used in Experiment 1 with one exception. In this experiment, we used orthographic syllable frequency instead of phonological syllables. Hence, the factors involved were (1) morphological family size (high vs. low) and (2) orthographic syllable frequency (high vs. low). Sixty-four bisyllabic Korean words were chosen from the *Sejong* corpus database. The words are the same as those used in previous studies [10][11]. All the materials were controlled by word frequency and other frequencies as in Experiment 1 (**Table 3**). For the semantic categorization task, the stimuli included animal and plant names. These stimuli, as they were insertion materials, were excluded from the actual analysis.

**Table 3**. Features of conditional words in Experiment 2

| Features of stimuli | H-MFS | | L-MFS | |
|---|---|---|---|---|
| | **H-OSF** | **L-OSF** | **H-OSF** | **L-OSF** |
| Orthographic syllable frequency | 90.1 | 36.5 | 87.9 | 31.7 |
| Phonological syllable frequency | 59.5 | 58.2 | 60.4 | 57.8 |
| Morphological family size | 33.4 | 27.4 | 4.13 | 5.94 |
| Word frequency | 15.5 | 15.6 | 15.2 | 11.3 |
| Phonemes and graphemes | 5.5 | 6.0 | 6.0 | 6.0 |
| Orthographic neighborhood size | 15.2 | 12.0 | 14.8 | 11.3 |
| Bigram frequency | 3.3 | 3.2 | 3.3 | 3.3 |
| Higher-frequency orthographic neighborhood size | 75.4 | 33.5 | 76.0 | 26.5 |

*Note*. H-MFS refers to high morphological family size; L-MFS refers to low morphological family size; H-OSF refers to high orthographical syllable frequency; and L-OSF refers to low orthographical syllable frequency.

### Apparatus

The same types of computer, keyboard, monitor, and program used in Experiment 1 were used in Experiment 2.

### Procedure

The same procedure used in Experiment 1 was employed in Experiment 2.

## 3.2 Results

The method of analysis used was identical to that used in the Experiment 1. An incorrect response caused removal of less 1% of the cases. The relevant statistics are shown in **Table 4**.

**Table 4**. Mean reaction times (M; in milliseconds), standard deviation of mean reaction times (SD; in milliseconds), and error rates (E; in percentage) from Experiment 2

| | H-OSF | | | L-OSF | | |
|---|---|---|---|---|---|---|
| | M | SD | E | M | SD | E |
| H-MFS | 629 | 82 | 5 | 623 | 69 | 4 |
| L-MFS | 643 | 76 | 7 | 653 | 88 | 5 |

*Note*. H-MFS: H-MFS refers to high morphological family size; L-MFS refers to low morphological family size; H-OSF refers to high orthographical syllable frequency; and L-OSF refers to low orthographical syllable frequency.

Orthographical syllable frequency did not have any significant effect on either participants or items [$F_1\,(1,27) = 1.13$, $p > .05$; $F_2\,(1,15) = .00$, $p > .05$]. However, morphological family size had a significant effect on both participants and items [$F_1\,(1,27) = 15.82$, $p < .05$; $F_2\,(1,15) = 11.10$, $p < .05$]. Words with a high morphological family size elicited faster response times than words with a low morphological family size. There was no interaction between the participants and items [$F_1\,(1,27) = 1.37$, $p > .05$; $F_2\,(1,15) = .00$, $p > .05$].

In the analysis of error rate, the main effect of morphological family size was not significant for either participants or items [$F_1\,(1,27) = 1.91$, $p > .05$; $F_2\,(1,15) = .25$, $p > .05$]. The main effect of orthographical syllable frequency was also not significant on either participants or items [$F_1\,(1,27) = 3.05$, $p > .05$; $F_2\,(1,15) = .19$, $p > .05$].

The results of the second experiment showed that morphemes affect orthographical syllables and phonological syllables differently. The facilitatory effect of a high morphological family size and the marginal interaction between the two factors supported the possibility that in the Korean language, orthographical syllables might have a closer relationship with morphemes than do phonological syllables.

## 4. Discussion

The purpose of this study was to determine whether morphemes had an impact on the syllable frequency effect (either phonologically or orthographically) by using semantic categorization tasks that were known to be more sensitive to semantic processing. The study sought to explore an area overlooked in previous research, namely, how syllable frequency might overlook the possible role of morphemes and how morphemes might be more relevant to orthography than to phonology.

The results of Experiment 1 demonstrated that the morphological family size did not affect the phonological syllable frequency effect: there was no significant difference between large and small morphological family size in both high and low phonological syllable frequencies. On the contrary, the results of Experiment 2 showed that morphemes might be more closely related to the orthographically defined syllable frequency effect. Words with a large morphological family size and a high orthographical syllable frequency elicited a faster response rate than words with a small morphological family size and a high orthographic syllable frequency.

One explanation for these results is that phonological and orthographic representations might be processed in different stages during lexical processing, since the effect of morphological family size at the semantic level involves only an orthographic syllable frequency effect. Indeed, in the Korean language, morphemes may exhibit a stronger association with orthography than with phonology. In other words, there exists the possibility that skilled readers access orthographic information (i.e., spelling) to obtain semantic information after they have processed phonological information (i.e., sound).

Native speakers of the Korean language do not rely on grapheme-to-phoneme conversion processes since the language strictly follows the grapheme-to-phoneme correspondence (GPC) rule. These readers have already internalized the rule to a point at which they can automatically process phonological syllables through an initial processing stage (from input to lexical entry level). The output of the initial processing is the group of words sharing the first phonological syllable of the target word. Meanwhile, processing the orthography of said targets necessitate the referring information of the lexicon (including spellings and meanings) in order to select correctly among the activated lexical candidate group in a lexical entry level. For this reason, only Experiment 2 was able to demonstrate that morphological family size as represented in the lexicon can manipulate the syllable frequency.

Furthermore, studies on the effects of pseudohomophones as well as electroencephalography (EEG) studies support this interpretation. In research involving pseudohomophones to establish the phonological influences on visual word recognition, skilled readers misunderstood a pseudohomophone word as a legal word, such as *nale* for *nail*, and their lexical decision for *nale* was slower than for *nail*. This suggests that skilled readers phonologically process a given word as fast as possible without considering orthography or matching the phonology of a target with its meaning.

EEG research on the subject also provides supplementary evidence. EEGs can record brain activity within milliseconds, helping to demonstrate the processing stage sequence. An EEG study by Vergara and Carreiras (2004) using Spanish words showed that the different brain waveforms produced between high and low phonological syllable frequencies appeared 200 ms after the target onset (P200 component), while the different brain waveforms in semantic activation usually appeared around 400 ms after target onset (N400 component) [13]. Although this evidence did not clearly state the orthographic and morphemic information that were represented in the same level in the lexicon, it was clear that phonological syllables were processed earlier than orthographic syllables.

In the Korean language, the phonological syllable frequency effect might exert influence on activating lexical candidates, whereas the orthographic syllable frequency effect might be a semantically related representation.

## 5. Conclusion

The present study investigated the relationship between morphological family size and syllable frequency effect. To this end, we divided the relationship into the phonologically and orthographically related parts and attempted to find the different effects of each part using semantic categorization. The results showed that morphological family size, which is directly related to semantics, had an influence on both phonological and orthographic syllable frequency effects. However, the response times in each condition were very different. This indicates that phonological and orthographic syllables play different roles in lexical processing, i.e., that phonological information might be processed initially while orthographic information might be activated after initial processing in the word process stages.

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