

The Time-course of Cross-language Morphological Activation in Korean-English Bilinguals: Evidence from a Masked Priming Experiment*

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A masked priming experiment with three prime durations (36, 48, and 72 ms) was conducted to examine the time course of cross-language activation of constituent morphemes in Korean-English bilingual readers. Results showed that real suffixed words in Korean L1 as the primes significantly facilitated responses for the corresponding English L2 translated stems at all prime durations. In contrast, suffixed pseudo-word primes (i.e., an illegal combination of a stem and a suffix) in Korean elicited a significant priming effect on English L2 stems only when the prime duration was 48 or 72 ms. These results suggest that there is an early cross-language activation of constituent morphemes in morphological complex words in bilingual reading. However, the time course of the decompositional process is dependent upon the lexicality of the complex words. The early morphological processing in bilingual readers may be driven by supralexical analysis, whereas sublexical analysis of complex words occurs later in cross-language activation in bilingual reading.

Keywords: *decomposition, derivational morphology, cross-language activation, masked priming*

1. Introduction

A great amount of literature has provided evidence that decomposition

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is a robust mechanism underlying morphological processing using different experimental paradigms including simple lexicon decision (Taft, 2004; Taft and Forster, 1975), cross-modal priming (Marslen-Wilson, Tyler, Waksler, and Older, 1994), and visual masked priming (Longtin and Meunier, 2005; Longtin, Segui, and Hallé, 2003; Rastle, Davis, and New, 2004). In particular, results from those visual masked priming experiments suggest that readers' morphological sensitivity is based on morphological relatedness (e.g., *teacher*-TEACH) and pseudomorphological relatedness (e.g., *corner*-CORN). The latter case is more interesting in that *corner* facilitates the activation of CORN. However, *brothel* has no priming effect on BROTH, which is only orthographically related. Therefore, it appears that morphological priming effect is largely dependent upon the embedded morphological structure, rather than simple orthographic relatedness (Longtin, Segui, and Hallé, 2003; Rastle, Davis, and New, 2004).

To address the question of decomposition in processing morphologically complex words, Longtin and Menuier (2005) conducted a masked priming study with a 47 ms prime duration. The researchers manipulated the relationship between the prime and target pairs in French in terms of their orthographic, morphological, and semantic relatedness. The researchers sought to examine whether morphological priming effect is the result of analysis of individual constituent morphemes (i.e., decomposition) or the whole word form. If a morphologically complex pseudoword as prime (e.g., *quickify*) induces a faster reaction time to its stem as target (i.e., *quick*) as compared to the control item, it suggests that morpheme-based decomposition must have occurred and it cannot be explained by the shared lexical representation with the whole pseudoword which does not exist. The relationship between primes and targets was manipulated into four conditions: existing derived words (e.g., *canaliser*-CANAL), interpretable derived pseudowords (e.g., *canaleur*-CANAL), non-interpretable derived pseudowords (e.g., *canalitude*-CANAL), and non-morphological ending pseudowords (e.g., *canalare*-CANAL). In their results, significant priming effects were observed when real derived words and derived pseudowords with illegal combination of a stem and a suffix regardless of interpretability were used as the primes and the stems as the targets. However, there was no priming effect for non-morphological ending

pseudowords as compared to unrelated words. These results suggested that the morphological structure of the complex words plays a critical role in the early stage of word recognition, regardless of lexicality or interpretability.

SY. Kim, Wang and IY. Ko (2011) extended Longtin and Meunier (2005)'s study to Korean-English bilingual readers. A set of lexical decision experiments were designed to examine whether cross-language activation occurs via decomposition during the processing of derived words in Korean-English bilinguals. In their experiments, when participants were given a real derived word (e.g., 매력적, "maylyekcek", *attractive* in English), an interpretable derived pseudoword (e.g., 매력화, "maylyekhwa", which is similar to English pseudoword *attract-ization*), and non-interpretable derived pseudoword (e.g., 매력식, "maylyeksik", which is similar to English pseudoword *attract-icide*) in Korean as a prime, response times for the corresponding English-translated stem (i.e., *attract*) were significantly faster than when they had received an unrelated word (Experiments 1 and 3). In addition, no priming effect was shown when non-morphological ending words (e.g., 매력래, "maylyeklay", which is similar to English pseudoword *attract-el*) were used as primes (Experiment 2). Their findings demonstrated that cross-language activation of morphologically complex words occurs in bilingual reading and, furthermore, bilingual readers decompose complex words and are sensitive to morphological structure independent of lexicality or interpretability, consistent with the findings in monolingual studies (e.g., Longtin and Meunier, 2005).

SY. Kim et al. (2011)'s findings provided strong evidence for shared bilingual lexical storage at the morphemic level. Several studies on bilingual lexical processing using a masked translation priming methodology showed that the priming effect from L1 to L2 is robust across different bilingual populations such as Spanish-English (e.g., Basnight-Brown and Altarriba, 2007), Hebrew-English (Gollan, Forster, and Frost, 1997), and Chinese-English (Jiang, 1999; Jiang and Forster, 2001). In these studies, bilinguals showed faster lexical decision latencies when the L2 target was preceded by its translated L1 prime. However, it is unclear whether the translation priming effect observed on morphologically less complex words used in aforementioned bilingual studies (e.g., Basnight-Brown and

Altarriba, 2007; Jiang and Forster, 2001; Jin, 1990) can be extended to processing morphologically complex words. Thus, taking both morphological priming and cross-language priming into account, SY. Kim et al.'s study (2011) suggested that the decomposition of morphologically complex words may be considered as a robust processing mechanism not only within a language but also across languages.

Note that the experiments in SY. Kim et al. (2011) employed a relatively long prime duration (150 ms) which made the primes more visible. Therefore, in order to examine whether the morphological priming effect shown in SY. Kim et al. was indeed a fast and automatic process, we included shorter prime durations in the present study to address the time course of cross-language morphological decomposition. The present study employed the same design in SY. Kim et al. but varied the prime duration (36 ms, 48 ms, and 72 ms). This design allows us to test whether early morphological decomposition occurs in bilingual lexical processing and how it changes over time.

Several studies have examined the time-course of morphological priming in monolingual readers (Dominguez, Segui, and Cuetos, 2002; Marslen-Wilson, Bozic, and Randall, 2008; Rastle, Davis, Marslen-Wilson, and Tyler, 2000). For instance, Marslen-Wilson et al. (2008) used three different SOAs (36, 48, and 72 ms in Experiment 1) and varied the relationship between primes and targets (e.g., morphological decomposability, semantic relatedness, and orthographic overlap). The strongest priming effect was shown from the morphologically related prime and target pairs at all SOAs, regardless of whether they are semantically related (e.g., *bravely-brave*) or not (e.g., *archer-arch*). In addition, semantic relatedness between the prime and target pairs showed facilitation effect at all SOAs (e.g., *bravely-brave* for morphologically and semantically related condition; *accuse-blame* for only semantically related condition). More importantly, the magnitude of the priming effect from the morphological decomposable prime was not modulated by the semantic relatedness between the prime and target pair. Orthographic related only pairs (e.g., *scandal-scan*) did not show any priming effect across all SOAs. These results suggested that the morphological structure plays a significant role in the early stage

of visual word recognition and the morphological priming is independent of both semantic and orthographic relatedness. Since very little is known about how bilingual readers process morphologically complex words, the present study is one of the first studies that investigated the time course of cross-language morphological activation in bilingual reading. Furthermore, we decided to include both derived pseudoword and real word primes to examine the effect of lexicality. This allows us to differentiate between supralexicial and sublexical decomposition accounts in bilingual morphological activation (Giraudo and Grainger, 2000, 2001a, 2001b, 2003).

The present study addressed the following questions: 1) Is there an early and automatic morphological decomposition and cross-language activation of constituent morphemes? 2) What is the time-course of processing derived words in Korean-English bilinguals? In relation to these questions, we hypothesized that the lexicality of primes would have influence on cross-language activation of constituent morphemes. The derived pseudoword primes may require more time for participants to access morphemic information to induce morphological priming as compared to real derived word primes. For real derived words, due to the lexical information shared by the whole word and constituent stem morpheme in L1, we expected that there will be a significant facilitation effect on the translated stem in L2 even at the shortest prime duration (i.e., 36 ms). However, morphological priming from L1 derived pseudowords may be observed at longer prime durations only (i.e., 48 ms or 72 ms).

2. Method

2.1. Participants

Forty-five Korean-English bilingual speakers at a Mid-Atlantic State University participated in this experiment. The mean age of the participants was 29 ($SD = 3.4$), and the majority of them were graduate students. All of the participants were asked to fill out a language background questionnaire (the Language Experience and Proficiency Questionnaire by Marian, Blumenfeld, and Kaushanskaya, 2007) in which age, gender,

general education backgrounds and language-related backgrounds were collected. The average of length of formal education of the participants was 19 years ($SD = 2.4$). Korean was their native and dominant language, and English was the second language for all participants. The average age at which they began acquiring English was 10.1 ($SD = 2.8$). Participants' subjective ratings of their proficiency levels for reading and speaking Korean and English reflected their language dominance. Their responses were analyzed and summarized in Table 1. Analyses on the data from the questionnaire showed that three component skills were rated as being significantly better in Korean than English [for speaking, $t(44) = 9.7$, $p < .001$; for listening, $t(44) = 12.8$, $p < .001$; for reading, $t(44) = 6.38$, $p < .001$, respectively]. They have normal or corrected-to-normal vision.

Table 1. Means and Standard Deviations of Self-rated proficiency and Language Profiles of Participants

	Korean	English
Age of acquisition (years)	1.8 (.4)	10.1 (2.8)
Age of reading acquisition (years)	5.4 (1.2)	10.8 (2.6)
Age of reading fluency (years)	7.8 (2.2)	19.9 (3.4)
Length of residence - country (years)	26.1 (5.7)	2.3 (1.5)
Length of residence - family (years)	26.7 (5.6)	0.5 (1.1)
Length of residence - school/work (years)	19.3 (5.7)	3.1 (1.9)
Speaking rating (0-10)	9.6 (.9)	5.6 (1.6)
Listening rating (0-10)	9.7 (.8)	6.7 (1.2)
Reading rating (0-10)	9.6 (1.1)	6.9 (1.2)
Percentage of current exposition (%)	51 (24)	49 (24)

2.2. Design and materials

Stimuli were based on those used in SY. Kim et al. (2011). The stimulus set was consisted of 60 pairs of primes (i.e., 30 real derived words and 30 derived pseudowords in Korean) and targets (i.e., translated English stems). Derived pseudowords were illegal but interpretable combinations of a stem and a suffix, for example, 매력화, "maylyekhwa." In addition, a set of unrelated words for each target were included as the control condition. Previous studies (SY. Kim et al., 2011; Longtin and Meunier, 2005) used both interpretable and non-interpretable derived pseudowords. The

non-interpretable derived pseudowords were the illegal and non-interpretable combination of a stem and suffix, for example, 매력각, “maylyekkak.” Since both Longtin and Meunier (2005) and SY. Kim et al. (2011) showed the absence of interpretability and lexicality effect in morphological processing, we decided to focus only on interpretable derived pseudoword condition to address whether lexicality has an influence on the early stage of morphological decomposition or whether there is an early pre-lexical morphological processing. Word length across prime conditions was fixed as three syllables. Word frequency for both a real derived word and an unrelated word preceding the same target was controlled. For instance, for the target *attract* in English both the real derived word 매력적, “maylyekcek” (*attractive*) and the unrelated word 공격수, “kongkyeksu” (*offender*) were controlled for their log-frequencies and word length.

The average of log surface frequencies for the real derived words, unrelated words, and target words was 1.13, 1.15, and 4.3, respectively based on the Korean Word Database (2001) (frequency count of one per 1.5 million) and the Collins Cobuild corpus (frequency count of one per 3.2 million). A series of *t*-tests indicated that there was no statistical difference between frequency of real derived words and that of unrelated words ($t < 1$). In addition, the means of suffix log frequencies for the real derived words and derived pseudowords and unrelated words were 2.7 ($SD = .43$), 2.33 ($SD = .27$), and 2.5 ($SD = .6$), respectively. There were no statistical differences across these conditions. An example list of three types of primes and targets is presented in Table 2.

The 90 test pairs (3 prime conditions x 30 targets) were split into three lists. In each list, one third of the targets were preceded by a real derived word prime, one third of the targets were preceded by a derived pseudoword prime, and one third by an unrelated control real word prime. These three stimuli lists were counterbalanced across the participants. Ninety filler pairs were added to each list (30 filler pairs were unrelated word pairs of Korean and English and 60 filler pairs were unrelated word/nonword pairs of Korean and English). Each participant was given 120 English targets, 60 words and 60 nonwords to ensure an equal number of yes and no responses. In total, the proportion of related prime-target pairs in the stimuli list was

0.25. In addition, prior to the experimental session, participants were given 10 practice trials.

In order to examine the time-course of cross-language morphological activation, three prime durations (36, 48, and 72 ms) with a fixed 75 ms of inter-stimulus-interval (ISI) were employed. SY. Kim et al., (2011) provided evidence that cross-language morphological activation with visible prime duration (150 ms). In the present study, we used shorter prime durations to examine whether the cross-language morphological activation is a quick and automatic process. The reason why we chose the three prime durations was because the 48 ms has been frequently used for masked priming experiments (e.g., Pastizzo and Feldman, 2002), the 36ms was used for even faster priming experiments (e.g., Rayner, Sereno, Lesch, and Pollatsek, 1995), and the 72 ms was used as a duration when the primes normally become visible (e.g., Rastle, Davis, Marslen-Wilson, and Tyler, 2000) which is shorter than the one used in the previous study by SY. Kim et al. (150 ms). These three prime durations were also used in Marslen-Wilson et al. (2008).

2.3. Procedure

Participants were seated in front of a computer monitor in a quiet room. They received written instructions about the experiment. The presence of a visual prime was not mentioned at this time. Participants were informed that they would see a letter string on the screen one at a time and they would have to respond as quickly and as accurately as possible whether the letter string was an English word or not.

During the experimental session, a masked priming lexical decision task procedure similar to that used by Forster and Davis (1984) was employed. For each trial, a fixation sign (+) was presented for 500ms and then a forward mask (▣▣▣▣▣▣▣▣) appeared in the center of the screen for 500ms. This forward mask was immediately followed by the prime (e.g., 매력적 for a real derived word, 매력화 for an interpretable derived pseudoword), displayed for 36 ms or 48 ms or 72 ms depending on the prime duration condition. A fixed post mask (▣▣▣▣▣▣▣▣) was presented for 75 ms,

immediately followed by the target (i.e., attract). The target remained on the screen for 3000 ms or until a response was made. Reaction times were measured from the onset of the target to the time point when the response was made. The experiment was run on a PC, using the E-Prime software (Schneider, Eschman, and Zuccolotto, 2002) with a random trial order. Responses were given via keyboard (“x” key for the “yes” response and “m” key for the “no” response). The total length of the experiment was about 10 minutes.

3. Results

Incorrect responses and response latencies that were above or below 2 standard deviations (SD) from the mean of each participant were excluded from data analysis (4.6%). A 3 (prime type as a within-subject variable: derived real word primes vs. derived pseudoword prime vs. unrelated word prime) x 3 (prime duration as a between-subject variable: 36 ms vs. 48 ms vs. 72 ms) ANOVA was conducted for reaction times (RTs) and accuracy data. We reported both subject (F_1) and item (F_2) analyses; however we focused on the results from subject analyses for our decision of significance as did Kim et al. (2011). Since all stimuli were matched on many variables (e.g., frequency, interpretability, and word length) and were selected only from the relevant item pools, subject analyses were considered more appropriate than item analyses for the present study (see Raaijmakers, 2003 and Raaijmakers, Schrijnemakers, and Frans, 1999, for discussion). Error analysis revealed that there were no significant main effects of prime duration and prime type or their interaction. Thus, the remainder of the analyses focused on reaction time data (see Table 2 for the means and standard deviations across prime durations and prime types). The main effect of prime type was significant for the subject analysis, $F_1(2, 72) = 11.955, p < .001$; $F_2(2, 58) = 2.282, p = .114$. The main effect of prime duration was significant for both analyses, $F_1(2, 41) = 4.47, p = .018$; $F_2(2, 58) = 64.053, p < .0001$. The interaction effect between prime types and prime durations was significant for the item analysis, $F_1(4, 36) = 1.635, p = .189$; $F_2(4, 116) = 3.355, p = .019$.

Table 2. Mean of Response Times (msec) for Prime Types at each Prime Duration and Error Rates (%)

Prime types	Examples prime-target	PD = 36ms		PD = 48ms		PD = 72ms	
		RT(ms)	Error(%)	RT(ms)	Error(%)	RT(ms)	Error(%)
Derived word	매력적-attract	1116	6.0	1131	6.0	953	4.2
Derived pseudoword	매력화-attract	1203	7.3	1149	7.3	978	7.7
Unrelated	공격수-attract	1198	4.7	1229	7.3	1007	6.7

The derived real word condition (DR) showed a significant priming effect across all prime durations. DR condition facilitated target recognition compared to the unrelated word condition (UW) for the 36ms prime duration, $F_1(1, 12) = 14.525$, $p = .002$; $F_2(1, 27) = 2.278$, $p = .143$; for the 48ms prime duration, $F_1(1, 12) = 16.041$, $p = .002$; $F_2(1, 27) = 1.542$, $p = .225$; and for the 72 ms prime duration, $F_1(1, 12) = 37.346$, $p < .0001$; $F_2(1, 27) = 2.091$, $p = .160$. The derived pseudoword condition (DP) showed an interesting pattern because the comparison between DP and UW was not significant for the shortest primed duration (36 ms), $F_1 < 1$; $F_2(1, 27) = 2.416$, $p = .132$. However, it became significant for the two longer prime durations, for the 48ms duration, $F_1(1, 12) = 5.716$, $p = .034$; $F_2(1, 27) = 3.386$, $p = .077$, and for the 72 ms duration, $F_1(1, 12) = 6.713$, $p = .024$; $F_2(1, 27) = 2.034$, $p = .165$. The absence of the priming effect from the derived pseudoword prime in the shortest prime duration suggests that lexicality plays a role in the early stage of morphological processing in Korean derived words, in other words, sublexical analysis may occur later in processing morphologically complex words.

4. General Discussion

The present study sought to address whether there is an early and automatic cross-language morphological activation and what the time course of cross-language morphological activation would be in bilingual reading. Our results provided evidence that Korean-English bilingual readers decompose morphologically complex real words in Korean as prime, and

even when the prime was only presented for a short period of 36ms. It is apparent that the decomposition in Korean L1 derived words facilitated the recognition of the translated stem word in English L2. The fact that the derived real word condition showed a significant priming effect across three different prime durations suggests that the cross-language morphological activation is robust and reliable.

Our findings contribute to the current bilingual mental lexicon models by extending the shared lexical information between L1 and L2 to include the morphemic level of cross-language activation. In the current bilingual lexicon models, for example, the Revised Hierarchical Model (RHM) (Kroll and Stewart, 1994) and the Bilingual Interactive Model (BIA and BIA+) (Dijkstra and Van Heuven, 1998, 2000), the link between L1 and L2 lexical information did not specifically state whether morphologically complex words are involved. Therefore, it was unclear whether cross-language activation shown in previous bilingual priming studies (e.g., Basnight-Brown and Altarriba, 2007; Jiang and Forster, 2001) occurred in both single-morpheme words and morphologically complex words or single-morpheme words only. In the present study, we examined cross-language activation of morphologically complex words using derived words as the critical stimuli. Our results demonstrated that bilingual mental lexicon involves the shared lexical information between L1 and L2 not only for single-morpheme words but also for morphologically complex words.

In contrast to real word prime condition, the derived pseudoword primes did not show a significant priming effect at the shortest prime duration (36 ms), and the priming effect became significant at the longer prime durations (48 and 72 ms). The morphological model (Giraudo and Grainger, 2000, 2001a, 2001b, 2003) based on supralexic and sublexical analyses can be used for explaining the differential processing patterns driven by real word and pseudoword primes. As shown in Figure 1, the critical difference between the two analyses is the location of morphemic representation in the hierarchical model of the morphologically complex words. The sublexical analysis assumes activation of the morphemic units prior to whole-word access. Therefore, morphemic units can be activated even if there is no whole-word representation available. In contrast, the supralexic

analysis assumes that whole-word units are activated before the morphemic units are accessed.

To explain the null effect from the pseudoword prime condition at the shortest prime duration, we suggest that there is a time course in terms of supralexicial and sublexical analysis. That is, the early stage of morphological processing is sensitive to its full form's lexical status via supralexicial analysis. In the pseudoword prime condition, since there is no whole-word representation, its morphemic units cannot be activated via supralexicial analysis; therefore no priming effect was shown for pseudowords in the shortest prime duration. After lexical access failed via the supra-segmental analysis for the pseudoword primes, the sublexical analysis may be subsequently applied so that the primes could be decomposed into an existing stem and an affix when presented for a relatively longer duration. We also expect that this time course fits only for derived pseudowords, but not for non-morphological ending pseudowords. Indeed, Kim et al. (2011) showed that no priming effects from non-morphological ending prime conditions (i.e., illegal combination of an existing stem and an orthographic ending syllable) even though the prime duration was quite long (150 ms).

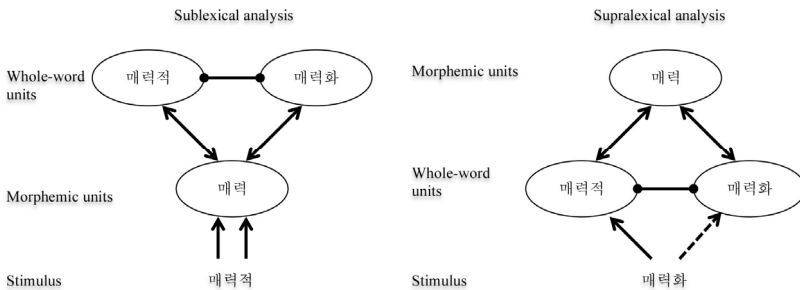


Figure 1. Two Possible analyses applied for suffixed real and pseudoword type in Korean (adapted from Giraudo and Grainger, 2000).

We showed that the lexicality of the complex words is an important factor for bilingual readers at the shortest SOA. However, it is still unclear whether this lexicality effect is important only for Korean readers or for bilingual readers with other L1-L2 combinations. It is possible that supralexicial analysis is the initial step for processing derived words in Korean L1;

however, it may not be the case for other languages. For example, German L1 readers may utilize sublexical analysis in the initial step for processing German derived words. Therefore, German-English bilingual readers may show the morphological priming effect from both derived real and pseudowords in German L1 on the translated English L2 stems. In order to examine this possibility systematically, different bilingual populations with various languages and scripts need to be included for comparison (e.g., Spanish-English, Chinese-English, or Japanese-English).

Furthermore, in order to fully understand how derived words are processed in bilingual readers, prefixed words should be examined to form comparison with the suffixed words because of their structural differences. While the stem is the first piece of information available for its access in suffixed words, the stem can only be accessed once the prefix has been stripped off. In addition, when one of the two languages in bilingual reading has its language-specific characteristics such as the semantic ambiguity of a monosyllabic morpheme in Korean orthography, we may expect to observe the differential processing of prefixed versus suffixed derived words.

Finally, with regard to the statistical analysis the present study only employed the conventional ANOVA with emphasis on the subject-analysis. In future research, a linear mixed-effects model that takes into account of both subjects and items as random effects should be considered.

5. Conclusion

The present study provided novel evidence regarding the time-course of cross-language morphological activation. It appears that there is an early cross-language activation of L1 morphologically complex words in facilitating the recognition of L2 translated stem as the target words. The late morphological activation of L1 derived pseudowords suggests that supralexical analysis may occur earlier than sublexical analysis in cross-language morphological activation by bilingual readers.

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