Parallel Activation in Bilingual Phonological Processing

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Submitted to the Department of Speech-Language-Hearing: Sciences and Disorders and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for degree of Doctor of Philosophy

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ABSTRACT

In bilingual language processing, the parallel activation hypothesis suggests that bilinguals activate their two languages simultaneously during language processing. Support for the parallel activation mainly comes from studies of lexical (word-form) processing, with relatively less attention to phonological (sound) processing.

According to studies of monolingual phonological processing, phonotactic probability, the likelihood of occurrence of a sound sequence, influences both word recognition and production. Specifically, common sound sequences are recognized and/or produced more quickly and more accurately than rare sound sequences (Edwards, Beckman & Munson, 2004; Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997; Vitevitch & Luce, 1998; 1999). The goal of this research was to examine the influence of phonotactic probability on phonological processing when phonotactic probability was matched (Experiment 1) versus mismatched (Experiment 2) across the bilingual speakers' two languages.

In Experiment 1, three groups of children participated: English monolinguals, Korean monolinguals, and Korean-English bilinguals. A same-different task with nonword stimuli was used. The nonwords were matched in phonotactic probability across the two languages (i.e., English-low/Korean-low versus English-high/Korean-high). Results showed that all three groups responded more accurately and quickly to English-high/Korean-high than English-low/Korean-low nonwords. This replicates past findings of the facilitative effects of phonotactic probability for English monolinguals and extends it to Korean monolinguals and Korean-English bilinguals.

In Experiment 2, only bilingual children participated in a same-different task with nonword stimuli mismatched in phonotactic probability. Specifically, phonological processing of English-low/Korean-high versus English-high/Korean-low nonwords was examined across two phonetic contexts (i.e., English-phonetic and Korean-phonetic). Phonetic context was based on the speaker who recorded the stimuli (i.e., native English versus native Korean speaker). Results showed a significant interaction between phonotactic probability and phonetic context. In the *English*-phonetic context, *English-low*/Korean-high nonwords were responded to more accurately and quickly than *English-high*/Korean-low nonwords. In contrast, in the *Korean*-phonetic context, English-high/*Korean-low* nonwords tended to be responded to more accurately and quickly than English-low/*Korean-high* nonwords. The results are interpreted as bilinguals encounter competition effects of phonotactic probability on phonological processing when the probability was mismatched across the two languages. This competition effect from mismatched probability suggests the presence of parallel activation of both languages in phonological processing. Combined with the results of Experiment 1, the magnitude of parallel activation was found to vary across the native and non-native languages. Specifically, both facilitation and competition effects were significant in non-native (English) language processing, while the effects were not significant in native (Korean) language processing. Such an asymmetry in the magnitude of parallel activation between the native and non-native languages is consistent with previous findings of parallel activation in bilingual lexical processing. Taken together, the findings of the current study suggest that phonological representations of the two languages are activated simultaneously and language status may be a factor that mediates the magnitude of parallel activation.

ACKNOWELDMENTS

I would like to thank many people who have aided in the completion of this dissertation. First of all, I am very thankful for the mentorship of my primary advisor, Holly Storkel. She trained me to be a strong, independent researcher who seeks answers through the logical and critical thinking process. She did not feed me with the answers but guided me to search for the ways to find answers. I deeply appreciate her advice and support throughout my doctorate and sufficient time on discussing this project. Thank you!

I am thankful for my committee members as they provided such advice and insights that improved the quality of this project.

I am thankful for the lab members of the Word and Sound Learning lab, who helped me with stimuli recording and reliability checks.

I am thankful for the pastor and his wife at Lawrence Korean Presbyterian Church. They assisted me with the recruitment of bilingual children which was the most difficult part of this project. I appreciate their support and encouragement for me.

I am thankful for Byungmi Lee who assisted me with this project. She made genuine efforts for the recruitment of Korean monolingual children and offered me her place with no hesitation for data collection. In fact, she has been a constant kind support since the beginning of our friendship which started from my college years and I am so appreciative.

Finally, I am thankful for my family. I cannot seem to find the words to express my gratitude for their love and support. They have been supportive of all my endeavors and I couldn't have completed this project without their support and encouragement. Thank you!

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CHAPTER I: INTRODUCTION

Viewed globally, the majority of world's population speaks more than one language, referred to as a "bilingual" or "multilingual" population (Romaine, 1995). In the United States, approximately 47 million people speak a language other than English, constituting about 18% of U.S. population (2000 U.S. Census). The Asian American population comprises about 4.8% of the U.S. population and the Korean American population stands at 1,423,784, representing 10% of the Asian American community (2010 U.S. Census). This population has increased rapidly in the past 20 years, with about 80% increase in Korean population over the 1990 Census figure.

While some researchers claim that individuals are considered to be bilingual only if they are exposed to two languages from birth, others define bilingualism as some functional use or facility of more than one language on a regular basis. Historically bilingual children have been divided into two groups (i.e., simultaneous or sequential) depending on the age at which bilingual children acquire each language. Simultaneous bilinguals are those who are in environments to acquire both languages from birth or before age 3, while sequential bilinguals are those who acquire one language after the other (Goldstein, 2006).

With the continuous increase in bilingual and multilingual populations, many aspects of bilingualism and multilingualism have been studied and accordingly several models and hypotheses have been proposed for each aspect, including the acquisition of the second language (Kein, 1986), the representation of the two (or more) languages in the brain (Albert & Obler, 1978; Kim, Relkin, Lee, & Hirsh, 1997; Schreuder & Weltens, 1993), and language processing (Doctor & Kelin, 1992; Marian & Spivey, 2003; Nas, 1983; Van Wijnedaele & Brysbaerrt, 2002). Particularly, in bilingual language processing, the main debate has been focused on whether bilinguals use their two languages independently, or whether they activate their two languages and process them at the same time.

The earlier studies have proposed the ***language switch hypothesis***, suggesting that bilinguals selectively activate and deactivate their two languages (Gerard & Scarborough, 1989; MacNamara & Kushnir, 1971). More recent findings challenge this hypothesis and propose the ***parallel activation hypothesis***, suggesting that bilinguals activate their two languages at the same time during monolingual input (Ju & Luce, 2004; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004).

Whereas most of the research has concentrated on parallel activation of language processing at the level of word forms (i.e., lexical processing), this issue has not received much attention at the level of phonemes (i.e., phonological processing). The aim of the present study is, therefore, to investigate whether there is parallel activation during bilingual language processing at the sublexical level. Before describing in more detail the present study, the following sections provide an overview of previous work relevant to language processing and influential variables on language processing from the monolingual population followed by relevant studies with the bilingual population.

Lexical and phonological processing in monolingual speakers

The monolingual literature suggests two levels of representation in the mental lexicon: a form representation and a semantic representation. A form representation contains information about the sounds of a word, whereas a semantic representation contains information about the meaning or referent of a word.

Within a form representation, many models of spoken language processing adopt two types of a form representation: lexical and phonological (e.g., Dell, 1988; Levelt, 1989; Luce, Goldinger, Auer, & Vitevitch, 2000, McClelland & Elman, 1986, Norris, 1994). A lexical representation refers to the mental representation of whole-word sound sequences as an integrated unit. For example, the ***lexical representation*** of the word is "pig" is /pɪg/. On the other hand, a ***phonological representation*** refers to the mental representation of individual sounds in a word. For example, the word "pig" contains three phonological representations, /p/, /ɪ/, /g/.

The characteristics of these representations and their role in spoken language processing have received much attention over the past decade. In particular, two characteristics have been shown to affect language processing; neighborhood density and phonotactic probability. ***Neighborhood density*** is a characteristic of lexical representations and refers to the number of words that differ from a given word by a one phoneme substitution, deletion, or addition in any word position (Luce & Pisoni, 1998). Words that sound like many other words are said to reside in dense neighborhoods. Others that have few similar sounding words are said to reside in sparse neighborhoods. ***Phonotactic probability*** is a characteristic of phonological representations and refers to the likelihood of occurrence of a given sound or sound sequences in an ambient language (Vitevitch & Luce, 1999). Certain sounds and sound sequences such as those in the word "cat" are highly likely to occur in other words and are consequently considered as common sound sequences which are said to have high phonotactic probability. In contrast, sounds and sound sequences such as those in the word "cheese" are less likely to occur in other words and are consequently considered as rare sound sequences which are said to have low phonotactic probability.

These two characteristics have shown divergent effects on language processing: competitive effects of density and facilitative effects of phonotactic probability. Specifically, Vitevitch and Luce (1998) found that *words* from high density neighborhoods, which also tend to have common sound sequences, were processed more slowly than *words* from low density neighborhoods, which tend to have rare sound sequences, (see also Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997). In contrast, *nonwords* composed of common sound sequences (and dense neighborhoods) were processed faster than *nonwords* composed of rare sound sequences (and sparse neighborhoods).

Vitevitch and Luce (1998) suggested that the differential effects of neighborhood density and phonotactic probability are accounted for by the two levels of representation and processing: lexical and phonological. In particular, they suggested that the competitive effects of dense neighborhoods may arise from competition among many similar lexical representations. On the other hand, the facilitative effects of phonotactic probability may emerge for nonwords because nonwords do not have lexical representations, negating lexical competition. Instead, high probability nonwords yield high activation of phonological representations, speeding recognition.

In addition to the demands of particular stimuli (i.e., words vs. nonwords), contextual effects in a Same-different task have been shown to influence the dominant level of processing. Particularly, Vitevitch (2003) hypothesized that lexical processing dominated for a Same-different task which consisted of primarily real words (i.e., more than 75% of the task), resulting in competitive effects of density. On the other hand, phonological processing presumably dominated for a Same-different task with greater portion of nonwords (i.e., more than 75% of the task), yielding facilitative effects of phonotactic probability.

Lexical processing in bilingual speakers

In bilingual language processing, the traditional language switch hypothesis, proposed by Macnamara and Kushnir (1971), suggested that bilinguals activate the relevant lexicon while switching off the irrelevant one. The lexical decision paradigm has been used to support language switch (Soares & Grosjean, 1984; Grainger & Beauvillain, 1987; Gerad & Scarborugh, 1989). These studies show that longer processing time is required to make a lexical decision within a mixed list of words or sentences from two languages. The findings suggest that extra processing time may be necessary to switch off one lexicon and switch on the other.

A second paradigm is word-fragment completion (Durgunoglu & Roediger, 1987; Watkins & Peynircioglu, 1983). Watkins and Peynircioglu (1983) reported that word-fragment completion performance was better only when the languages at study and test were the same but no facilitation was found when tested in a different language.

These previous findings have been challenged by more recent findings that have demonstrated compelling evidence for the parallel activation hypothesis in bilingual language processing through testing different linguistic features, such as code switching (Grainger, 1993; Grainger & Dijkstra, 1992), cognates (Kroll & Stewart, 1994), interlingual homographs (Dijkstra, van Jaarsveld, & ten Brinke, 1998), phoneme monitoring (Colome, 2001), interlingual neighbors (van Heuven, Dijkstra, & Grainger, 1998), masked orthographic priming (Bijeljac-Babic, Biardeau, & Grainger, 1997), and phonological overlap (Brysbaert, Van Dyck, & Vand de Peol, 1999; DeGroot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & van Heuven, 1999; Marian, Blumenfel, & Boukrina, 2007). Particularly, visual-word recognition paradigms have shown slow responses and high error rates associated with words that sound the same but mean different things in different languages (i.e., interlingual homophones or interlingual neighbors) (Brysbaert, Van Dyck, & Van de Poel, 1999; Brysbaert, Van Wijnendaele & Brysbaert, 2002; Dijkstra, Grainger, & van Heuven, 1999; Doctor & Klein, 1992). The findings indicate that non-target language information may become activated during reading in a target language, leading to slower recognition for interlingual homophones or interlingual neighbors. Based on an extensive body of research, the bilingual interactive activation model of visual word recognition (BIA) has been proposed with the main claim that bilinguals activate information about words in both languages in parallel (Dijkstra & Van Heuven, 1998; Dijkstra, Van Jaarsvel, & Ten Trinke, 1998; Van Heuven, Dijkstra, & Grainger, 1998).

While these previous studies focus on parallel activation in the visual domain, a relatively small number of studies has shown evidence for parallel activation in the auditory domain (e.g., Ju & Luce, 2004; Marian & Spivey, 2003a, 2003b; Schulpen, Dijkstra, Schriefers, & Hasper, 2003; Weber & Culter, 2004). Most of the recent studies use an eye-tracking paradigm which merges input from both the visual and auditory modalities, allowing one to index the activation of a second language nonlinguistically (Marina, 2000; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999). In this eye-tracking paradigm, bilinguals heard object names in one language, and were asked to identify these from a set of objects, which included a competitor from their other language that was phonological similar to the target language. For instance, when Russian-English bilinguals heard the word *marker* in English, they were likely to look longer at the similar-sounding Russian competitor *marka* (meaning *stamp* in Russian) than control objects that had no phonetic relationship with either language (Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999). Participants' eye-movements to the competitors from their other language were interpreted as evidence of parallel activation of bilinguals' two languages during spoken word recognition.

Regardless of visual or auditory domains, the majority of studies in bilingual language processing demonstrate competitive effects of interlingual neighbors which were similar to the competitive effects of neighbors in monolinguals (e.g., Allopenna, Magnuson, Tanenhaus, 1998; Magnuson, Tanenhaus, Aslin, & Dahan, 1999, Tanenhaus, Spivey-Knowlton, Eberhard &

Sedivy, 1995). This competitive effect in bilingual language processing has been referred to as *cross-language competition* or *interlingual competition* (e.g, Marian & Spivey, 2003b; Marin, Spivey, & Hirsh, 2003; Spivey & Marin, 1999; Weber & Cutler, 2004). This interlingual competition indicates that bilinguals experience interference from interlingual neighbors because they access both languages in parallel; this has been shown for a variety of languages including Dutch-English (Weber & Cutler, 2004), Spanish-English (Canseco-Gonzales, Brick, Fishcer, & Wagner, 2005; Ju & Luce, 2004), French-English (Weber & Paris, 2004), Japanese-English (Cutler, Weber, & Otake, 2006), and German-English (Blumenfeld & Marian, 2007). While previous studies have demonstrated that bilinguals activate both languages simultaneously at the lexical level, this issue has not received much attention at the phonological level.

Phonological Processing in Bilingual children

With regard to the phonological level of bilingual language processing, there is only one study that compares monolingual and bilingual children's sensitivity to phonotactic constraints (Sebastian-Galles & Bosch, 2002). Because phonological information is language specific, bilingual children should acquire separate phonotactic constraints (legal sound sequences in a language) and phonotactic probabilities (the likelihood of occurrence of sound sequences) for each of their languages. Sebastian-Galles and Bosch (2002) compared four groups of children: Catalan monolinguals, Spanish monolinguals, Catalan-dominant Spanish-Catalan bilinguals, and Spanish-dominant Spanish-Catalan bilinguals. At ten months of age, Catalan monolinguals and Catalan-dominant Spanish-Catalan bilinguals showed a similar pattern of preference for nonwords with legal over illegal sequences in Catalan, while Spanish-dominant Spanish-Catalan bilinguals showed an ambiguous pattern that is between the Catalan and the Spanish monolinguals. The results of this study indicate that bilinguals show an early preference for the native language (as determined by the amount of exposure to their maternal language). This study raises the issue of the influence of language status on parallel activation, which has been addressed more thoroughly in the lexical processing literature.

Asymmetry in parallel activation

Studies of bilingual lexical processing reveal an asymmetry in parallel activation between the native and non-native languages. Specifically, a number of studies have demonstrated activation of the native language during non-native language processing (Blumenfeld & Marian, 2007; Jared & Kroll, 2001; Marian & Spivey, 2003b, Weber & Cutler, 2004), but activation of the non-native language during native language processing was not always shown (Ju & Luce, 2004; Weber & Cutler, 2004). Moreover, it was suggested that the magnitude of cross-language competition effect may vary across the native and non-native languages. For example, Marian and Spivey (2003) found that bilinguals' eye movements to the cross-language competitor objects from the native language were significantly longer than the control filler objects during non-native language processing. However, they did not find a significant difference in the proportion of eye movements to cross-language competitor objects from the non-native language compared to control filler objects during native language processing. The cross-language competition effect from the non-native language was still observed (more eye-movements to the cross-language competitor objects compared to the control filler objects). Their findings suggested that cross-language competitors from the native language may be stronger competitors than cross-language competitors from the non-native language during bilingual language processing.

Taken together, despite the compelling evidence for the effects of phonotactic probability in monolinguals, it has not been addressed in a bilingual domain. Particularly, the facilitative effects of phonotactic probability have been observed when language processing is dominated by a phonological level as for nonwords which do not have direct contact with a lexical representation (Norris, 1994; Pitt & McQueen, 1998; Vitevitch & Luce, 1999). With regard to a bilingual setting, phonotactic probability may play a role in bilingual phonological processing. According to the language switch hypothesis, the effects of phonotactic probability may be restricted to a target language. On the other hand, the parallel activation hypothesis predicts that phonotactic probability of both languages would be activated and influential across languages.

The purpose of the current study, thus, was to investigate parallel activation of phonological representations in bilingual children by examining the effects of phonotactic probability on bilingual phonological processing. To accomplish this purpose, children participated in an auditory processing task (i.e., a Same-different judgment task) tapping phonological representation (i.e., a nonword task). Phonotactic probability and language status were systematically manipulated to examine parallel activation of the two languages. The following are specific research questions and predictions.

Study Questions and Predictions

1) Experiment 1 Research Question: Does phonotactic probability influence phonological processing differently for typically developing English monolingual, Korean monolingual and Korean-English bilingual preschool children when phonotactic probability is matched across languages?

This question is addressed in Experiment 1. Nonwords for the same-different task were selected so that the phonotactic probability was the same in both languages. For example, a nonword /nib/ is low probability in both English and Korean, whereas a nonword /sug/ is high probability in English and Korean.

Predictions

A possible outcome is that there will be a main effect with no interaction between phonotactic probability and group. That is, sound sequences with high phonotactic probability may be processed faster and more accurately by all groups. This prediction matches findings from the past studies with monolingual adult speakers (e.g., Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997; Vitevitch & Luce, 1998, 1999) and would suggest that phonotactic probability has a similar influence on bilingual phonological processing as on monolingual phonological processing. The facilitative effect of phonotactic probability in bilinguals can be accounted for by both hypotheses, language switch and parallel activation, with a different architecture of language processing.

The language switch hypothesis predicts that one language is activated while the other is switched off. This case, bilinguals are assumed to activate only one of their languages and thus use the phonological knowledge of the “on” language. In this scenario, if the “on” language is English, phonotactic probability of English will be activated, and then English high probability nonwords are expected to be processed faster and more accurately than English low probability nonwords. The same scenario would occur for Korean except that only Korean phonotactic probability is activated, favoring Korean high probability nonwords.

In contrast, the parallel activation hypothesis predicts that two languages are activated and influence phonological processing simultaneously. Specifically, phonotactic probability of both languages will be activated, and then high probability nonwords in *both* languages presumably would be processed faster and more accurately than low probability nonwords in *both* languages. Taken together, because the probability of two languages is matched in Experiment 1, the two theories may not be differentiated by the results of Experiment 1. The mismatched probability of Experiment 2 may better differentiate the two theories.

2) *Experiment 2 Research Question:* Does phonotactic probability influence phonological processing by typically developing bilingual preschool children when phonotactic probability differs across languages and does the effect vary by language status?

This question was addressed in Experiment 2. Here, nonwords for the same-different task were selected so that the phonotactic probability differed across languages. For example, a nonword /jub/ is low probability in English but high probability in Korean, whereas a nonword /pim/ is high probability in English but low probability in Korean. In addition, the effect of language dominance on phonological processing was manipulated by testing the exact same stimuli in four different contexts: a neutral context consisting of only nonword stimuli in an English-phonetic context determined by the phonetic characteristics of the recorded stimuli (i.e. English-speaker stimuli); a neutral context consisting of only nonwords stimuli in a Korean-phonetic context determined by the phonetic characteristics of the recorded stimuli (i.e. Korean-speaker stimuli); an English-lexical biased context consisting of 25% English real words and 75% target nonwords; a Korean-lexical biased context consisting of 25% Korean real words and 75% target nonwords. Note that nonwords are the predominant stimuli in all contexts to evoke phonological rather than lexical processing (Vitevitch, 2003).

Predictions

Several patterns of results are possible based on different hypotheses in the bilingual literature. Under the language switch hypothesis, the context would determine which language is "on" and which is "off." Thus, in the English-biased context, English would be "on" and Korean “off,” leading to the reverse pattern. In this case, *English high*/Korean-low would be faster and more accurate than *English-low*/Korean-high. In contrast, in the *Korean*-biased context, Korean would be “on” and English “off.” In this case, English-low/*Korean-high* would be faster and more accurate than English high/*Korean-low*. In the neutral context, it is also hypothesized that only one language is “on” and that this is determined by the phonetic characteristics of the recorded stimuli (i.e. English-speaker vs. Korean-speaker stimuli). That is, the English speaker produced the nonword stimuli with acoustic characteristics that matched English, while the Korean speaker produced the nonword stimuli with acoustic characteristics that matched Korean. For example, although both languages contain cognate stops, the exact distinction between the cognates differs. In this way, the phonetic context (Korean-speaker vs. English-speaker) would determine which language was switched “on”, leading to patterns similar to the two language-biased contexts. Thus, the main effect of phonotactic probability may not be significant but a significant interaction between phonotactic probability and either (or possibly both) lexical and/or phonetic context may be found.

The parallel activation hypothesis predicts that the main effect of phonotactic probability and interactions will not be significant. It is predicted that the two types of mismatched probability may be processed similarly at a median level of accuracy and reaction times regardless of lexical or phonetic contexts because bilinguals activate both languages and are influenced by phonotactic probability of both languages. That is, English low-probability and Korean high-probability will sum to a “mid” probability. Likewise, English high-probability and Korean low-probability will sum to a “mid” probability. In this scenario, there is no difference between English-low/Korean-high and English-high/Korean-low probability.

Another prediction is that there may be an asymmetry between the native and non-native languages. The native language can be determined from the language history questionnaire and/or can be inferred from the effect of phonotactic probability across contexts. For purposes of illustration, it is assumed that Korean is the native language and dominant language as determined by the maternal language and the percentage of its use at home.). Thus, in the neutral context English-low/*Korean-high* would be faster and more accurate than /English-high/*Korean-low*. Likewise, in the Korean-lexical biased context, a similar effect would be observed. In both cases, the non-native language has minor influence on the native language (Marian & Spivey, 2003, Weber & Cutler, 2004; Weber & Paris, 2004). In the English-lexical biased context, the native language, Korean, would still influence processing minimizing the effect of English phonotactic probability. Thus, English-low/Korean-high may be as fast and accurate as English-high/Korean-low (i.e., no effect of combined probability). It is also possible that Korean would be "too dominant" in which case the effect of phonotactic probability could be similar to the other two contexts with English-low/Korean-high being processed faster and more accurately than English-high/Korean-low.

In summary, the current study is the first attempt to test the parallel activation and language switch account at the phonological level of processing in bilingual children. Moreover, the study investigates the role of language status in phonological processing by bilingual children. While much is known about the activation of the lexicon in bilingual language learners, little attention has been paid to activation of phonological representation in bilingual language learners.

CHAPTER II: METHODS

Experiment 1

The first experiment explores the influence of phonotactic probability on phonological processing by typically developing monolingual and bilingual preschool children when phonotactic probability is matched across languages.

Participants

Three groups of typically developing preschool children partcipated in the study: (1) 24 English-monolingual (14 boys; *M* = 5 years; 0 months, *SD* = 4 months; range 4;4 – 5;9), (2) 24 Korean-monolingual (14 boys; *M* = 5;4 , *SD* = 6 months; range 4;6 – 5;11), and (3) 24 Korean-English-bilingual children (12 boys; *M* = 5;1, *SD* = 6 months; range 4;1 – 5;11). English-monolingual and bilingual participants were recruited from the local community through posted announcements and advertisements in Lawrence, Kansas. Korean-monolingual participatns were recruited from Seoul, Korea through posted announcements and word-of-mouth. All participants passed a hearing screening before participation and had no history of speech, hearing, or cognitive disorders or other developmental delays reported by the parent on a questionnaire (Appendix A & B).

English-monolingual participants were native English speakers with no exposure to other languages. These children showed age-appropriate English vocabulary on the *Peabody Picture Vocabulary Test-4* (PPVT-4; Dunn & Dunn, 2007) and the *Expressive Vocabulary Trest-2* (EVT-2; Williams, 2007), and age-appropriate English productive phonology on the *Goldman-Fristoe Test of Articulation-2* (GFTA-2, Goldman & Fristoe, 2000). Mean standard scores were 115 (*SD* = 11.71; range 93 – 147) on the PPVT-IV and 117 (*SD* = 11.90; range 96 – 141) on the EVT-2, and 113 (*SD* = 4.86; range 101 – 120) on the GFTA-2.

Korean-monolingual participants were monolingual native Korean speakers and showed age- appropriate Korean vocabulary on the *Receptive and Expressive Vocabulary Test* (REVT; Kim, Hong, Kim, Jang, Lee, 2009), and age-appropriate Korean productive phonology on the *Assessment of Phonology & Articulation for Children* (APAC, Kim, Pae, & Park, 2007). Mean standard scores were 119 (SD = 22.35; range 87 – 191) on the RVT, and 112 (SD = 16.44; range 86 – 147) on the EVT, and 109 (SD = 7.09; range 90 – 114) on the APAC.

All bilingual participants were sequential bilinguals who were selected based on the following inclusion criteria:

- Birth or arrival in United States before the age of 3 years, and lived in United States for at least 2 years prior to participating in this study (Average length of residency in United States; *M* = 4;5, *SD* = 1;1, range 2;3 – 5;11) (Appendix C for more detailed information).
- Exposure to Korean from birth.
- Start of English learning after the age of two (*M* = 3;1, *SD* = 8 months; range 2;0 – 4;7) (Appendix D for more detailed information).
- Participation in English education program for at least one year prior to study participation (*M* = 1;9, *SD* = 7 months; range 1;0 – 3;1) (Appendix E for more detailed information).
- Currently exposed to both languages at least 20 % each from home or education programs.

All bilingual participants were administered both sets of language tests and showed some knowledge of both languages. Table 2-1 and Table 2-2 contain the mean standard scores, standard deviations, standard errors, minimum and maximum standard scores, *p* values, and

Cohen's *d* effect sizes (Cohen, 1992) by group. Both monolingual groups outperformed bilinguals on all measures ($p<.001$) except the articulation test. In terms of the overall size of bilinguals' vocabulary, it is expected to be half of an average monolingual child in each language at least until the age of four due to cognitive limits in the preschool years (Nicoladis & Genesee, 1997). Within the bilingual group, English vocabulary scores were within the normal ranges (see Table 2-1), while Korean vocabulary scores were below the normal range (see Table 2-2). It is common for young bilingual children to have higher proficiency in one language, which is likely to shift extremely rapidly by a change in child-care circumstances (Nicoladis & Genesee, 1997). Thus, it is likely that bilingual children in the current study became more proficient in English due to their immersion in an English-dominant education program at least one year prior to study participation. However, it should be noted that Korean was the native language (the maternal language) of the bilingual group and was used more dominantly at home by most parents based on parent's reports. The percentage of Korean used by the parents at home was about 78% (*SD* = 23.6) and the percentage of Korean used by children was 57% (SD = 29.4). Therefore, Korean was considered to be the native language and dominant language at least in home settings.

TABLE 2-1: *Means, Standard Deviations, Standard Errors, Minimum and Maximum Standard Scores, p Values, and Effect Sizes by the English monolingual group and the Bilingual group for the English Language Assessments*

	Mean	*SD*	*SEM*	*Min-Max*	*p*	*d Effect Size*
Receptive Vocabulary[1]						
English Monolingual Group (n=24)	115.04	11.71	2.39	93 ~ 147		
Bilingual Group (n=24)	99.79	11.84	2.42	83 ~ 124	< .001	1.24
Expressive Vocabulary[2]						
English Monolingual Group (n=24)	117.38	11.90	2.43	96 ~ 141		
Bilingual Group (n=24)	99.21	12.82	2.62	76 ~ 131	< .001	1.48
Articulation Development[3]						
English Monolingual Group (n=24)	112.96	4.86	0.99	101 ~ 120		
Bilingual Group (n=24)	110.37	6.35	1.30	93 ~ 121	< 1	0.42

[1] *Peabody Picture Vocabulary Test-4* Standard Score
[2] *Expressive Vocabulary Trest-2* Standard Score
[3] *Goldman-Fristoe Test of Articulation-2* Standard Score

TABLE 2-2: *Means, Standard Deviations, Standard Errors, Minimum and Maximum Standard Scores, p Values, and Effect Sizes by the Korean monolingual group and the Bilingual group for the Korean Language Assessments*

	Mean	*SD*	*SEM*	*Min-Max*	*p*	*d* *Effect Size*
Perceptive Vocabulary[1]						
Korean Monolingual Group (n=24)	118.68	22.35	4.56	87 ~ 191		
Bilingual Group (n=24)	63.19	22.38	4.57	29 ~ 101	< .001	3.15
Expressive Vocabulary[2]						
Korean Monolingual Group (n=24)	111.63	16.44	3.36	86 ~ 147		
Bilingual Group (n=24)	31.54	32.05	6.54	< 1 ~ 83	< .001	4.15
Articulation Development[3]						
Korean Monolingual Group (n=24)	109.07	7.09	1.45	90 ~ 114		
Bilingual Group (n=24)	109.42	6.55	1.34	89 ~ 115	< 1	0.02

[1] *Receptive Vocabulary Test* Standard Score
[2] *Expressive Vocabulary Test* Standard Score
[3] *Assessment of Phonology & Articulation for Children* Standard Score

Sound selection

The sound pattern of standard Korean consists of 19 consonants, 10 vowels and 12 diphthongs (Lee & Ramsey, 2000). Table 2-3 provides the 10 Korean vowels categorized with respect to tongue position (high-mid-low, front-central-back) and lip rounding (rounding-unrounding) (Ha, Johnson, & Kuehn, 2009). Table 2-4 provides a classification of the 19 Korean consonants by manner and place of articulation with the English consonant system presented in the same table (Ha, Johnson, & Kuehn, 2009).

TABLE 2-3: Korean Vowels

	Front		Central		Back	
Place Tongue	Lips Unround	Round	Lips Unround	Round	Lips Unround	Round
High	i	y	ɨ			u
Mid	e	ø				o
					ʌ	
Low	ɛ					
					ɑ	

Source: From Characteristics of Korean phonology (Ha, Johnson, & Kuehn, 2009)

For the syllable-initial position, 18 Korean consonants, except /ŋ/, are possible, and only seven lax consonants /b, d, g, m, n, ŋ, l/ with no aspiration are allowed in the syllable-final position. These lax syllable-final consonants are unreleased and sound similar to English consonants with no audible release in syllable-final position. No consonant clusters are possible in syllable-initial or syllable-final positions in Korean. Only intersyllabic consonant clusters are allowable with restrictions for possible clusters (Kim & Pae, 2007).

TABLE 2-4: Korean and English consonants

	Bilabial		Labio-dental		Lingua-dental		Lingua-alveolar		Lingua-palatal		Velar		Glottal	
	K	E	K	E	K	E	K	E	K	E	K	E	K	E
Stop														
Tense	p*						t*				k*			
Lax[a]	p						t				k			
Aspirate	p^h						t^h				k^h			
Voiceless		p						t				k		
Voiced		b						d				g		
Affricate														
Tense									ç*					
Lax									ç					
Aspirate									$ç^h$					
Voiceless										tʃ				
Voiced										dʒ				
Fricative														
Tense							s*							
Lax							s							
Aspirate													h	
Voiceless				f		θ		s		ʃ				h
Voiced				v		ð		z		ð				
Nasal	m	m					n	n			ŋ	ŋ		
Liquid							l	l		r				
Glide		w								j				

Note: K = Korean; E = English; * = traditionally described as having a "tense" quality in Korean; h = traditionally described as having an "aspirated" quality Korean;
[a] Korean symbols /p, t, k, c, s/ without the diacritics * and h are traditionally described as have a "lax" quality.
Source: From Characteristics of Korean phonology (Ha, Johnson, & Kuehn, 2009)

In the sound system of English, there are 24 consonants, 14 vowels and 5 diphthongs.

Table 2-5 provides the 12 English vowels categorized with respect to tongue position (high-mid-low, front-central-back) (Small, 2005). Among the 24 English consonants, 22 consonants are possible in the syllable-initial position and 21 are allowed in the syllable-final position. English has more complex syllable shapes containing two-, three-, and four-element consonant sequences, which are allowable with restrictions for possible syllable positions (Gildersleeve-Neumann, Kester, Davis, & Pena, 2008).

TABLE 2-5: English Vowels

Place Tongue	Front	Central	Back
High	ɪ ɪ		u ʊ
Mid	e ɛ	ə ɝ ɚ ʌ	o
Low	æ		ɔ ɑ

Source: From Fundamentals of Phonetics (Small, 2005).

Although there may be subtle acoustic differences in articulation cross-linguistically, some sounds are similar enough to be nominally categorized as belonging to the same phonetic category. Languages have some equivalent vowels and consonants shared between languages since there are about 7000 languages in the world but only about 200 different vowels and 600 different consonants have been estimated (Ladefoged, 2001), leading to a principle idea behind the international phonetic alphabet (IPA; Pullum & Ladusaw, 1996). Cross-language perception studies have shown that some of the English consonants are consistently labeled as legal Korean consonants (Kim, 1972; Schmidt, 1994). Specifically, it has been reported that English voiceless stops /p, t, k/ and affricate /tʃ/ were labeled as the aspirated Korean consonants and affricate /p^h, t^h, k^h, ç^h/, while English voiced stops /b, d, g/ and affricate /dʒ/ were labeled as either tense /p*, t*, k*, ç*/ or lax /p, t, k, ç/ Korean stops and affricates corresponding in manner and place of articulation (Kim, 1972; Schmidt, 1994). Moreover, the English fricatives /s, h/ and nasals /m, n, ŋ/ were labeled as the same Korean consonants. Two English liquids /r, l/ were labeled as the same Korean liquid /l/. The consonants which have been categorized as the same phoneme across two languages in the past reports (Kim, 1972; Schmidt, 1994) are defined as shared consonants herein for the current study using the same IPA for both languages (i.e. English sound system symbols). Table 2-6 displays the consonants that are categorized as the same phoneme across the two languages. In summary, the shared consonants that occur in both languages using the same IPA are 16 consonants /p, t, k, b, d, g, tʃ, dʒ, s, h, l, m, n, ŋ, w, j/. In terms of vowels, 6 vowels /i, ɛ, ʌ, ɑ, o, u / appear to occur in both languages based on the vowel classification with respect to tongue position as shown in Table 2-3 and 2-5 (Ha, Johnson, & Kuehn, 2009; Small, 2005).

TABLE 2-6. Shared consonants across two languages

	Bilabial	Lingua-Alveolar	Lingua-Palatal	Velar	Glottal
Stop	p b	t d		k g	
Affricate			tʃ dʒ		
Fricative		s			h
Nasal	m	n		ŋ	
Liquid		l			
Glide	w		j		

Database

To compute phonotactic probability for the English language, an online dictionary called the Hoosier Mental Lexicon (HML, Nusbaum, Pisoni, & Davis, 1984) was used. The HML consists of over 19,000 words and the word frequency of each word taken from Kucera and Francis (1967). The HML has been used in a number of other studies of phonotactic probability and neighborhood density (e.g., Luce & Pisoni, 1998; Metasala; 1997; Morrisette & Gierut, 2002; Newman & German, 2002; Storkel, 2001, 2003, 2004, Vitevitch, 1997, 2002; Vitevitch & Luce, 1998, 1999; Vitevitch & Sommers, 2003). Using this database, an on-line calculator (http://www.bncdnet.ku.edu/cml/info_ccc.vi) was used to calculate two measures of phonotactic probability (positional segment average and biphone average) and one measure of neighborhood density.

For Korean phonotactic probability, an adult corpus was obtained from the Korean Mental Lexicon (KML, The National Institute of the Korean Language, 2002), which contains over 58,000 words and word frequency. Using this database, a calculator was developed by the author to calculate two measures of phonotactic probability (positional segment average and biphone average) and one measure of neighborhood density for the Korean language.

Using each database (i.e., KML for Korean, HML for English), *positional segment frequency*, which is the likelihood of occurrence of a given sound in a given word position, was computed as an index of phonotactic probability for shared sounds in each language (Storkel, 2004). To compute the positional segment frequency for each sound in word initial position, the log frequency of the words in the database (i.e., KML for Korean, HML for English) containing the target sound in word initial position was summed and then divided by the sum of the log frequency of the words in each database containing any segment in the target word position.

Then, the segment frequency for each sound was converted to a z score by subtracting the mean positional segment frequency for all the sounds in word initial position from the obtained value and then dividing by the standard deviation for all the sounds in word initial position, i.e., z = (obtained value-M)/SD. The converted z scores were used to categorize sounds as high or low in each language. Table 2-7 displays z score for each shared sound in each language.

TABLE 2-7: Initial segment frequency z score for each language

	Phoneme	English_z	Korean_z
1	s	2.7979	2.6738
	m	1.1427	1.0199
	b	0.923	1.7145
	d	0.945	1.0006
2	l	0.2968	-0.5871
	n	-0.0804	0.2619
3	k	2.4427	-0.441
	p	2.1388	0.6616
	t	0.6777	-0.0772
4	h	0.4909	1.1081
	g	0.0002	3.0955
	dʒ	-0.4466	2.5305
	tʃ	-0.626	0.6616

Note: 1 Matched high phonotactic probability
2 Matched low phonotactic probability
3 Mismatched phonotactic probability: English-high/Korean-low probability
4 Mismatched phonotactic probability: English-low/Korean-high probability

The comparison of z scores across two languages shows several sounds that are matched in phonotactic probability across two languages, with high phonotactic probability or low phonotactic probability in both languages. Specifically, two sounds, /s, m/, are matched in high phonotactic probability across two languages and thus are selected for the matched-high probability condition. Two sounds, /n, l/, are matched in low phonotactic probability across two languages and thus are selected for the matched-low probability condition. In each condition, five shared vowels - /i, ʌ, ɑ, o, u / and seven final consonants /b, d, g, m, n, l, ŋ/ were used for the nonwords.

Nonword Selection

Using these phonemes, a pool of all consonant-vowel-consonant (CVC) sequences and consonant-vowel-consonant-vowel (CVCV) sequences that are legal both in Korean and English was created and submitted to both a Korean calculator and an English on-line calculator (http://www.bncdnet.ku.edu/cml.info_ccc.vi) to identify real words in an adult corpus for each language. Then, real words in either language were eliminated from stimuli selection leaving only nonwords in both languages as stimuli. Phonotactic probability was computed for the remaining nonwords in each language using the language-specific calculator as described previously. Appendix F provides the list of nonword selection in each condition.

The *positional segment average* was used to compute values of phonotactic probability in each language. First, the *positional segment average* was computed by summing the positional segment frequency of each sound in the word and then dividing by the number of segments in the word. The positional segment frequency for a given sound in a given word was computed by summing the log frequency of the words in the database containing the target sound in the target word position and then dividing by the sum of the log frequency of the words in the database containing any segment in the target word position. Secondly, the obtained raw value of the positional segment average for each nonword was converted to a *z* score in order to compare phonotactic probability across languages. A *z* score for each nonword was computed by subtracting the positional segment average for the 3-phoneme or 4-phoneme words from the obtained value and then dividing by the standard deviation for the 3-phoneme or 4-phoneme words. This yields a length-sensitive *z* score which has shown to decrease the positive correlation between word length and phonotactic probability (Storkel, 2004).

Based on the length-sensitive *z* score, 12 nonwords were selected for each matched-phonotactic probability condition; 12 have low phonotactic probability and 12 have high phonotactic probability in both languages. Table 2-8 displays the obtained *z* scores of each language for the conditions. The low or high probability condition was constructed based on the segment average z scores to create nonoverlapping ranges of segment average *z* score between two conditions in each language. Specifically, the English segment average *z* score in the low probability was -0.689 (*SD* = 0.310) and the English segment average *z* score in the high probability was 0.557 (*SD* = 0.424). In addition, the range of the segment average *z* score for English in the low-probability condition is from -1.066 to - 0.074 and the range in the high-probability condition is from 0.03 to 1.93. This pattern was also observed in the Korean segment average *z* score in the low-probability condition was -0.231 (*SD* = 0.288) while the Korean segment average *z* score in the high-probability condition was 0.924 (*SD* = 0.5). The range in the low-probability condition is from -0.663 to 0.143 and the range of the segment average *z* score for Korean in the high-probability condition was from 0.304 to 1.760. This nonoverlapping range of segment average *z* scores between the two probability conditions was used to construct the two different probability conditions while having a similar pattern of probability for the two conditions between languages.

TABLE 2-8: *z* scores for nonwords selection in Matched-probability conditions

		Matched Low Probability	Matched High Probability
English Seg Mean	Mean	-0.689	0.557
	SD	0.310	0.424
	Range	-1.066 ~ -0.074	0.030 ~ 1.193
Korean Seg Mean	Mean	-0.231	0.924
	SD	0.288	0.500
	Range	-0.663 ~ 0.143	0.304 ~ 1.760
English Bip Mean	Mean	-0.686	-0.261
	SD	0.207	0.416
	Range	-1.0 ~ -0.269	-0.731 ~ 0.692
Korean Bip Mean	Mean	-0.754	0.588
	SD	0.407	0.675
	Range	-1.196 ~ -0.206	-0.190 ~ 1.522
English Nb Mean	Mean	-0.281	-0.267
	SD	1.042	0.832
	Range	-1.517 ~ 2.10	-1.205 ~ 1.628
Korean Nb Mean	Mean	-0.702	0.223
	SD	0.299	0.872
	Range	-1.074 ~ -0.107	-0.653 ~ 2.030

Note: Seg Mean= Positional segment average; Bip Mean= biphone average; Nb= Neighborhood density; M= Mean; SD= Standard deviation;

Stimuli were not explicitly selected to manipulate or control biphone average or neighborhood density. These were free to vary. The *biphone average* was computed by summing the biphone frequency for a given pair of adjacent sounds in a given word and then dividing by the number of biphones in the word. The biphone frequency was computed by summing the log frequency of the words in the database containing the target pair of sounds in the target word position and then divided by the sum of the log frequency of the words in the database containing any pair of sounds in the target word position. Then, the obtained raw value of the biphone average for each nonword was converted to a length-sensitive *z* score by subtracting the biphone average for 3-phoneme or 4-phoneme words from the obtained value and then dividing by the standard deviation for the 3-phoneme or 4-phoneme words.

Although the biphone average was found to be highly correlated with segment average within languages, it was observed to be mismatched across two languages. Because the frequencies of vowels and final consonants considerably differed across two languages, it was impossible to select nonwords that were matched in low and high on biphone *z*-scores. Thus, nonwords were selected only based on positional segment average *z*-scores constructing the nonoverlapping range for segment average *z*-scores between the two conditions.

Additionally, *neighborhood density* for each language was computed by counting the number of words in each database that differ from the target CVC or CVCV by a one sound substitution, deletion, or addition in any word position (Storkel, 2004). This obtained raw value of neighborhood density was converted to a *z*-score by subtracting the average neighborhood density for 3-phoneme or 4-phoneme words from the obtained value and then dividing by the standard deviation for the 3-phoneme or 4-phoneme words. The English neighborhood density *z* score was not clearly correlated with phonotactic probability, while the Korean neighborhood density *z* score was correlated. The English neighborhood density in the matched-high probability condition (*M* = -0.267 SD = 0.832) was slightly higher than that in the matched-low probability condition (*M* = -0.281, *SD* = 1.042). The Korean neighborhood density in the matched-high probability condition (*M* = 0.223, *SD* = 0.872) was higher than that in the matched-low probability condition (*M* = - 0.702, *SD* = 0.299). Because the main purpose of the current study was to examine the phonotactic probability, neighborhood density was not explicitly manipulated in the current study.

Stimulus materials

The selected nonwords and instructions were recorded one at a time in a list by a female native English speaker and a female native Korean speaker (who had been staying in the U.S. less than a year) in a sound-proof room. In this way, the selected nonwords were the same but they differed in phonetic context based on the speaker who recorded the stimuli. This served as another independent variable (i.e., English-phonetic context and Korean-phonetic context). The English-monolingual group heard stimuli recoded by the English speaker and the Korean-monolingual group heard stimuli recorded by the Korean speaker. The bilingual group heard both language stimuli, each in a separate session. The order of stimuli was counterbalanced. The stimuli were digitized and edited into individual audio files. The durations of the stimuli were measured by two judges using a spectrogram, and the average of the measurement by two judges was compared to determine interjudge reliability. The durations of the stimuli in the two phonotactic probability conditions were equivalent but differed across languages with English stimuli being longer than Korean.

Procedure

The monolingual groups participated in one session to complete screening tests and the experimental task, while the bilingual group participated in two sessions on different days to complete screening tests and the experimental task in each language. First, participants' hearing was tested to determine study eligibility. If participants passed the hearing screening, the experimental task proceeded. The experimental task was a same-different task. Each participant was seated in front of a laptop computer equipped with a response box and a table-top speaker.

The left button on the response box was used for DIFFERENT responses while the right button was used for SAME responses. The left button on the response box had two different stickers (i.e., one yellow smiley face and one red star), and the right button had two yellow smiley faces. The right button was placed under the dominant hand. Only SAME responses were analyzed for reaction times and accuracy because reaction times with the dominant-hand may differ from reaction times with the nondominant-hand (Kauranen & Vanharanta, 1996). All auditory instructions and stimuli were played over table-top speakers at comfortable listening level.

Prior to the experimental trials, each participant received instructions and training in their native language, or in the case of bilinguals, the language randomized to that session. The training procedure started with eight practice trials with non-object pictures. Participants were instructed by pre-recorded instructions to press the right button if the pictures on the computer were the same and to press the left button if the two pictures were not the same. Feedback was presented for each practice trial by pre-recorded instructions whether the pictures were the same or different. Four practice trials consisted of presentation of identical pictures (constituting SAME responses) and the other four consisted of presentation of different stimuli (constituting DIFFERENT responses). Once participants mastered the task, which was defined as six correct responses out of eight trials, they were presented with an auditory practice with nonwords. Similar to the picture task, participants were instructed to press the right button if the two nonwords that they heard were the same and to press the left button if the two nonwords that they heard were not the same. Stimuli in a pair were separated by 500 ms. Participants were presented with eight practice trials with feedback. Once they achieved mastery for practice (i.e., six correct responses out of eight), they started the experimental trials which consisted of 4 practice trials with no feedback, followed by the 48 experimental trials.

If a participant did not pass the non-object picture training, he or she received a more extensive training protocol which consisted of training with real-object pictures and continued with non-object pictures. Once participants mastered the task with the non-object pictures, they were presented with an auditory practice with real words and feedback. Once participants mastered that the real word practice, then they continued with nonwords. If participants failed in any phase of training, they repeated all training phases again on a different day. Only participants who passed the nonword training phase continued with experimental trials. In the English-monolingual group, nine children needed this extensive training and four was excluded because they could not pass the training. In the Korean group, five children needed this extensive training and two were excluded. In the bilingual group, 11 children needed this extensive training and four were excluded because they could not pass training.

Reaction times were measured from the onset of the second stimulus in the pair to the button press response. If participants did not press a button in three seconds, the computer automatically recorded an incorrect response and presented the next trial. Twenty-four stimuli (i.e., 12 low probability and 12 high probability nonwords) were presented as SAME responses and 24 as DIFFERENT responses. DIFFERENT responses were created by pairing the target nonwords with one of the other target nonwords, while attempting to match the same initial phoneme and the same vowel as much as possible. Trial order was randomized within and between the phonotactic probability conditions by Direct RT software which was also used to collect accuracy and reaction times. For the data analysis, reaction times were corrected by subtracting the stimulus duration from the total reaction time for each item because the durations of the stimuli differed across two languages. This method allows comparisons across the two languages (i.e., monolingual Korean to monolingual English; bilingual's responses in Korean-phonetic context to bilingual's responses in English-phonetic context).

Experiment 2

The second experiment examined the effects of phonotactic probability on phonological processing by bilingual preschool children when phonotactic probability differs across languages and to explore the effects of language status on phonological processing.

Participants

The same bilingual children, who participated in Experiment 1, participated in Experiment 2. Only the bilingual group participated in Experiment 2 because this experiment examined parallel activation of two languages on phonological processing for the sounds that are mismatched in phonotactic probability across the two languages, which required participants to have a phonological knowledge in both languages. Bilingual children participated in four experimental sessions for Experiment 2. In each session, they participated in a same-different task under different lexical contexts; neutral context (a neutral context with English-phonetic stimuli and a neutral context with Korean-phonetic stimuli), and language-biased context (an English-language biased context with English phonetic stimuli, and a Korean-language biased context with Korean phonetic stimuli). Administration of the Experiment 1 task always occurred first (on sessions one and two). The neutral context of Experiment 2 was always tested next (on sessions three and four) with the order of the two phonetic contexts counterbalanced across participants. The biased contexts of Experiment 2 were always tested last (on sessions five and six) with the order of the two languages counterbalanced across participants. The language biased contexts were implemented by filler stimuli: filler nonwords for neutral contexts but filler real words for biased contexts. Fillers constituted 25% of the experimental trials in order to invoke the sublexical processing for the task as suggested by Vitevitch and Luce (1999).

Sound Selection

Among shared phonemes that exist in both languages as previously described in Experiment 1, four sounds were selected which were observed to be mismatched in phonotactic probability across two languages, with low phonotactic probability in one language but high phonotactic probability in the other language (See Table 2-7). Specifically, two phonemes /k/ and /p/ occur frequently in English (i.e., English initial segment *z* score of 2.443 and 2.139, respectively), but infrequently in Korean (i.e., Korean initial segment z score of -0.441 and 0.662, respectively). In contrast, two phonemes /g/ and /dʒ/ occur infrequently in English (i.e., English initial segment *z* score of 0.0002 and -0.447, respectively), but frequently in Korean (i.e., Korean initial segment z score of 3.096 and 2.531, respectively).

Nonword Selection

The same procedures from Experiment 1 were used to construct nonwords using the same vowels and codas but with these mismatched initial phonemes. A total of 24 nonwords were constructed in such a way that phonotactic probabilities were mismatched across the two languages. Twelve nonwords were formed with segment patterns that had low phonotactic probability in English but high phonotactic probabilities in Korean (English-low/Korean-High), and 12 nonwords were formed with segment patterns that had high phonotactic probability in English but low phonotactic probabilities in Korean (English-High/Korean-Low). Table 2-9 provides the *z* scores for each condition in each language that are in a reversed direction (i.e., negative *z* scores in English but positive *z* scores in Korean for the English-Low/Korean-High condition).

TABLE 2-9: *z* scores for nonword selection in Mismatched-probability conditions

		Mismatched E-Low/K-High Probability	Mismatched E-High/K-Low Probability
English Seg Mean	Mean	-1.081	0.485
	SD	0.332	0.263
	Range	-1.687 ~ -0.452	0.052 ~ 1.015
Korean Seg Mean	Mean	1.060	-0.146
	SD	0.464	0.312
	Range	0.491 ~ 1.788	-0.618 ~ 0.280
English Bip Mean	Mean	-0.854	-0.650
	SD	0.237	0.259
	Range	-1.154 ~ -0.346	-1.111 ~ -0.269
Korean Bip Mean	Mean	1.060	-0.146
	SD	0.464	0.312
	Range	0.491 ~ 1.788	-0.618 ~ 0.280
English Nb Mean	Mean	-1.082	-0.256
	SD	0.626	0.771
	Range	-1.796 ~ -0.025	-1.296 ~ 0.802
Korean Nb Mean	Mean	0.459	-0.644
	SD	0.636	0.462
	Range	-0.518 ~ 1.247	-1.196 ~ 0.069

Note: E-Low/K-High: Sounds with English low phonotactic probability but Korean high phonotactic probability; E-High/K-Low: Sounds with English high phonotactic probability but Korean low phonotactic probability; Seg Mean= Positional segment average; Bip Mean= biphone average; Nb= Neighborhood density; M= Mean; SD= Standard deviation.

The English segment average *z* score in the English-Low/Korean-High condition is -1.081 (*SD* = 0.332), while the Korean segment average *z* score in the English-Low/Korean-High condition is 1.060 (*SD* = 0.464). On the other hand, the English segment average *z* score in the

English-High/Korean-Low condition is 0.485 (*SD* = 0.263), while the Korean segment average *z* score in the English-High/Korean-Low condition is -0.146 (*SD* = 0.312). Appendix G provides the list of nonwords in each condition.

In an attempt to bias language activation at the sublexical level, eight filler items were selected for each lexical context (i.e., neutral and language-biased) using the same initial phonemes (i.e., /k, p, g, dʒ/) as target nonwords. Eight nonwords were selected for the neutral context, eight English real words for the English-lexical biased context, and eight Korean real words for the Korean-lexical biased context. Appendix H provides a list of the nonword fillers for the neutral context and the English and Korean real word fillers for the lexical biased contexts. For the neutral context, eight nonwords pairs were added as fillers in attempt to construct no lexical biased context. For the lexical biased context, the word frequency for the selected real words in each language was converted to *z* scores to compare across two languages. The word frequency *z* scores were matched across two lexical-biased contexts (i.e., *M* = 1.809, *SD* = 0.933 for English words; *M* = 2.151, *SD* = 1.079 for Korean words). The eight real words were paired with the identical stimuli constituting nine SAME responses and eight were paired with different stimuli (with the same initial phoneme and the same vowel if possible) constituting eight DIFFERENT responses. A total of 16 trials with real word pair fillers constituted 25% of the task under each language context (i.e., 16 trials with word pairs, 48 trials with nonwords pairs) such that the language to process the stimuli was biased and constructed to invoke the phonological processing for the task (i.e., nonword stimuli make up the majority of the stimuli).

Stimulus materials

The words and nonwords were recorded in a sound proof booth by the same speakers who recorded the stimuli for Experiment 1. As in Experiment 1, the acoustic characteristics of the speaker were expected to invoke a particular phonetic context (English, Korean). Stimuli were digitized and edited into individual audio files. The durations of the stimuli were measured by two judges using a spectrogram. The average of the measurement by two judges was compared to determine interjudge reliability, verifying the equivalent durations of the stimuli for the two phonotactic conditions but differences across languages with longer duration for English.

Procedure

Bilingual children participated in four experimental sessions for Experiment 2. In each session, they participated in a Same-different task under different language contexts: a Neutral context with English-phonetic stimuli, a Neutral context with Korean-phonetic stimuli, an English-language biased context with English-phonetic stimuli, and a Korean-language biased context with Korean-phonetic stimuli. As in Experiment 1, Experiment 2 began with practice trials. However, picture recognition and nonword practice trials with feedback were not used since they already had participated in Experiment 1 with the same tasks. Instead, the task began with eight nonword practice trials with no feedback. Practice had to be passed by showing six of eight correct responses. Once training was passed, the 68 experimental trials were administered. Upon the completion of the task, the children were administered an articulation or expressive vocabulary test for the language that was tested

CHAPTER III: RESULT

Experiment 1

The influence of phonotactic probability on phonological processing when phonotactic probability was matched across languages was evaluated by the mean proportion of correct responses and the mean reaction time for the SAME responses. Reaction time data for the SAME responses were only used if a response was accurate and within 2 standard deviations of the mean for that subject. The mean proportion of correct responses (i.e., mean accuracy) and the mean reaction time were calculated for each phonotactic probability condition and each group. A series of mixed model ANOVAs with phonotactic probability as a within-participants factor and group as a between-participants factor was performed on the mean accuracy and corrected-reaction time for each language. The first analysis was to compare English monolinguals' responses and Korean monolinguals' responses. The second analysis was to compare English monolinguals' responses and bilinguals' responses in the English-phonetic context. Lastly, Korean monolinguals' responses were compared with bilinguals' responses in the Korean-phonetic context. The Huyhn-Feldt correction for sphericity for repeated measures was used (Huynh & Feldt, 1976). All significant effects had p values of .05 or less. An effect size for each independent variable was measured by partial eta squared ($\eta^2_{partial}$).

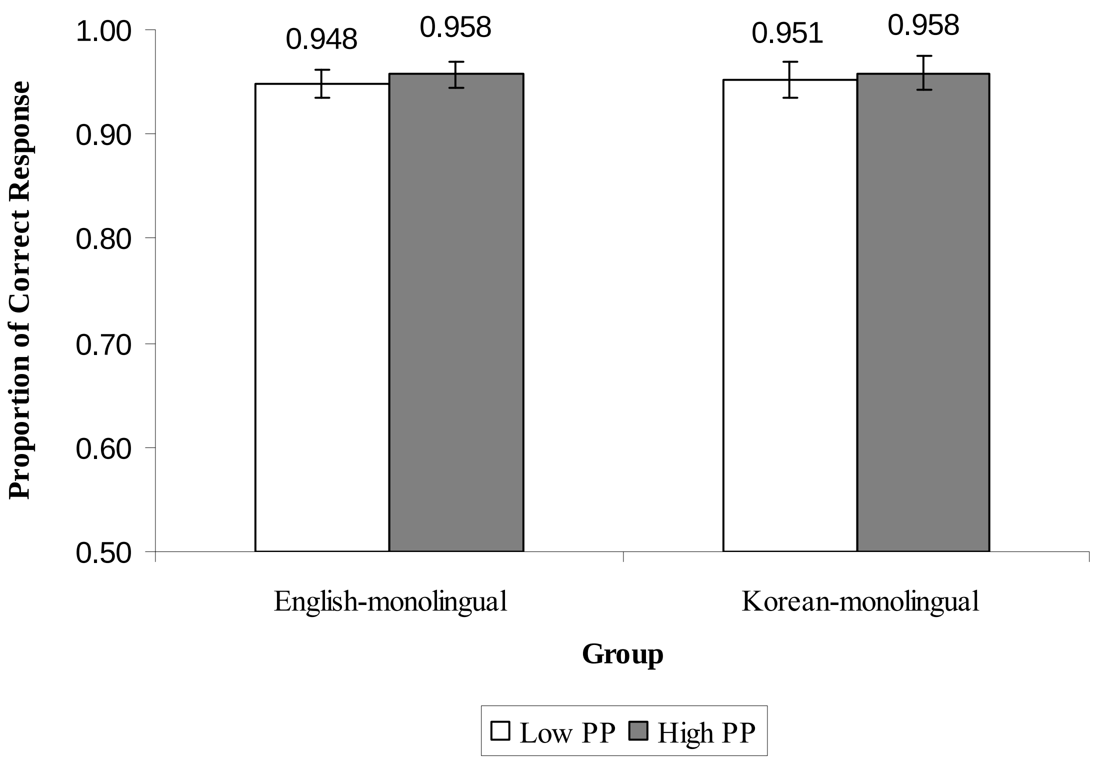
Accuracy Analysis

The mean proportions of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the Korean-monolingual group are shown in Figure 3-1. Two (phonotactic probability: low vs. high) x 2 (group: English monolingual vs. Korean monolingual) ANOVA revealed no significant effects for accuracy (all p

values > .05) with a near ceiling performance in each condition (all above 95% accuracy) by both groups.

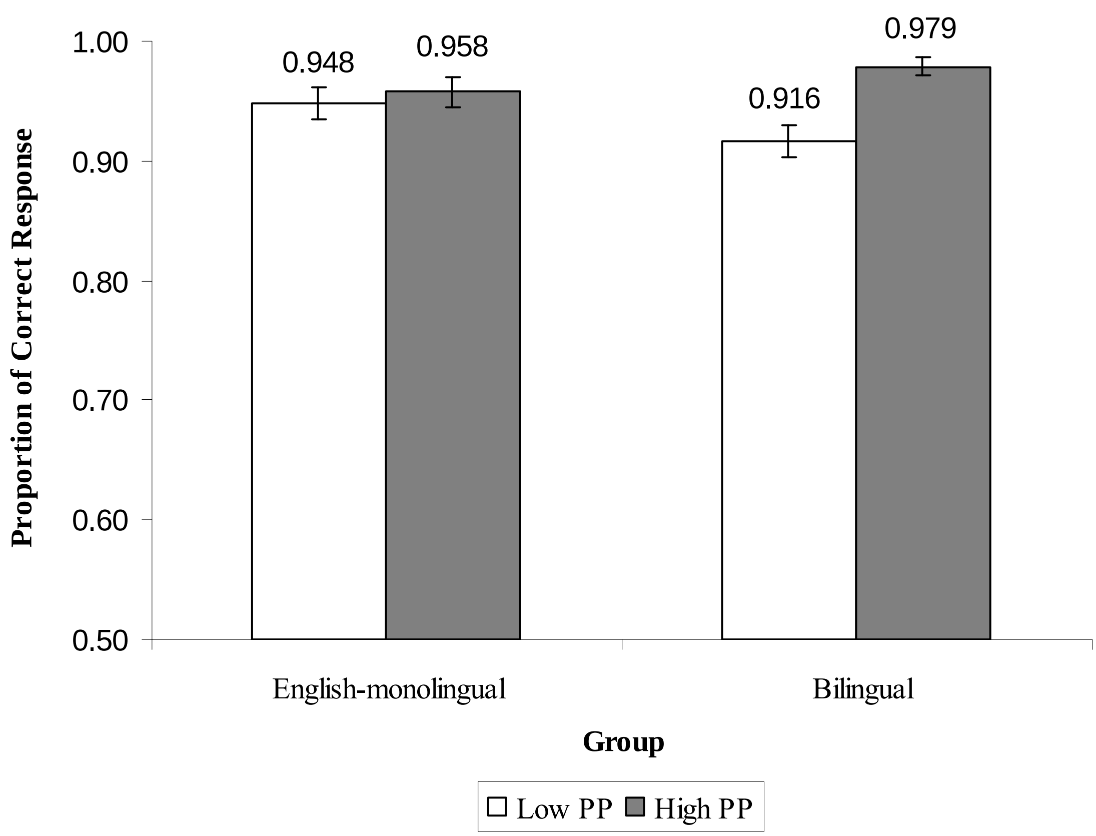
To assess monolingual versus bilingual differences in language processing, accuracy for each phonetic context (English-phonetic and Korean-phonetic) was analyzed separately.

Figure 3-1. The mean proportions of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the Korean-monolingual group. Error bars indicate the Standard Error of Measurement (SEM).



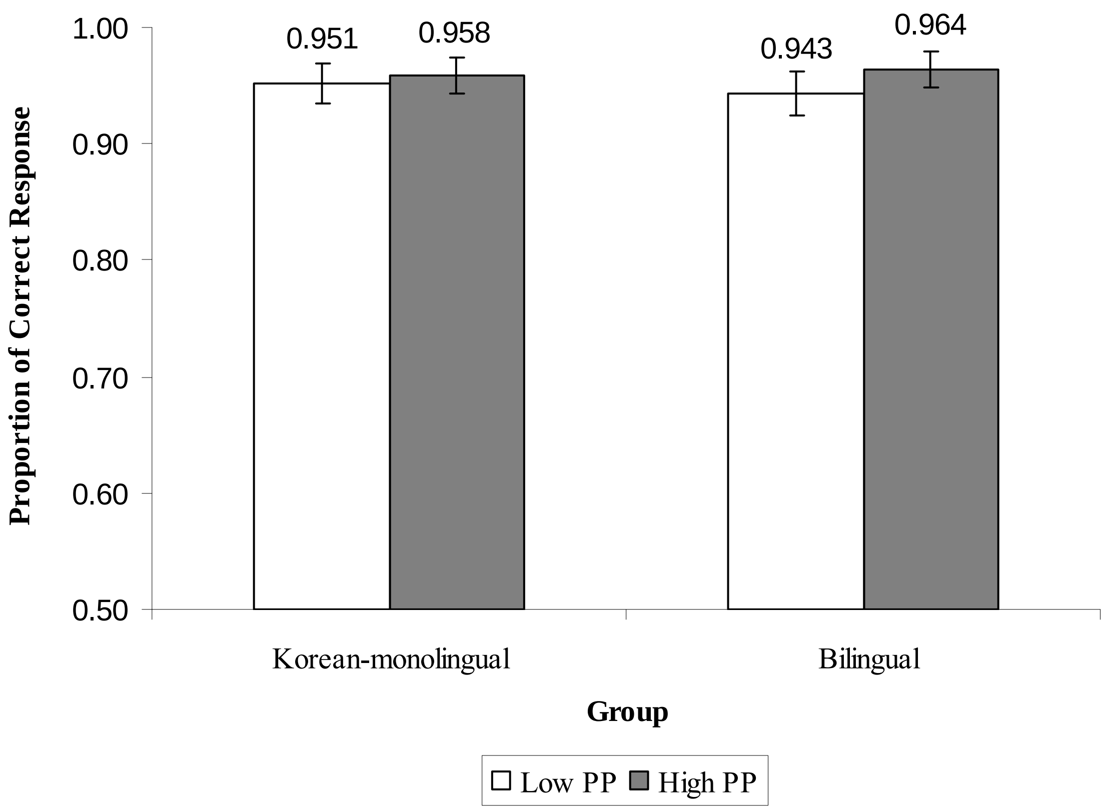
English-phonetic context Figure 3-2 displays the mean proportions of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the bilingual group's English data. Two (phonotactic probability: low vs. high) x 2 (group: English monolingual vs. Bilingual) ANOVA showed a significant main effect of phonotactic probability ($F(1, 46) = 9.53$, $p = .003$, $\eta^2_{partial} = .172$). High probability items (*M* = .979, *SD* = .052) were responded to more accurately than low probability items (*M* = .932, *SD* = .066). The effect of group was not significant ($F(1, 46) = .19$, $p = .668$, $\eta^2_{partial} = .004$), but an interaction of phonotactic probability and group was significant ($F(1, 46) = 5.07$, $p = .029$, $\eta^2_{partial} = .099$). A follow-up analysis for each group revealed a significant effect of phonotactic probability in the bilingual group ($F(1, 23) = 18.82$, $p < .001$, $\eta^2_{partial} = .450$), but not in the English monolingual group ($F(1, 23) = .28$, $p =.601$, $^2_{partial} = .012$).

Figure 3-2. The mean proportions of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the Korean-monolingual group. Error bars indicate the Standard Error of Measurement (SEM).



Korean-phonetic context Figure 3-3 displays the mean proportion of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the Korean-monolingual and the bilingual group's Korean data. Two (phonotactic probability: low vs. high) x 2 (group: Korean monolingual vs. Bilingual) ANOVA revealed no significant effects for accuracy (all p values > .05) with a near-ceiling performance in each condition (all above 94% accuracy) by both groups.

Figure 3-3. The mean proportions of correct responses on high phonotactic probability versus low phonotactic probability nonwords in the Korean-monolingual and the bilingual group. Error bars indicate the Standard Error of Measurement (SEM).



Cross-language comparison A subanalysis with only the bilingual group was performed to compare accuracy across the two languages. Two (phonotactic probability: low vs. high) x 2 (phonetic context: English-phonetic vs. Korean-phonetic) ANOVA revealed a significant main effect of phonotactic probability ($F(1, 23) = 13.86$, $p = .001$, $\eta^2_{partial} = .376$). High probability items ($M = .971$, $SD = .009$) were responded to more accurately than low probability items ($M = .930$, $SD = .011$). The effect of phonetic context was not significant ($F(1,23) = .115$, $p = .738$, $\eta^2_{partial} = .005$), but the interaction of phonetic context and probability was significant ($F(1,23) = 4.453$, $p = .046$, $\eta^2_{partial} = .162$). A follow-up analysis for each phonetic context revealed a significant effect of phonotactic probability in the English-phonetic context ($F(1, 23) = 18.82$, $p < .001$, $\eta^2_{partial} = .450$) but not in the Korean-phonetic context ($F(1, 23) = 1.70$, $p = .205$, $\eta^2_{partial} = .069$).

Reaction Time Analysis

The mean corrected-reaction times on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the Korean-monolingual group are shown in Figure 3-4. Two (phonotactic probability: low vs. high) x 2 (group: English monolingual vs. Korean monolingual) ANOVA revealed a significant main effect of phonotactic probability ($F(1, 46) = 6.13$, $p = .017$, $\eta^2_{partial} = .118$). High probability items ($M = 838$, $SD = 499$) were responded to more quickly than low probability items ($M = 954$, $SD = 639$). The effect of group was not significant ($F(1,46) = .89$, $p = .350$, $\eta^2_{partial} = .019$), nor was the interaction of phonotactic probability and group ($F(1,46) = .061$, $p = .807$, $\eta^2_{partial} = .001$).

To assess monolingual versus bilingual differences in language processing, reaction times for each phonetic context (English-phonetic and Korean-phonetic) was analyzed separately.

English-phonetic context Figure 3-5 displays the mean reaction times on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the bilingual group’s English data. Two (phonotactic probability: low vs. high) x 2 (group: English monolingual vs. Bilingual) ANOVA revealed a significant main effect of phonotactic probability ($F(1, 46) = 4.12$, $p = .048$, $\eta^2_{partial} = .082$). High probability items (*M* = 786, *SD* = 487) were responded more quickly than low probability items (*M* = 886, *SD* = 644). The effect of group was not significant ($F(1, 46) = 3.06$, $p = .087$, $\eta^2_{partial} = .062$), nor was the interaction of phonotactic probability and group ($F(1, 46) = .007$, $p = .934$, $\eta^2_{partial} = .000$).

Figure 3-4. The mean reaction times on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the Korean-monolingual group. Error bars indicate the Standard Error of Measurement (SEM).

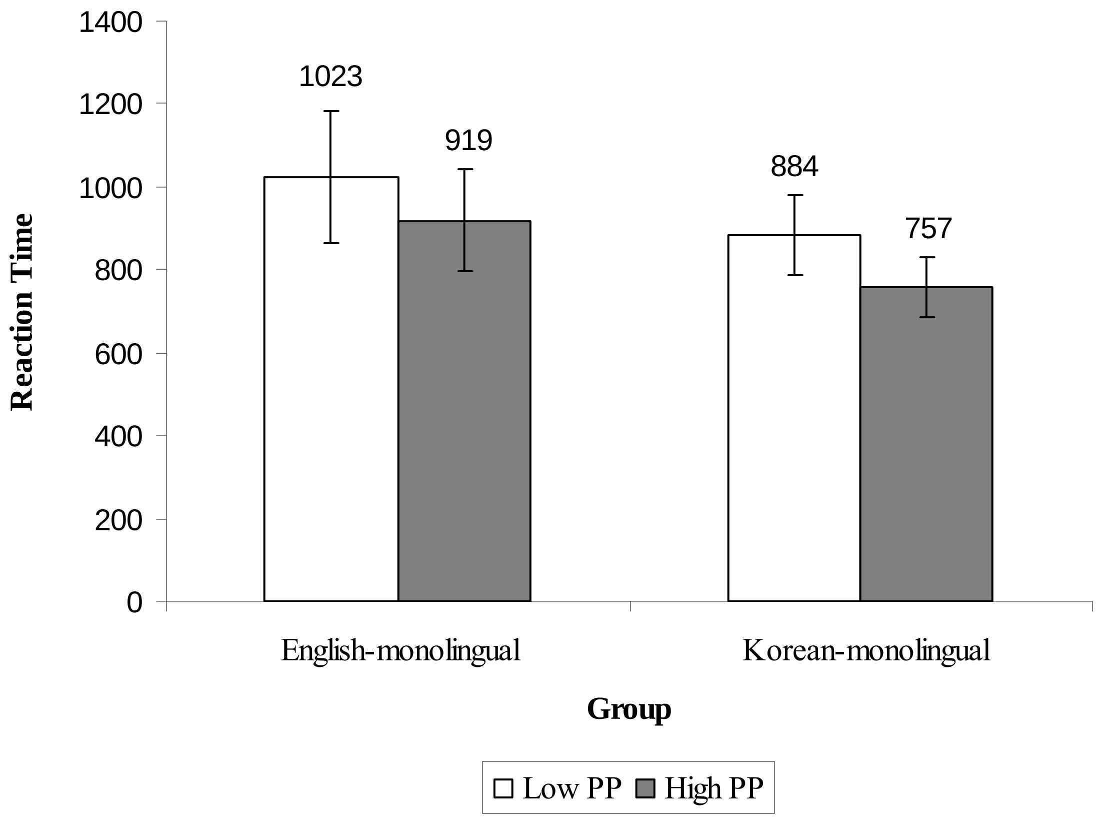
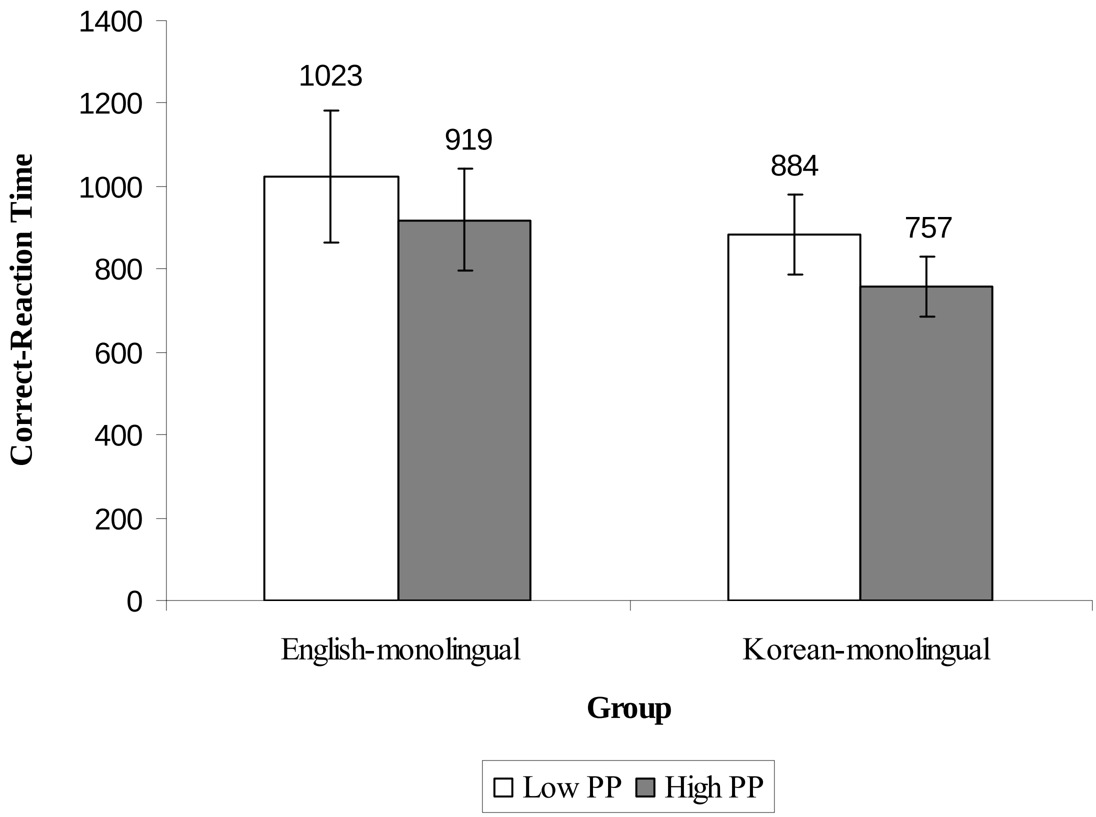
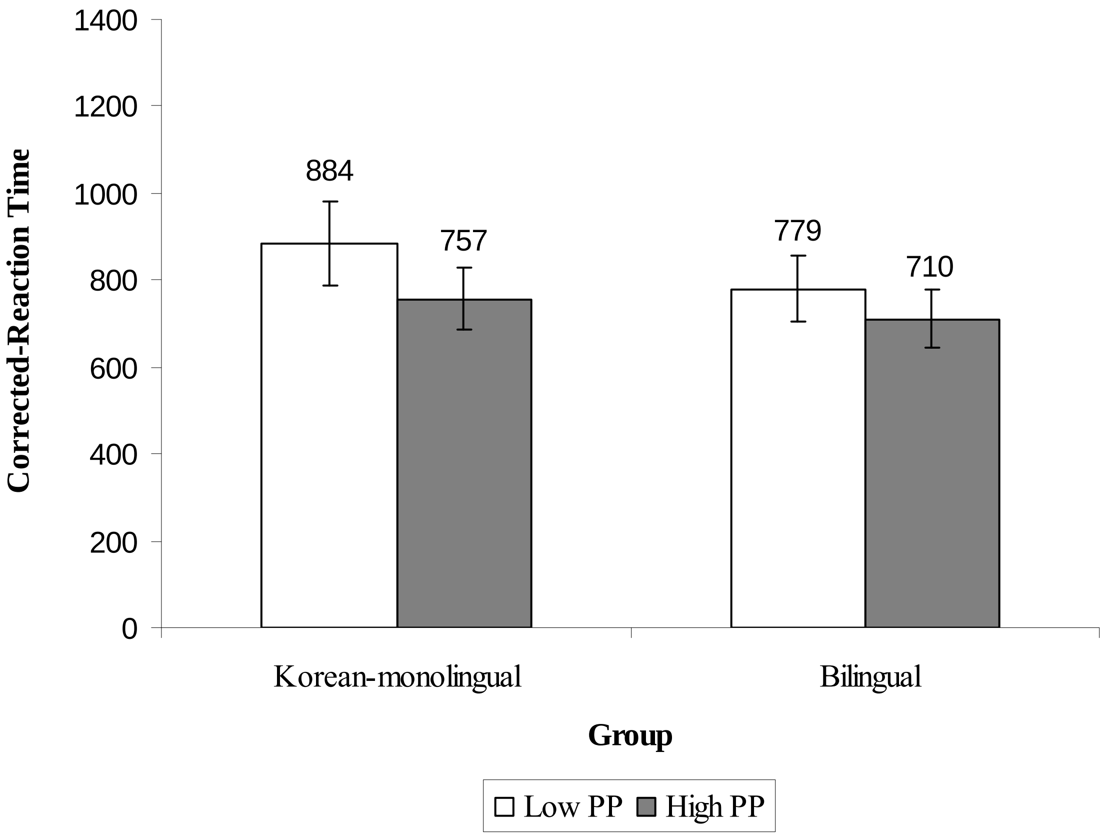


Figure 3-5. The mean reaction times on high phonotactic probability versus low phonotactic probability nonwords in the English-monolingual and the bilingual group. Error bars indicate the Standard Error of Measurement (SEM).



Korean-phonetic context Figure 3-6 displays the mean reaction times for high phonotactic probability versus low phonotactic probability nonwords in the Korean-monolingual and the bilingual group's Korean data. Two (phonotactic probability: low vs. high) x 2 (group: Korean monolingual vs. Bilingual) ANOVA revealed a significant main effect of phonotactic probability ($F(1, 46) = 7.46$, $p = .009$, $\eta^2_{partial} = .140$). High probability items ($M = 734$, $SD = 342$) were responded to more quickly than low probability items ($M = 832$, $SD = 428$). The effect of group was not significant ($F(1, 46) = .51$, $p = .480$, $\eta^2_{partial} = .011$), nor was the interaction of phonotactic probability and group ($F(1, 46) = .65$, $p = .423$, $\eta^2_{partial} = .014$).

Figure 3-6. The mean reaction times on high phonotactic probability versus low phonotactic probability nonwords in the Korean-monolingual and the bilingual group. Error bars indicate the Standard Error of Measurement (SEM).



Cross-language comparison A subanalysis with only the bilingual group was performed to compare reaction times across languages. Two (phonotactic probability: low vs. high) x 2 (phonetic context: English-phonetic vs. Korean-phonetic) ANOVA revealed a significant main effect of phonotactic probability ($F(1, 23) = 4.86$, $p = .038$, $\eta^2_{partial} = .174$). High probability items ($M = 682$, $SD = 307$) were responded more quickly than low probability items ($M = 764$, $SD = 418$). The effect of phonetic context was not significant ($F(1, 23) = .22$, $p = .647$, $\eta^2_{partial} = .009$), nor was the interaction of phonotactic probability and phonetic context ($F(1, 23) = .11$, $p = .746$, $\eta^2_{partial} = .005$).

In summary, the accuracy analysis showed a significant main effect of phonotactic probability and an interaction of phonotactic probability and group in the English-phonetic context. Specifically, the effect of phonotactic probability for the bilingual group was significant but the effect was not significant for the English-monolingual group. No main effect of phonotactic probability or an interaction of phonotactic probability and group was obtained in the Korean-phonetic context. These results should be interpreted with caution due to the near ceiling performance for accuracy. Given this high accuracy, the reaction time measure may be the more sensitive and revealing measure. Specifically, the reaction time analysis revealed a significant main effect of phonotactic probability by all groups regardless of the phonetic context. All groups responded more quickly for high probability nonwords than low probability nonwords in the target language.

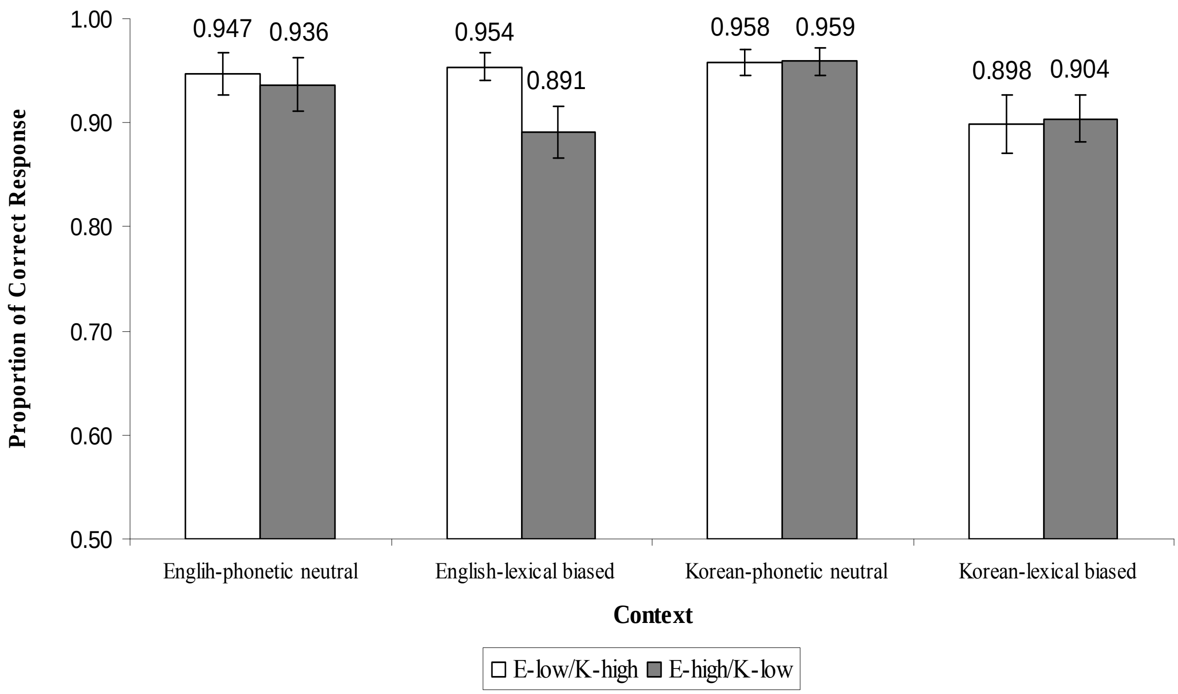
Experiment 2

The influence of phonotactic probability on phonological processing when phonotactic probability was mismatched across languages was examined in Experiment 2. Proportion correct and mean corrected-reaction time for correct responses to SAME items were analyzed. Repeated measures ANOVAs with three within-participants factors (phonetic context: English-phonetic versus Korean-phonetic; lexical context: neutral versus lexical-biased; phonotactic probability: low versus high) were performed on the mean proportions of correct responses and the mean corrected-reaction times. Huyhn-Feldt correction for sphericity for repeated measures was used (Huynh & Feldt, 1976). All significant effects had *p* values of .05 or less. An effect size for each independent variable was measured by partial eta squared ($\eta^2_{partial}$).

Accuracy Analysis

The mean proportions of correct responses on English-low/Korean-high versus English-high/Korean-low phonotactic probability nonwords in the neutral contexts and the lexical-biased contexts are shown in Figure 3-7. Two (phonetic context: English-phonetic versus Korean-phonetic) x 2 (lexical context: neutral versus lexical-biased) x 2 (phonotactic probability: English-low/Korean-high versus English-high/Korean-low) ANOVA revealed a significant main effect of lexical context (F(1, 23) = 5.60, p = .027, $\eta^2_{partial}$ = .196). The mean proportion of correct responses in the neutral context (*M* = .950, *SD* =.088) was higher than that in the lexical-biased context (*M* = .912, *SD* = .108). An interaction of phonetic context and phonotactic probability was significant (F(1, 23) = 4.95, p = .036, $\eta^2_{partial}$ = .177). A follow-up analysis revealed that the effect of phonotactic probability was significant in the English-phonetic context (F(1, 23) = 4.55, p =.038, $\eta^2_{partial}$ = .088) but not significant in the Korean-phonetic context (F(1 ,23) = .05, p = .824, $\eta^2_{partial}$ = .001) No other main effects or interactions had *p* values of .05 or less (see Appendix I for the full analysis). As in Experiment 1, accuracy was high (near ceiling), and thus the reaction time analysis may be more revealing of phonological processing patterns.

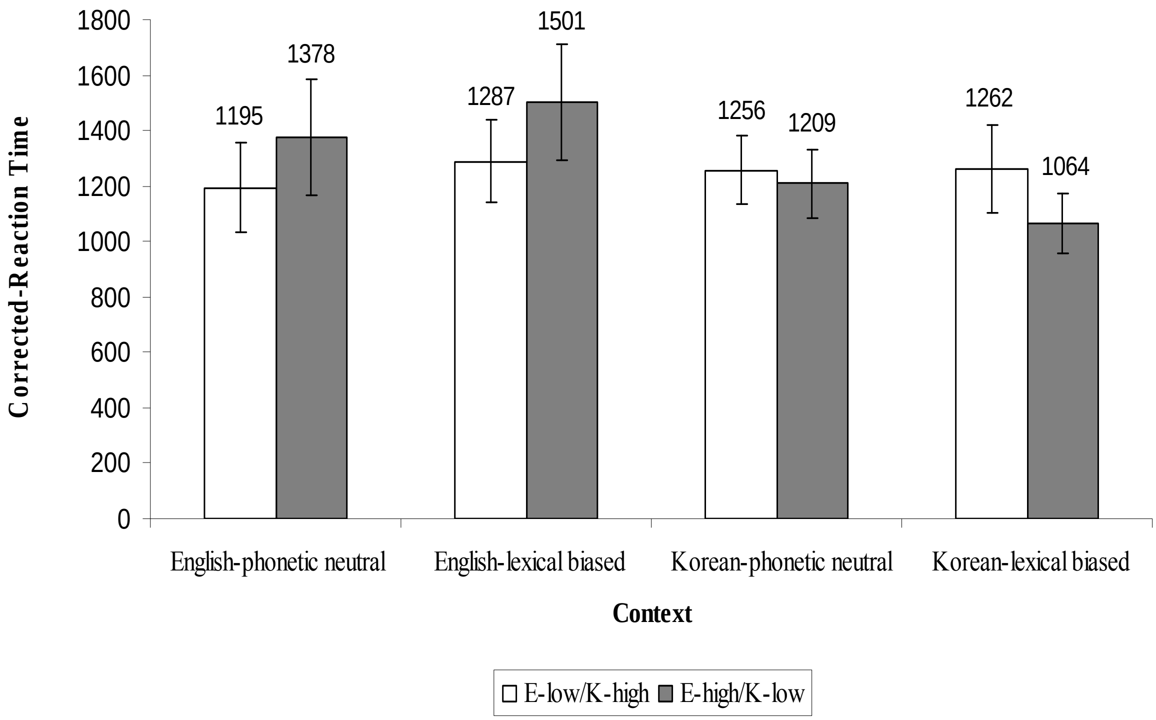
Figure 3-7. The mean proportions of correct responses on English-low/Korean-high versus English-high/Korean-low phonotactic probability nonwords in the neutral contexts and the lexical-biased contexts. Error bars indicate the Standard Error of Measurement (SEM).



Reaction Time Analysis

The mean corrected-reaction times for correct responses on English-low/Korean-high versus English-high/Korean-low phonotactic probability nonwords in the neutral contexts and the lexical-biased contexts are shown in Figure 3-8. Two (phonetic context: English-phonetic versus Korean-phonetic) x 2 (lexical context: neutral versus lexical-biased) x 2 (phonotactic probability: English-low/Korean-high versus English-high/Korean-low) ANOVA revealed an interaction of phonetic context and phonotactic probability ($F(1,23) = 8.94$, $p = .007$, $\eta^2_{partial} = .280$). No other main effects or interactions were obtained (all p values > .05, see Appendix J for the full analysis).

Figure 3-8. The mean reaction times on English-low/Korean-high versus English-high/Korean-low phonotactic probability nonwords in the neutral contexts and the lexical-biased contexts. Error bars indicate the Standard Error of Measurement (SEM).



Based on the significant interaction, separate repeated measures ANOVAs were performed for each phonetic context. In the *English-phonetic context* (left side of Figure 3-8), a significant main effect of phonotactic probability was obtained ($F(1,23) = 6.30$, $p = .016$, $\eta^2_{partial} = .118$). English-low/Korean-high probability nonwords ($M = 1241$, $SD = 747$) were responded to more quickly than English-high/Korean-low probability nonwords ($M = 1439$, $SD = 1016$).

In the *Korean-phonetic context* (right side of Figure 3-8), no significant main effect of phonotactic probability was obtained ($F(1,23) = 3.01$, $p = .089$, $\eta^2_{partial} = .060$). However, the same trend was observed favoring low probability in the target language. Specifically, English-high/Korean-low probability nonwords ($M = 1137$, $SD = 565$) were responded to more quickly than English-low/Korean-high probability nonwords ($M = 1259$, $SD =689$).

In summary, the accuracy analysis showed the main effect of lexical context and interaction of phonetic context and phonotactic probability. Particularly, bilinguals' responses were more accurate under the neutral context. A significant interaction of phonetic context and phonotactic probability showed differences in the effect of phonotactic probability by the phonetic contexts. In the *English-phonetic* context, the effect of phonotactic probability was significant; favoring *English-low*/Korean-high probability over *English-high*/Korean-low probability nonwords. In the *Korean-phonetic* context, the effect of phonotactic probability did not reach significance, but the pattern of probability effects was similar, favoring low probability in the target language (*English-high*/*Korean-low* nonwords were responded to more accurately than vice versa).

Likewise, the reaction time analysis showed an interaction of phonetic context and phonotactic probability. In the *English-phonetic* context, the effect of phonotactic probability was significant; favoring *English-low*/Korean-high probability nonwords (English-low/Korean-high probability nonwords were responded to more quickly than *English-high*/Korean-high probability nonwords). In the *Korean-phonetic* context, the effect of phonotactic probability was not significant, but the same pattern of probability effects was observed, favoring low probability in the target language (English-high/*Korean-low* nonwords were responded to more quickly than Korean-high/English-low nonwords).

CHAPTER IV: DISCUSSION

Two experiments were designed to examine phonological processing in Korean-English bilingual speakers. Experiment 1 focused on phonological processing when the phonotactic probability was matched across the bilingual speakers' two languages to examine the effects of matched phonotactic probability. Experiment 2 focused on sublexical processing when the phonotactic probability was mismatched across the bilingual speakers' two languages to examine the effects of mismatched phonotactic probability. Across both experiments, the goal was to determine whether the language switch or parallel activation account for bilingual language processing could capture effects of phonotactic probability on bilingual phonological processing.

Experiment 1: The Effects of Matched Phonotactic Probability

Findings of Experiment 1 confirmed that phonotactic probability influences phonological processing in both monolinguals and bilinguals. Results showed that English monolinguals and bilinguals in the English-phonetic context responded to high probability nonwords more accurately and quickly than low probability nonwords. Similarly, Korean monolinguals and bilinguals in the Korean-phonetic context responded to high probability nonwords more quickly than low probability nonwords, although they did not show accuracy differences. These findings replicate previous findings of a facilitative effect of high phonotactic probability on phonological processing by native monolingual speakers of English and extend this phenomenon to native monolingual speakers of another language (i.e., Korean) and to the bilingual domain.

Account for the monolingual data The facilitative effect of phonotactic probability has been accounted for by several models of spoken word recognition in the monolingual literature, such as TRACE (McClelland & Elman, 1986), Shortlist (Norris, 1994), and adaptive resonance theory (ART; Grossberg, 1986; Grossberg, Boardman, & Cohen, 1997; Vitevitch & Luce, 1999).

In particular, according to Vitevitch and Luce (1999), when auditory input (i.e., a word “pig”) is presented, *items* (i.e., the components of the input such as /p/ /ɪ/ /g/) are activated in working memory, which are linked to *list chucks* (i.e., lexical representations-corresponding to words and phonological representations-corresponding to the components of words) in short-term memory. Then, a resonance is established between list chunks and items, and the strength of resonances is hypothesized to determine response. In real word recognition, a lexical representation (i.e., the word itself /p ɪ g/) is assumed to dominate and establish the strongest resonance with the items in working memory. Because lexical representations receive inhibitory signals from similar lexical items, a lexical representation for a word that sounds like many other words (i.e., words in a high density neighborhood) is predicted to establish a weaker resonance than the resonance for a word in a low density neighborhood. Then, processing times for words in high density neighborhoods are predicted to be slower than those for words in low density neighborhoods (Vitevitch & Luce, 1999).

On the other hand, for nonwords, phonological representations are assumed to establish a resonance with the items in working memory because no lexical representations in short-memory correspond to the items. Then, phonological representations for high probability nonwords are predicted to establish stronger resonances with items in working memory than phonological representations for low probability nonwords, resulting in faster processing times. The results of Experiment 1 support the prediction of the facilitative effect of high phonotactic probability; both monolingual groups (i.e., English-monolingual and Korean-monolingual) responded to high probability nonwords more accurately and quickly than low probability nonwords.

Account for the bilingual data To account for the bilingual data, the account above can be combined with the language switch or parallel activation theory. The language switch hypothesis predicts that the input would switch on one language and switch off the other. In this case, phonological processing would resemble the above scenario. Specifically, if the "on" language is English, then English phonological representations of high probability nonwords presumably would establish stronger resonances with items in working memory than English phonological representations for low probability nonwords. This would result in faster processing times for high probability nonwords in English. The same scenario would occur for Korean except that only Korean phonological representations would establish resonance with the items in working memory. Thus, the data from Experiment 1 are consistent with the predictions of the language switch hypothesis.

In contrast, the parallel activation theory predicts that phonological representations from both languages will simultaneously influence phonological processing. Specifically, phonological representations of *both* English and Korean will establish resonance with items in working memory. Here, English and Korean phonological representations of high probability nonwords in *both* languages presumably would establish stronger resonances with items in working memory than English and Korean phonological representations for low probability nonwords in *both* languages. The data from Experiment 1 are consistent with the predictions of the parallel activation theory, showing faster processing times for high probability nonwords in *both* languages.

Taken together, the matched probability of Experiment 1 does not appear to differentiate the two theories. The mismatched probability of Experiment 2 may better differentiate the two theories.

Experiment 2: The Effects of Mismatched Phonotactic Probability

The results of Experiment 2 showed different patterns of probability effects. That was, bilinguals responded to *English-low*/Korean-high probability nonwords more quickly than *English-high*/Korean-low probability nonwords when *English* was the target language (i.e., in the English-phonetic context). Likewise, when *Korean* was the target language (i.e., the Korean-phonetic context), bilinguals responded to English-high/*Korean-low* probability nonwords more quickly than English-low/*Korea-high* probability. These results indicated the low probability advantage which contrasted with the findings of Experiment 1, showing a facilitative effect of high probability for both monolinguals and bilinguals when probability was matched across the languages.

Language Switch Hypothesis As described in Experiment 1, the language switch hypothesis predicts that only one language is activated and thus the phonological representations of the "on" language would be activated and establish resonance with the items in the working memory. In this case, phonological processing would resemble the scenario for the matched condition, predicting a facilitative effect of high probability in the "on" language regardless of the mismatched probability across languages. Specifically, if the "on" language is English, high probability nonwords in English (*English-high*/Korean-low probability) would be processed faster than low probability nonwords (*English-low*/Korean-high probability). The same scenario would occur for Korean except that only Korean phonological representations would establish resonance with the items in working memory, predicting faster processing times for high probability nonwords in Korean (English-low/*Korean-high*), than low probability nonwords in Korean (English-high/*Korean-low*).

The data from Experiment 2 are inconsistent with the predictions of the language switch hypothesis. Note that *English-low*/Korean-high probability nonwords were processed faster than *English-high*/Korean-low probability nonwords when the "on" language was English. Similarly, English-high/*Korean-low* probability nonwords were processed faster than English-low/*Korean-high* probability nonwords when the "on" language was Korean. These findings are inconsistent with the prediction of the language switch hypothesis and the results of Experiment 1 where a facilitative effect of high probability was observed.

Parallel Activation Hypothesis It predicts that sublexical representations from both languages will be activated simultaneously and both will have an influence on phonological processing. Under this hypothesis, the phonological representations of each language are predicted to establish resonances with the items in working memory. Here, the probability was mismatched across the languages, and thus resonances between phonological representations of each language with the items in working memory would be established at a different strength. Specifically, for the *English-high*/Korean-low probability nonwords, resonances between the phonological representations of *English* and items in working memory would be stronger than resonances between the phonological representations of Korean and items in working memory. In contrast, for the English-low/*Korean-high* probability nonwords, resonances between the phonological representations of *Korean* and items in working memory would be stronger than resonances between the phonological representations of English and items in working memory. Taken together, it is likely that the overall amount of resonances between the phonological representations and items in working memory for the two types of nonwords may be similar at a "mid" level, predicting a similar rate of processing times for the mismatched probability nonwords.

The data from Experiment 2, however, are inconsistent with the predictions of the parallel activation theory, showing a difference in reaction times for the two types of mismatched probability nonwords, with low probability nonwords being processed faster than high probability nonwords in the target language. Taken together, the results are not accounted for by either theory.

Alternative account One possible explanation for the pattern of results is that the mismatched probability interferes with establishing resonance between phonological representations and items in working memory leading to a competitive effect similar to lexical competition in word recognition. It is possible that the mismatched probability across the languages may cause confusion, which in turn produces competition on phonological processing. This competition from the mismatched probability across the languages may interfere with establishing resonances between the phonological representations and items in working memory. Under this hypothesis, the phonological representations for high probability nonwords in a language may have increased competition because they are more likely to occur in the ambient language, resulting in a greater interference with establishing resonances. On the other hand, the phonological representations for low probability nonwords in a language may have less competition since low probability patterns are less likely to occur in the ambient language, resulting in a lesser interference with establishing resonances. For example, when *English* is the target language, *English-high* probability nonwords are more likely to compete with Korean-low probability than *English-low* probability nonwords. Then, stronger competition for *English-high* probability nonwords may interfere with establishing resonances between the phonological representations and items in working memory, resulting in slower responses for *English-*

high/Korean-low probability nonwords than *English-low*/Korean-high probability nonwords. Similarly, when *Korean* is the target language, *Korean-high* probability nonwords are more likely to compete with English-low probability than *Korean-low* probability nonwords. Then, stronger competition for *Korean-high* probability nonwords may interfere with establishing resonances between the phonological representations and items in working memory, resulting in slower responses for English-low/*Korean-high* probability nonwords than English-high/*Korean-low* probability. Thereby, it is possible that processing times for low probability nonwords are faster than those for high probability nonwords due to lesser competition from the mismatched probability. This competition effect may indicate that the phonological representations of the two languages are activated in parallel, supporting the parallel activation hypothesis.

The Korean data from Experiment 2 are consistent with the account of the English data from Experiment 2. *English-low*/Korean-high probability nonwords were processed faster than *English-high*/Korean-low when *English* was the target language. The situation for *Korean* language processing was much the same, with English-high/*Korean-low* probability nonwords being processed faster than English-low/*Korean-high* probability nonwords. These findings suggest the presence of parallel activation on phonological processing and interactivity across the two languages, influencing each other.

In addition, the data revealed a significant interaction between the probability and the language status, which was defined by the maternal language (native language) and the amount of its exposure (i.e., English was the non-native language, while Korean was the native language). Specifically, when the target language was English (non- native language), the competition effects of the mismatched probability was significant, resulting in slower processing times for *English-high*/Korean-low than those for *English-low*/Korean-high probability nonwords. On the other hand, when the target language was *Korean* (native language), the competition effects of the mismatched probability did not reach significance, although the trend of competition effects was still observed. Specifically, when English was the target language (non-native language processing), competition between English (non-native language) probability and Korean (native language) probability was significant. When Korean was the target language (native language processing), competition between Korean (native language) probability and English (non-native language) probability was not significant.

Together, the results suggest that the magnitude of influence from the native language into non-native language processing was stronger than that from the non-native language into native language processing. This asymmetry in the magnitude of parallel activation between the two languages is consistent with previous findings from lexical processing studies (i.e., Marian & Spivey, 2003), suggesting the language status as a factor that modulates the extent to which parallel activation of the two languages is more readily induced.

Limitations

The first limitation of the current study is variation in language backgrounds of bilingual children. Although all bilingual children have participated in English education programs for at least one year prior to study participation, there is variation in the length of English education (M = 1;9, SD = 7 months; range 1;0 – 3;1). Specifically, some children have participated in an English education program for just a year, whereas some children have three years of English education. Then, it is possible that the children with only one year of English education have been exposed to the native language for an extended period, which may increase the activation level for the native language and decrease the non-native language activation. On the other hand, the children with three years of English education may have increased the activation level for the non-native language (English), as a result of an extended period in English education programs. This variability in history of language use may contribute to an asymmetrical level of parallel activation across languages. Thus, the patterns of results observed in the current study may not hold for a more homogeneous group of bilingual children with an extended period in English education. Future works could systematically control the length of English education and test the activation level of the non-native language during native language processing.

Another limitation is related to the experimental setting. In the current study, bilinguals were tested in their home where the native language, Korean was used dominantly by most parents. Thus, Korean may become dominant and more readily available for processing, leading to the stronger degree of parallel activation in non-native language processing (English). It is possible that the activation level of the non-native language may be increased by conducting experiments outside of their home environment where the non-native language (English) is used dominantly, such as school settings or public libraries. These contexts may increase an activation level of the non-native language, and therefore may increase the amount of parallel activation of the non-native language in native language processing. Future studies could address the contribution of different contexts to a level of parallel activation of two languages in bilingual phonological processing.

Future Directions

Future research can be a longitudinal or cross-sectional study to capture influence of language status on bilingual phonological processing at different developmental stages. It is possible that the native language may be kept as a dominant language and thus still be more readily activated in parallel during non-native language processing due to its early and longer exposure throughout bilingual speakers' lives. On the other hand, increase in the length of non-native language (English) exposure from community and education programs may lead to an increased level of parallel activation of the non-native language (English) during native language processing (Korean). In this scenario, when they become more balanced in the two languages, the facilitative effects or competition effects of the probability across the languages may be observed in phonological processing of both languages. Lastly, it is also possible that English may become dominant and more readily available for processing as a result of an extended period in English-education programs. In this case, English may be more likely to be activated during Korean language processing and may overshadow parallel activation of the Korean language during English language processing. Future studies will address the language status and the length of non-native education and its influence on the magnitude of parallel activation.

Another direction for future research will focus on the interaction between vocabulary size and phonotactic probability effects on bilingual phonological processing. In the monolingual literature, it has been shown that the effect of phonotactic probability is decreased as the vocabulary size is increased (Edwards, Beckman, & Munson, 2004). Thus, it is possible that the low probability advantage from mismatched probability may be decreased as bilingual children add more words to their lexicon. Similarly, adult bilinguals who are more proficient in both languages may show smaller influences of phonotactic probability during phonological processing. Future works will be needed to test the interaction between the vocabulary size and phonotactic probability effects on phonological processing within the language and across languages. The findings will help our understanding of interactivity and influential factors in bilingual phonological processing.

Lastly, future research will focus on the effects of phonotactic probability on phonological processing of the language-specific sounds that are not shared by the two languages. The responses for these two types of sounds can be compared to address the extent to which an effect of phonotactic probability is restricted to the target language or affects both languages. This may be another way to differentiate the two hypotheses, the language switch and the parallel activation hypothesis, and may help understanding of the structure of the two phonological systems and find possible constraints or factors that may influence bilingual phonological processing.

Conclusion

While the majority of bilingual research focuses on the bilingual lexical processing, little research has addressed phonological processing in bilingual speakers. The current study investigated the dynamic nature of bilinguals language processing and interactivity in two languages of bilinguals at the phonological level. Specifically, the effects of phonotactic probability were examined, and the different patterns of probability effects were observed: facilitative effects of the matched phonotactic probability and competition effects of the mismatched probability across the two languages. Such differences in the pattern of probability effects indicate that the two language systems of bilinguals are interconnected and activated simultaneously given auditory inputs. It is likely that a property of one language can be also activated simultaneously and has influence on the other language processing. The findings from the study take a few preliminary steps towards a better understanding of the structure of bilinguals' lexicons and interactivity between the two languages during bilingual phonological processing.

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Appendix A

Korean-English Bilingual Child History Questionnaire

Please answer the following questions.

1. Was your child born in the United States? YES NO
   a. If no, how old was your child when she/he first arrived at the United States?
      ______ years and _____ months old
2. How long has your child attended in an English-speaking education institution?

   ______ years and _____ months
3. How long does your child stay in an English-speaking education institution in each day?

   ______ hours
4. What language(s) is (are) spoken at home?
5. What is the proportion of your native language used by you at home? _____________ %
6. What is the proportion of your native language used by your child at home? _________ %
7. Do you have any concerns about your child's development? YES NO

   If yes, please describe your concerns below:

8. Does your child have normal vision (with or without glasses)? YES NO

   If no, please describe visual problems below:

9. Does your child have any hearing problems? YES NO

   If no, please describe hearing problems below:

10. Do you feel your child is generally coordinated? Does she or he cut with scissors, jump, and run like other children? YES NO

    If no, please describe coordination problems below:

11. Does your child have any physical or medical problems that might contribute to speech or language development? YES NO

If yes, please describe below:

12. Is your child currently receiving special education services? YES NO

If yes, what services are being received?

Who is providing these services?

13. Has your child ever experienced frequent ear infections? YES NO

If yes, please describe your child's age, the frequency of infections, and the treatment.

14. Does your child have any physical or medical problems that might affect your child's ability to participate in this study? YES NO

If yes, please describe below:

15. Is your child right-handed or left-handed? *(please circle)* Left-handed Right-handed

Appendix B

Monolingual Child History Questionnaire

Please answer the following questions.

1. Do you have any concerns about your child's development? YES NO

    If yes, please describe your concerns below:

2. Is English the only language spoken at home? YES NO

    If no, what language does your child speak?

    What other languages does your child speak?

3. Does your child have normal vision (with or without glasses)? YES NO

    If no, please describe visual problems below:

4. Does your child have any hearing problems? YES NO

    If no, please describe hearing problems below:

5. Do you feel your child is generally coordinated? Does she or he cut with scissors, jump, and run like other children? YES NO

    If no, please describe coordination problems below:

6. Does your child have any physical or medical problems that might contribute to speech or language development? YES NO

    If yes, please describe below:

7. Is your child currently receiving special education services or instructions?

YES NO

If yes, what services are being received?

Who is providing these services?

8. Has your child ever experienced frequent ear infections? YES NO

If yes, please describe your child's age, the frequency of infections, and the treatment.

9. Does your child have any physical or medical problems that might affect your child's ability to participate in this study? YES NO

If yes, please describe below:

10. Is your child right-handed or left-handed? *(please circle)* Left-handed Right-handed

Appendix C

Length of U.S. residence distribution

Length of U.S. Residence (year; month)	Number of Children
2 - 2;6	2
2;7 - 2;11	1
3;0 - 3;6	2
3;7 - 3;11	1
4;0 - 4;6	4
4;7 -4;11	5
5;0 - 5;6	7
5;7 - 5;11	2

Appendix D

Starting age distribution of English education

Start age of English Education (year; month)	Number of Children
2;0 - 2;6	6
2;7 - 2;11	5
3;0 - 3;6	5
3;7 - 3;11	5
4;0 - 4;6	1
4;7 - 4;11	1

Appendix E

Length of English education distribution

Length of English Education (year; month)	Number of Children
1;0 - 1;6	11
1;7 - 1;11	0
2;0 - 2;6	8
2;7 - 2;11	2
3;0 - 3;6	3

Appendix F

Nonword selection in Matched-probability conditions

Matched Phonotactic Probability Condition	
Low Probability	High Probability
lim[1]	siŋ[1]
lid[1]	sʌd[1]
lʌd[2]	sug[2]
lub[2]	suŋ[2]
lʌti[3]	sʌti[3]
lʌtu[3]	sʌtu[3]
liki[4]	sʌki[4]
liku[4]	sʌku[4]
nib[5]	mim[5]
nʌd[5]	mʌn[5]
nʌtʌ[6]	mɑti[6]
nʌtu[6]	mɑtɑ[6]

Notes: Superscript numbers indicate the nonwords that were paired to create stimuli for different pairs.

Appendix G

Nonword selection in Mismatched-probability conditions

Mismatched Phonotactic Probability Condition	
E-Low/K-High Probability	E-High/K-Low Probability
gig[1]	kib[1]
giŋ[1]	kid[1]
gʌg[2]	kum[2]
gʌŋ[2]	kud[2]
gʌtu[3]	kiki[3]
gʌtɑ[3]	kiku[3]
giku[4]	kʌti[4]
gikɑ[4]	kʌtu[4]
dʒub[5]	pim[5]
dʒud[5]	pid[5]
dʒʌti[6]	piti[6]
dʒʌtɑ[6]	pitu[6]

Notes: E-Low/K-High: Sound sequences with English low phonotactic probability but with Korean high phonotactic probability; E-High/K-Low: Sound sequences with English high phonotactic probability but with Korean low phonotactic probability
Superscript numbers indicate the nonwords that were paired to create stimuli for different pairs.

Appendix H

Korean real word fillers for the Korean-language biased context

English Word	IPA
keen	kin[1]
keel	kil[1]
puppy	pʌpi[2]
puttee	pʌti[2]
guppy	gʌpi[3]
gutty	gʌti[3]
job	dʒɑb[4]
June	dʒun[4]

Nonword fillers for the neutral context

Nonword fillers
kʌki[1]
kʌkɑ[1]
pʌd[2]
pib[2]
gib[3]
gin[3]
dʒʌki[4]
dʒʌkɑ[4]

English real word fillers for the English-language biased context

Korean Word	IPA	English Translation
칼	kɑl[1]	knife
칸	kɑn[1]	pigeonhole
파기	pɑgi[2]	cancellation
파지	pɑdʒi[2]	scratch paper
김	gim[3]	seaweed
길	gil[3]	street
자파	dʒɑpɑ[4]	one´s own party
자타	dʒɑtɑ[4]	recognized by everyone

Notes: Superscript numbers indicate the words/nonwords that were paired to create stimuli for different pairs.

Appendix I

Statistical Analysis Results for Accuracy

Effect	F	Significance	Partial Eta Squared
Phonetic Context	0.023	0.88	0.001
Lexical Context	5.596	0.027	0.196
Phonotactic Probability	2.124	0.159	0.085
Phonetic Context * Lexical Context	2.368	0.137	0.093
Phonetic Context * PhonProb	4.954	0.036	0.177
Lexical Context * PhonProb	0.913	0.349	0.038
Phonetic * Lexical * PhonPorb	1.257	0.274	0.052

Appendix J

Statistical Analysis Results for Corrected-Reaction Time

Effect	F	Significance	Partial Eta Squared
Phonetic Context	1.577	0.222	0.064
Lexical Context	0.024	0.878	0.001
Phonotactic Probability	0.39	0.538	0.017
Phonetic Context * Lexical Context	0.932	0.344	0.039
Phonetic Context * PhonProb	8.935	0.007	0.28
Lexical Context * PhonProb	0.38	0.544	0.016
Phonetic * Lexical * PhonPorb	0.886	0.356	0.037

Appendix K

PARALLEL ACTIVATION IN BILINGUAL AUDITORY PROCESSING
INFORMED CONSENT STATEMENT (Monolingual child)

Your child is invited to participate in a research program on language perception conducted by Su Yeon Lee, a graduate student in the Speech-Language pathology program. The Department of Speech-Language-Hearing at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to have your child participate in the present study. You should be aware that even if you agree to have your child participate, you are free to withdraw your child at any time without penalty. If you do withdraw from this study it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE

The purpose of the research project is to examine language perception in English-monolingual preschool children, Korean-monolingual preschool children, and Korean-English-bilingual preschool children. We want to determine how the organization of words and sounds affects children's ability to process new words and sounds. A second purpose is to investigate how bilingual children process their two languages by examining how the organization of words and sounds in their two languages interacts in language processing. Your child is asked to participate in the tasks below at his or her school, after-school program, the University of Kansas, or in your home. For school and after-school programs, the classroom teacher or leader will be consulted for scheduling issues. You can observe all sessions that will be scheduled by the classroom teacher or leader. If you want to observe sessions, you may contact the primary researcher to find out the session scheduling for your child. For home sessions, you will be consulted for scheduling, and you will be asked to provide a quiet room free from distraction. You can observe all sessions.

PROCEDURES

Health questionnaire: You will be asked to complete a health questionnaire related to your child's development. This will require 5-10 minutes to complete.

Hearing Screening: Your child will be given a hearing screening to determine whether your child is eligible to participate in the research project. The *hearing test* requires that your child wear headphones and listen to tones. This test will require 5-10 minutes. If your child passes a hearing screening, then he or she will be invited to participate in the Same-different task.

Same-Different: Your child will listen to pairs of words or nonwords and will have to decide whether the items are the same or different. Your child will press one button if the words or nonwords are the same and a second button if the words or nonwords are different. Accuracy and reaction time will be recorded by a computer. This task will require 20-30 minutes.

Standardized Testing: Your child will be given several tests commonly used by speech therapists to examine vocabulary learning and articulation. All testing will require 30-40 minutes.

The *vocabulary comprehension test* requires your child to listen to words spoken by the investigator and point to the correct picture from four choices.

The *vocabulary production test* requires your child to name pictures.

The *articulation test* requires your child to name common pictures such as “house” or “cup.”

The articulation test will be audio recorded and used to transcribe your child’s production of each word. All procedures may be video recorded for the purpose of procedural checking. It is anticipated that all procedures will be completed in one or two 50-60-minute sessions, but this varies with individual children.

RISKS
Risks are not anticipated. It is possible that your child may become bored or tired during the 50-60 minute session. Children will be given breaks if this occurs. You are invited to observe all sessions. Please contact the primary researcher for session scheduling for your child if you want to observe sessions.

BENEFITS
You will be given a written report detailing your child’s performance on all standardized clinical tests which may be useful in future educational and clinical planning. In addition, the findings from this study may be used to improve understanding of language processing in monolingual and bilingual children.

PARTICIPANT CONFIDENTIALITY
To perform this study, researchers will collect information about your child. This information will be obtained from a health questionnaire you complete about your child. Also, information will be collected from the study activity that is listed in the procedure section of this consent form. The articulation test will be audio recorded and will be transcribed. Audio recordings will be maintained in a permanent archive stored in a locked cabinet. Your child’s sessions will also be video recorded. Video recordings of ALL sessions will be used to monitor administration and scoring of research tasks. Video recordings will be maintained in a permanent archive stored in a locked cabinet in Dr. Holly Storkel’s (faculty advisor) research laboratory. Only Su Yeon Lee (primary investigator), Dr. Storkel (faculty advisor), and members of Dr. Storkel’s research team will have access to this locked cabinet. Data sheets and computer files will be used to record your child’s responses to standardized tests and research tasks. These data also will be maintained in a permanent archive. All audio- and video- recordings and all data forms will be labeled with only the participant number. The name of your child and parent information on the health questionnaire form will be removed from the form after a participant number is assigned to your child.

When the entire study is completed, the results will be published as a research report. Complete confidentiality will be maintained. Your child’s name will not be associated in any way with the information collected about your child or with the research findings from this study. Your child will be identified only by participant number. The information collected about your child will be used by Su Yeon Lee (primary investigator), Holly Storkel (faculty advisor) and KUCR and officials at KU that oversee research, including committees and offices that review and monitor research studies. The researcher will not share information about your child unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your child’s information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your child’s information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION
You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right or your child’s right to any services you or your child are receiving

or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, your child cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent for your child to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about your child, in writing, at any time, by sending your written request to Su Yeon Lee (primary investigator) or Holly Storkel (faculty advisor), at the Department of Speech-Language-Hearing, 1000 Sunnyside Avenue, 3001 Dole Center, Lawrence, KS 66045-7555 (785-864-4873; suyeon@ku.edu; 785-864-0497; hstorkel@ku.edu). If you cancel permission to use your child's information, the researchers will stop collecting additional information about your child. However, we may use and disclose information that was gathered before they received your cancellation, as described above.

Even if you decide to withdraw from the study, you will still receive the written report of your child's speech and language testing scores.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s), Su Yeon Lee (primary investigator; 785-550-8997; suyeon@ku.edu) or Holly Storkel (faculty advisor; 785-864-0497; hstorkel@ku.edu).

PARTICIPANT CERTIFICATION

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about my child for the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7563, e-mail mdenning@ku.edu or jbutin@ku.edu.

I agree to have my child take part in this study as a research participant. I further agree to the uses and disclosures of my child's information as described above. By my signature I affirm that I am the legal parent or guardian of the child named below and that I have received a copy of this Consent and Authorization form.

Child's Name ___________________ Parent or Guardian's Name ___________________________

Parent or guardian signature ___________________________ Date ___________________________

Appendix L

PARALLEL ACTIVATION IN BILINGUAL AUDITORY PROCESSING
INFORMED CONSENT STATEMENT (Korean-English Bilingual Child)

Your child is invited to participate in a research program on language processing conducted by Su Yeon Lee, a graduate student in the Speech-Language pathology program. The Department of Speech-Language-Hearing at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to have your child participate in the present study. You should be aware that even if you agree to have your child participate, you are free to withdraw your child at any time without penalty. If you do withdraw from this study it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE
The purpose of the research project is to examine language processing in English-monolingual preschool children, Korean-monolingual preschool children, and Korean-English-bilingual preschool children. We want to determine how the organization of words and sounds affects children's ability to process new words and sounds. A second purpose is to investigate how bilingual children process their two languages by examining how the organization of words and sounds in their two languages interacts in language processing. Your child is asked to participate in the tasks below at his or her school, after-school program, the University of Kansas, or in your home. For school and after-school programs, the classroom teacher or leader will be consulted for scheduling issues. You can observe all sessions that will be scheduled by the classroom teacher or leader. If you want to observe sessions, you will be informed session scheduling by the teacher and can observe sessions at the scheduled time. For home sessions, you will be consulted for scheduling, and you will be asked to provide a quiet room free from distraction. You can observe all sessions.

PROCEDURES

Health questionnaire: You will be asked to complete a health questionnaire related to your child's development. This will require 5-10 minutes to complete.

Hearing Screening: Your child will be given a hearing screening to determine whether your child is eligible to participate in the research project. The *hearing test* requires that your child wear headphones and listen to tones. This test will require 5-10 minutes. If your child passes a hearing screening, then he or she will be invited to participate in the Same-different task.

Same-Different: Your child will listen to pairs of words or nonwords and will have to decide whether the items are the same or different. Your child will press one button if the words or nonwords are the same and a second button if the words or nonwords are different. Accuracy and reaction time will be recorded by a computer. This task requires 20-30 minutes. Your child will repeat the task six times during 3-6 weeks.

Standardized Testing: Your child will be given several tests as a set for each language (Korean and English) commonly used by speech therapists to examine vocabulary learning and articulation. A test set for each language will be administered on a separate date.

The *vocabulary comprehension test* requires your child to listen to words spoken by the investigator and point to the correct picture from four choices.

The *vocabulary production test* requires your child to name pictures.

The *articulation test* requires your child to name common pictures such as "house" or "cup."

It is anticipated that the test set for each language will require 30-40 minutes, but this varies with individual children. The articulation test will be audio recorded and used to transcribe your child's production of each word. All procedures will be video recorded for the purpose of procedural checking.

RISKS

Risks are not anticipated. It is possible that your child may become bored or tired during the 30-60 minute session. Children will be given breaks if this occurs. You are invited to observe all sessions.

BENEFITS

You will be given a written report detailing your child's performance on all standardized clinical tests which may be useful in future educational and clinical planning. In addition, the findings from this study may be used to improve understanding of language processing in monolingual and bilingual children.

PARTICIPANT CONFIDENTIALITY

To perform this study, researchers will collect information about your child. This information will be obtained from a health questionnaire you complete about your child. Also, information will be collected from the study activity that is listed in the procedure section of this consent form. The articulation test will be audio recorded and will be transcribed. Audio recordings will be maintained in a permanent archive stored in a locked cabinet. Your child's sessions will also be video recorded. Video recordings of ALL sessions will be used to monitor administration and scoring of research tasks. Video recordings will be maintained in a permanent archive stored in a locked cabinet in Dr. Holly Storkel's (faculty advisor) research laboratory. Only Su Yeon Lee (primary investigator), Dr. Storkel (faculty advisor), and members of Dr. Storkel's research team will have access to this locked cabinet. Data sheets and computer files will be used to record your child's responses to standardized tests and research tasks. These data also will be maintained in a permanent archive. All audio- and video- recordings and all data forms will be labeled with only the participant number. The name of your child on the health questionnaire form will be removed from the form after a participant number is assigned to your child.

When the entire study is completed, the results will be published as a research report. Complete confidentiality will be maintained. Your child's name will not be associated in any way with the information collected about your child or with the research findings from this study. Your child will be identified only by participant number. The information collected about your child will be used by Su Yeon Lee (primary investigator), Holly Storkel (faculty advisor) and KUCR and officials at KU that oversee research, including committees and offices that review and monitor research studies. The researcher will not share information about your child unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your child's information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your child's information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right or your child's right to any services you or your child are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, your child cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent for your child to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about your child, in writing, at any time, by sending your written request to Su Yeon Lee (primary investigator) or Holly Storkel (faculty advisor), at the Department of Speech-Language-Hearing, 1000 Sunnyside Avenue, 3001 Dole Center, Lawrence, KS 66045-7555 (785-550-8997; suyeon@ku.edu; 785-864-0497; hstorkel@ku.edu). If you cancel permission to use your child's information, the researchers will stop collecting additional information about your child. However, we may use and disclose information that was gathered before they received your cancellation, as described above.

Even if you decide to withdraw from the study, you will still receive the written report of your child's speech and language testing scores.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s), Su Yeon Lee (primary investigator; 785-864-4873; suyeon@ku.edu) or Holly Storkel (faculty advisor; 785-864-0497; hstorkel@ku.edu).

PARTICIPANT CERTIFICATION

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about my child for the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7563, e-mail mdenning@ku.edu or jbutin@ku.edu.

I agree to have my child take part in this study as a research participant. I further agree to the uses and disclosures of my child's information as described above. By my signature I affirm that I am the legal parent or guardian of the child named below and that I have received a copy of this Consent and Authorization form.

Child's Name ___________________________ Parent or Guardian's Name ____________________

Parent or guardian signature___________________________ Date ___________________________