

**PRODUCTION AND PERCEPTION OF KOREAN AND ENGLISH WORD-
LEVEL PROMINENCE BY KOREAN SPEAKERS**

By

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GOUN LEE

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ABSTRACT

Prominence refers to the relative emphasis that may be given to a syllable in a word (word-level prominence) or to one or more words in a phrase (phrase-level prominence). Korean has been claimed to have both word-level (Ko, 2013) and phrase-level (Jun, 1996) prominence, with the former realized mainly with duration and the latter with F0 height. However, given the claim that younger Korean speakers have lost duration as the main cue expressing word-level prominence (Kim & Han, 1998; Magen & Blumstein, 1993), it is not clear if and how younger Korean speakers produce word-level prominence. Thus, the primary goal of the current dissertation is to examine whether Korean still has word-level prominence. Two experiments investigated this research question in two domains – acoustically (Experiment 1) and perceptually (Experiment 2). Given the findings regarding the status of lexical stress in Korean, we further investigated which acoustic correlates/cues Korean learners of English are able to transfer from their L1 prosodic cues, and whether they can acquire a new cue that does not exist in their L1. Thus, the secondary purpose of this study is to investigate which acoustic correlates/cues Korean L2 learners of English utilize in producing and perceiving English lexical stress. These questions are addressed and examined in Experiments 3 and 4.

In the acoustic study of the production of Korean word-level prominence (Experiment 1), measurements of duration, intensity, F0, F1, and F2 on (so-called) Korean stress minimal pairs by older and younger Korean speakers revealed that only at the sentence level, duration and intensity systematically distinguish stress pairs for the older speakers. A perception study on word-level prominence in Korean (Experiment 2) revealed that both older and younger Korean listeners weighted the duration cue most heavily in identifying minimal pairs of Korean word-level prominence when two of the suprasegmental cues were orthogonally manipulated in each

syllable. Interestingly, this perceptual weighting was only observed in the first syllable: none of the listeners changed their perception when cues were signaling second-syllable stress. Based on these findings from an acoustic and a perception study, we conclude that Korean does not have word-level prominence, but only has a phonemic vowel length distinction.

In the acoustic study on the production of English word-level prominence (Experiment 3), measurements of duration, intensity, F0, F1, and F2 on English stress pairs found that Korean learners were able to use not only all suprasegmental cues to indicate lexical stress in English, but also acquire a new cue (e.g., vowel reduction) that does not exist in their native language, although in a non-native like manner. The results of the perception study on word-level prominence in English (Experiment 4) revealed that when identifying English stress pairs, Korean learners weighted vowel reduction more heavily than any suprasegmental cues. Both intensity and F0 were weighted in Korean learners' perception; however, duration was not weighted at all, although younger Korean speakers still retain the phonemic vowel length distinction in their L1.

Taken together, the current dissertation increases our understanding of the status of lexical stress in Korean, as well as the extent to which L2 learners produce and perceive L2 lexical stress by transferring prosodic features from their native language.

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CHAPTER I.

INTRODUCTION TO TWO DIFFERENT LEVELS OF PROMINENCE IN KOREAN

1.1. Introduction

Korean has been claimed to have word-level prominence realized mainly with duration, (e.g., Ko, 2013) and phrasal-level prominence realized with pitch height (e.g., Jun, 1996). However, given the claim that younger Korean speakers have lost the main cue expressing word-level prominence (i.e., vowel length distinction) (Kim, H-S & Han, 1998; Magen, H. S., & Blumstein, 1993; Kim, 2001), it is not clear whether what has been claimed to be stress is indeed stress or whether it is a phonemic vowel length contrast. Given these claims, there are several open questions that need to be addressed. If there is stress, then, how do younger Korean speakers cue word-level prominence without duration? Have they completely lost word-level prominence or have they traded duration for other cues, such as intensity? This dissertation examines whether the Korean language has word-level prominence, and if not, how Korean listeners use acoustic cues to mark phrasal-level prominence when perceiving L1 and L2 (i.e., English) word-level prominence.

This dissertation aims to tease apart the effect of phrasal-level prominence on the expression of word-level prominence by examining acoustic correlates of (so-called) Korean stress pairs between two age groups. More specifically, by using an acoustic and a perception study, this dissertation tries to determine whether Korean has lexical stress or simply has a vowel length distinction. We hypothesize that, if Korean has word-level prominence, the same effect of stress will be observed in two different contexts (at the sentence level vs. in word-isolation) in older Korean speakers' productions. If Korean has only phrasal-level prominence, prominence

will be expressed differently depending on the context. Target words produced as isolated words will receive phrasal prominence on the first syllable where a F0 peak occurs, whereas target words produced at the sentence level (i.e., in initial position in an Accentual Phrase) will receive phrasal-level prominence on the second syllable where a F0 peak occurs (when the initial consonant begins with lenis stops or affricates) (S-A. Jun, 1995, 2005). Therefore, by comparing which acoustic correlates express word-level prominence in Korean, we will be able to disentangle the effect of phrasal prosody from word-level prominence.

With respect to perception, we hypothesize that older Korean listeners will shift their perception of Korean word-level prominence depending on which syllable has prominence, if Korean has word-level prominence. In addition, we also examine how the loss of the phonemic vowel length distinction (or loss of lexical stress) in contemporary Seoul Korean has affected the production and perception of younger Korean speakers. If Korean had undergone a diachronic change from a language with word-level prominence to a phrasal-level prominence language, younger Korean speakers might compensate for duration cue with other cues, such as intensity or F0. If Korean simply had a vowel length distinction, it is predicted that younger Korean speakers will produce Korean stress pairs as homophones. Thus, two experiments (Experiments 1 & 2) will investigate which acoustic correlates Korean speakers use in the production of word-level prominence and which acoustic cues they weight in the perception of Korean word-level prominence.

The second purpose of this dissertation is to investigate whether the loss of word-level prominence (or vowel length distinction) in the native language (i.e., Korean) affects the production and perception of word-level prominence in a second language (i.e., English). Specifically, we examine whether younger Korean speakers will be able to acquire a new

phonological feature in L2 (i.e., lexical stress) even if their native language does not employ it. If they can, it is possible that the frequency of occurrence of a cue in higher-level prosodic domains in L1 may predict the learnability of that cue in implementing lexical stress in L2. Also, we examine whether Korean learners will be able to acquire a new cue (i.e., vowel reduction) that does not exist in their native language. If they do, will Korean learners show a similar degree of acquisition in both production and perception or will they show an asymmetrical pattern in their acquisition of vowel reduction between production and perception? These two points will be investigated in Experiments 3 and 4.

1.2. Overview of the dissertation

This dissertation consists of two parts: Part 1 examines production and perception of Korean word-level prominence, and Part 2 examines production and perception of English word-level prominence.

Experiment 1 presents acoustic evidence regarding Korean word-level prominence by examining the productions of older and younger Seoul Korean speakers. Five measurements – duration, F0, intensity, F1, and F2 – are taken from the first and second syllable of the target words, and the results are compared in terms of stress location, production context, and speaker age. The suprasegmental measurements are also converted into log ratios in order to examine the relative difference between the syllables. Thus, the raw values of the five measurements at the sentence-level and in isolation are provided, as well as the ratio values of the duration, F0, and intensity in the two different contexts.

Experiment 2 examines the perceptual cue weighting for Korean word-level prominence. Two cues were orthogonally manipulated for each syllable and Korean listeners were asked to identify which word they heard. By examining whether Korean listeners shift their perceptual

judgement depending on the prominence of each syllable, we are able to investigate whether Korean has lexical stress. The discussion and implications are discussed in Chapter 3.

In Chapter 4, previous literature examining production and perception of English stress by Korean learners of English will be reviewed. Then, two experiments examining production and perception of English word-level prominence will be presented.

Experiment 3 presents an acoustic analysis of the productions of English stress pairs by Korean learners and native speakers of English. Similarly to Experiment 1, five measurements – duration, F0, intensity, F1, and F2 – are taken from the first and second syllable of the target words, and the results were compared in terms of stress location. Duration, F0, and intensity are also converted into log ratios in order to examine the relative difference between the syllables.

Experiment 4 examined the perceptual cue weighting for English lexical stress. A spectral cue and one of the suprasegmental cues were orthogonally manipulated for each syllable and these tokens were used for the stress identification task. We examine whether Korean learners can acquire lexical stress, and also whether the frequency of occurrence of a cue in L1 will predict the weighting of that cue in L2. In addition, we also examine whether Korean learners can use a new cue (i.e., vowel reduction) in their perception of English stress. The implications are discussed in Chapter 6.

Chapter 7 summarizes the main findings of the four experiments and discusses implications of the findings.

1.3. Significance of the current dissertation

The current dissertation contributes to the investigation of word-level prominence in Korean by analyzing a comprehensive corpus of empirical data. By examining which acoustic correlates/cues Korean speakers of two generations use, we will be able to both shed light on the ongoing controversy about Korean stress, and enhance our understanding of language change,

especially regarding the Korean vowel length distinction. Thus, the major significance of this dissertation is to provide a clear picture regarding the status of lexical stress in Korean.

Additionally, this study aims to determine which acoustic cues Korean listeners weight the most in perceiving word-level prominence, as well as whether listeners of different generations will vary in their use of perceptual cues. The results of the first two experiments (Experiments 1 & 2) may also contribute to the field of second language acquisition by rendering an accurate prediction about which L1 cues may be available to Korean learners when acquiring L2 lexical stress.

The second part of the dissertation (Experiments 3 & 4) intends to investigate whether L2 learners can use higher-level prosody cues in L1 to implement L2 lexical stress and whether a new L2 prosody cue that does not exist in L1 prosody can be acquired. Also, we will be able to examine whether perception will precede the production of vowel reduction in acquiring L2 lexical stress, or whether production and perception of vowel reduction are acquired simultaneously. Taken together, this investigation will be able to tell us the extent of language transfer of prosodic features in the acquisition of L2 lexical stress.

We will begin by reviewing how prominence is defined in the literature. First, we will discuss studies that have examined intrinsic characteristics of stress in various languages and review studies about word-level and phrasal-level prominence in Korean. Then, we will address problems regarding the claim that Korean has lexical stress, and state the research goals of the first two experiments. The second part will discuss the production and perception of English word-level prominence. The relevant literature examining the production and perception of English lexical stress by Korean learners of English will be reviewed, followed by the research questions regarding acquisition of English stress by Korean learners.

1.4. Background

Prominence in language is comprised of two levels of prosodic cues – word-level prominence and phrasal-level prominence. Word-level prominence creates lexical contrasts based on the acoustic manifestation of at least one cue, while phrasal-level prominence is conveyed by F0 peaks or valleys that express context-dependent pitch accents, which distinguish a prosodic boundary between words (Beckman, 1986; Cooper, Eady, & Mueller, 1985; Fry, 1958; Shport & Redford, 2014)¹. For languages with word-level prominence, lexical prosody expresses whether certain syllables are more prominent than neighboring syllables within the same word. The prominence can be realized by multiple suprasegmental cues such as duration, pitch, and intensity. However, there is no absolute value that determines a prominent syllable: rather, the concept of strong-weak is abstract and relative to the adjacent syllables.

The lexical prosody of expressing word-level prominence is language-specific. Languages selectively pick and choose which cues to use in expressing prominence. In stress languages, each word has one primary stress expressed with multiple cues, and more than one acoustic manifestation dynamically expresses word-level prominence (M. E. Beckman, 1986). For example, in English, three stress levels – primary stress (e.g., the first syllable of *audiences*), secondary stress (e.g., the first syllable of *auditoria*), and unstressed (e.g., the first syllable of *addition*) – distinguish the prominence level of the syllables. The primary stressed syllable is typically realized with increased F0, longer duration, and higher intensity than unstressed syllables (Fry, 1955; Fry, 1958; Gay, 1978). While stressed syllables maintain their vowel quality, unstressed syllables may or may not reduce vowel quality. For instance, the first syllable

¹ See section 1.5. for further details.

of *addition* can be reduced to schwa, while the first syllable of *audition* is not reduced to schwa. Unstressed syllables have a more centralized vowel quality than stressed syllables (Gay, 1978; Koopmans-Van Beinum, 1980), resulting in mid-range values for F1 and F2. In addition to spectral segmental cues to vowel quality, suprasegmental cues also characterize stress patterns. Within unstressed syllables, unreduced vowels (e.g., *audition*) have longer duration, higher intensity, and less centralized vowel quality than reduced vowels (e.g., *addition*).

Although each cue distinguishes stressed syllables from unstressed syllables, stress patterns cannot be characterized by only one of these acoustic cues (Crystal, 1969), rather, there seems to be a hierarchical order of phonetic cues to stress (Adams, 1979; Beckman & Pierrehumbert, 1986; Fry, 1955; Fry, 1958; Huss, 1978; Lehiste, 1970; Pierrehumbert, 1980; Sluijter, van Heuven, & Pacilly, 1997; Vanderslice, R., & Ladefoged, 1972). Among the four perceptual cues to stress in English, vowel quality has been found to be the strongest perceptual cue (Zhang & Francis, 2010). Among suprasegmental cues, a strong consensus has not been reached about which cue is the strongest to perceiving English stress; while Sluijter and van Heuven (1996) claim that duration is the strongest cue to English stress and F0 is not as strong as intensity or duration, Fry (1955) and Beckman (1986) argue that F0 is the most reliable cue to stress. Yet, at least it is widely agreed that stress is not realized only with a single cue (Ladefoged, Draper, & Whitteridge, 1958; Lieberman, 1960).

However, when phonetic correlates signaling stress are also used in other phonological domains such as lexical tone or phonemic vowel length distinction, the cue may be minimally used or unavailable to signal stress (Berinsein, 1979; Hayes, 1995). This “functional load” of a cue within a syllable is tested in other stress-languages that have either lexical tone or phonemic vowel length (Berinsein, 1979; Potisuk, Gandour, & Harper, 1996; 1998; Shen, 1993). For

example, results for K'ekchi, a language with a fixed final-syllable stress and with a phonemic vowel length distinction, showed that duration was not used in implementing stress (Berinstein, 1979). When examining the duration, F0, and intensity in the productions of stressed and unstressed syllables in K'ekchi, it was found that only F0 and intensity reliably distinguish stressed syllables from unstressed syllables.

However, when a language employs stress, tone, and a vowel length distinction, the functional load hypothesis does not completely predict how a cue to stress is implemented. Thai is a stress language (Henderson, 1949; Hiranbūrana, 1971; Luangthongkum, 1978; Luksaneeyanawin, 1998) with 5 lexical tones and a phonemic vowel length distinction (Abramson, 1962). According to the functional load hypothesis, neither F0 nor duration were expected to implement stress in Thai, since both F0 and duration are preempted at the lexical level. However, inconsistent results were found regarding the use of these cues in lexical stress in Thai: duration was found to be the primary cue to stress in Thai, while F0 remained as a subservient cue and intensity was not a cue to stress (Potisuk et al., 1996). Moreover, when examining a phonemic vowel length minimal pair that shares both segmental as well as tonal construction, the duration difference was neutralized at the unstressed position (Potisuk et al., 1998). This is somewhat surprising, given the claims of the functional load hypothesis, since only intensity is predicted to cue stress in Thai. Potisuk et al. (1996) argued that the disparate pattern between duration and F0 to implement stress is due to the frequency of occurrence of a cue at the lexical level. The heavier weighting of duration over F0 is due to the fact that vowel length is used comparatively less than F0 to contrast lexical items. In a similar way, Swedish, another stress language with two lexical tones, was found to use F0 primarily to indicate stress because there is a very limited number of lexical items (about 500 pairs) of tonal contrasts

(Gårding & Eriksson, 1989). Thus, Potisuk et al. (1996) claimed that functional load is not just determined simply by whether a language has a feature of stress at the lexical level, but, how frequently a cue to stress is used at the lexical level must also be taken into account.

Thus, the emergence of phonetic cues to word-level prominence may be predicted by the functional load of a cue. If traditional Seoul Korean had word-level prominence, as Ko (2014) suggested, then, duration will serve as a cue to stress both on the first and second syllable, since duration is only a cue to stress in Korean. If Korean has both phonemic vowel length and word-level prominence, the first syllable will be realized with duration while the second syllable will be realized with other cues such as intensity and F0. Duration will not serve as a cue to stress, since duration is occupied as a cue to phonemic vowel length. If Korean has only phonemic vowel length, only duration will distinguish (so-called) Korean stress pairs on the first syllable.

For languages with phrasal-level prominence, pitch is used to group prosodic structure together that is determined by the domain of the accentual phrase. For example, in Japanese, which has both word-level prominence as well as phrasal-level prominence, a low boundary tone occurs at the beginning of every utterance and at the AP-final boundary. Thus, when this low tone occurs within a sentence, listeners interpret it as belonging to the phrasal boundary (Beckman & Pierrehumbert, 1986). This phrasal-level prominence is a crucial element in speech perception (Keating & Shattuck-Hufnagel, 2002) because listeners can interpret the acoustic consequences of the prosodic structure that is created by the speakers and use it in lexical segmentation (Cho, McQueen, & Cox, 2007; Christophe, Peperkamp, Pallier, Block, & Mehler, 2004; Shukla, Nespors, & Mehler, 2007).

However, distinguishing the cues that are used to mark word-level prominence from those used to express phrasal-level prominence might be difficult, because the same acoustic correlates that are used to indicate word-level prominence in stress languages – F0 and duration – are utilized to indicate prosodic prominence as well. Cross-linguistically, syllables in sentence-final position are lengthened, and pitch is raised at the non-sentence-final phrasal-boundary (Beckman, 1986; Tyler & Cutler, 2009; see Japanese for a low boundary tone at non-sentence-final phrasal-boundary position). It is sometimes claimed that Korean has both word-level prominence (i.e., stress) and phrasal-level prominence. Previous research has claimed that Korean has stress realized mainly with duration (e.g., Ko, 2013), and phrasal-level prominence realized with pitch (at AP-level), intensity (at AP-initial position), and duration (at IP-final position)². Thus, the current dissertation aims to examine the acoustic correlates to word-level prominence in two different contexts: in AP-initial position where the phrasal prominence falls on the second syllable of the target words (for words beginning with lenis stops and affricates) vs. in word-isolation where the phrasal prominence falls on the first syllable of the target words. Considering the claim that most younger Korean speakers have lost the vowel length distinction (Kim, 2001; Kim & Han, 1998; Magen & Blumstein, 1993), it may be the case that younger Korean speakers no longer preserve word-level prominence. With the disappearance of the long vowel in Korean, it is predicted that contemporary Seoul Korean will no longer have stress because long vowels that bear stress do not exist in contemporary Seoul Korean. The current dissertation aims to investigate whether the acoustic cues expressing higher-level prosody can

² See section 1.5.1. for detailed explanation.

also be used in producing and perceiving word-level prominence in Korean. In addition, the proposed research will determine the degree to which Korean learners of English use these acoustic cues in producing and perceiving word-level prominence in English. In the next section, we will briefly review Korean phrasal-level prominence and word-level prominence, and then discuss the cues that are used to indicate prominence at different levels.

1.5. Production and perception of Korean word-level prominence (Part 1)

First, we will review the literature on phrasal-level prominence in Korean, as the Accentual Phrase (AP) in Korean is well-established by consensus. Then, we will discuss claims about Korean lexical stress that are still controversial, with an acoustic study that examined and compared the productions of older Korean speakers and younger Chonnam speakers. Complications of this study will be addressed, and then the goals of the first part of the current dissertation will be discussed.

1.5.1. Phrasal-level prominence in Korean

Phrasal-level prominence plays a crucial role in speech segmentation and production by marking the phrasal boundary in terms of F0 or duration (e.g., Beckman, 1986). Phrasal boundary tones are marked with a raised F0 (Beckman & Pierrehumbert, 1986; Pierrehumbert, 1980), and phrase-final position is marked with an increased duration (Klatt, 1975; Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992). Listeners use these higher-level prosodic cues in segmenting ambiguous segmental information both in L1 and L2 speech (Cho et al., 2007; Christophe et al., 2004; Coughlin & Tremblay, 2012; Kim, 2004; Kim & Cho, 2009; Tremblay, Coughlin, Bahler, & Gaillard, 2012). The Accentual Phrase (AP), an intonationally defined unit, can mark a phrasal boundary in Korean. The hierarchical structure of prosodic boundaries consists of the syllable, the Phonological Word (PW), the Accentual Phrase (AP), and the Intonational Phrase (IP). The edge of the larger unit always coincides with the edge of the

smaller unit: the edge of IP always coincides with the edge of AP, and the edge of AP always coincides with the edge of PW (Selkirk, 1984). Jun (1993; 1998) proposed in her Accentual Phrase (AP) theory that Korean has intonationally defined units (AP) that pattern independently from the word-level prosody.

In the Korean AP system, the initial boundary of the prosodic domain is always delimited with a low tone and the final boundary with a high tone (i.e., #LHLH#; # refers to an AP boundary; each syllable is associated with a tone) Jun (1993; 1998). When the domain-initial syllable is either aspirated or tense, the pitch is raised on the first syllable, bearing #HHLH# intonational pattern (Jun, 2000; Kim, 2004; Kim & Cho, 2009). This LHLH tone pattern occurs when at least 4 syllables exist in one AP domain. When there are less than 4 syllables in an AP, 2 or 3 surface tone patterns appear by undershooting the initial two tones. For example, when an AP has 3 syllables, two different tone patterns can appear: a #LH# (or #HH#) pattern when the first two syllables are undershot, and a #LHH# (or #HHH#) when only the first syllable is undershot. When an AP has 2 syllables, only the #LH# (or #HH#) pattern can appear. Figures 1 to 3 illustrate the different tonal patterns as a function of syllable number in an AP. The X-axis indicates the time range that is synchronized across the three utterances (AP boundary is marked by { }). The double dotted vertical lines indicate the AP boundary, and the single dotted vertical line in Figure 3 indicates the first high pitch on the second syllable.

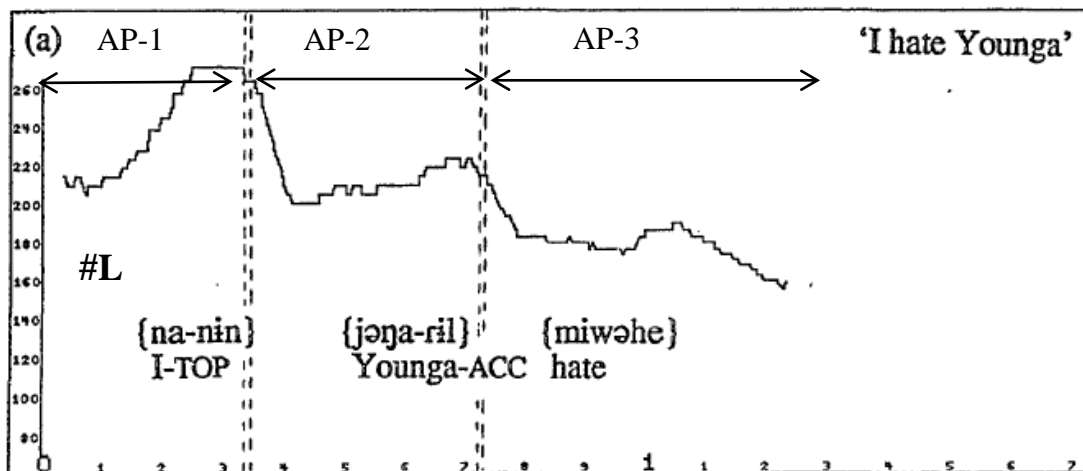


Figure 1. Pitch track of two-syllable words ([na.nin]) in the sentence-initial Accentual Phrase. Adopted from Jun (1993, p 44).

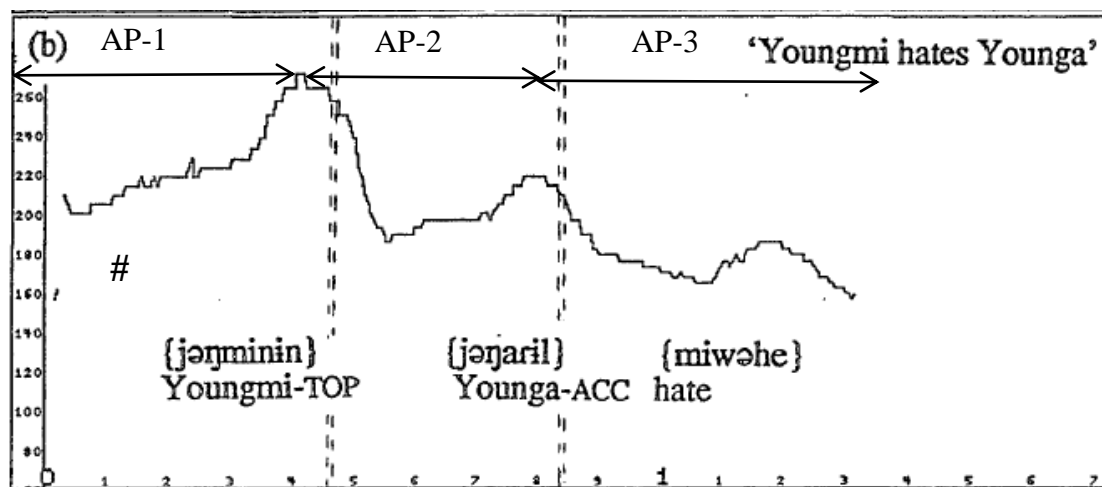


Figure 2. Pitch track of three-syllable words ([jəŋ.mi.nin]) in the sentence-initial Accentual Phrase adopted from Jun (1993, p 44)

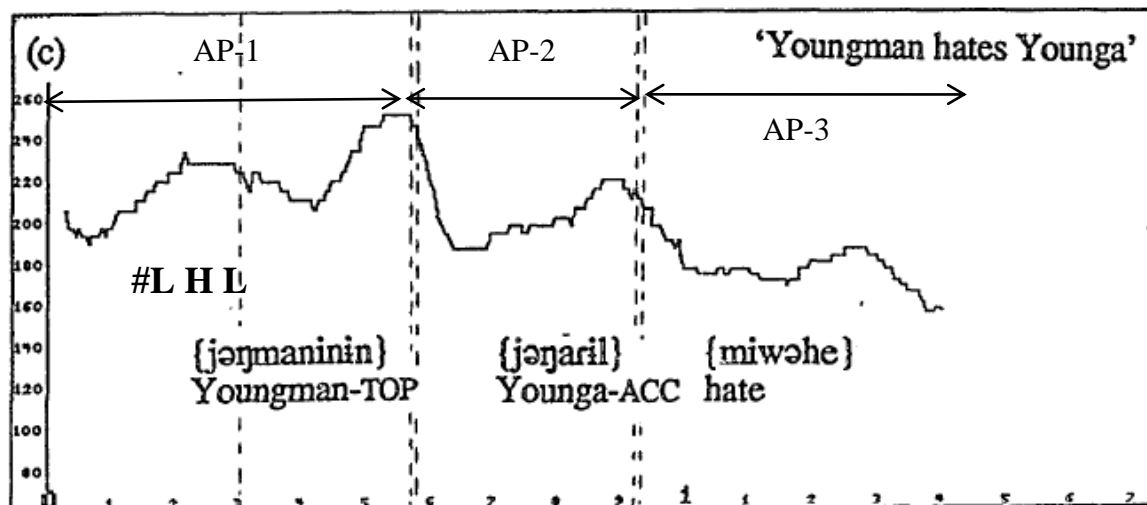


Figure 3. Pitch track of four-syllable words ([jəŋ.man.i.nin]) in the sentence-initial Accental Phrase. Adopted from Jun (1993, p 45)

The IP-final boundary is also characterized with different tonal patterns such as L%, H%, LH%, and HL% (% refers to an IP boundary). When the AP boundary coincides with the IP boundary, the AP-final tone (L#) is overridden by the IP-boundary tone. At the IP-boundary, final lengthening also occurs along with the IP-boundary tone.

The last characteristic of the AP domain is that the phonemic vowel length distinction in Korean disappears depending on the AP domain. Jun (1993) suggested that the long vowel is shortened in AP-medial position compared to AP-initial position. Figures 4 and 5 represent pitch tracks and spectrograms of the following two sentences Jun (1993).

- (1) AP-initial position (Figure 4):
 {joki-e} {nuinwasso}
 'here-at' ['(It) snow-past' => 'Here, it snowed.']
- (2) AP-medial position (Figure 5):
 {koki-to nunwasso}? (emphasizing 'koki')
 'there-too' '(It) snow-int.' => 'You had snow there too?'

The vowel duration in the AP-medial position (59.37 ms) is 35.94 ms shorter than in the AP-initial position (95.31 ms). Even though the syntactic position is identical between the two sentences, the target word [nu:n] 'snow' is captured as AP-medial position when the adverbial

phrase about time and place is preceded by VP-external position (Figure 5). (Cho, 1990; Silva, 1992)

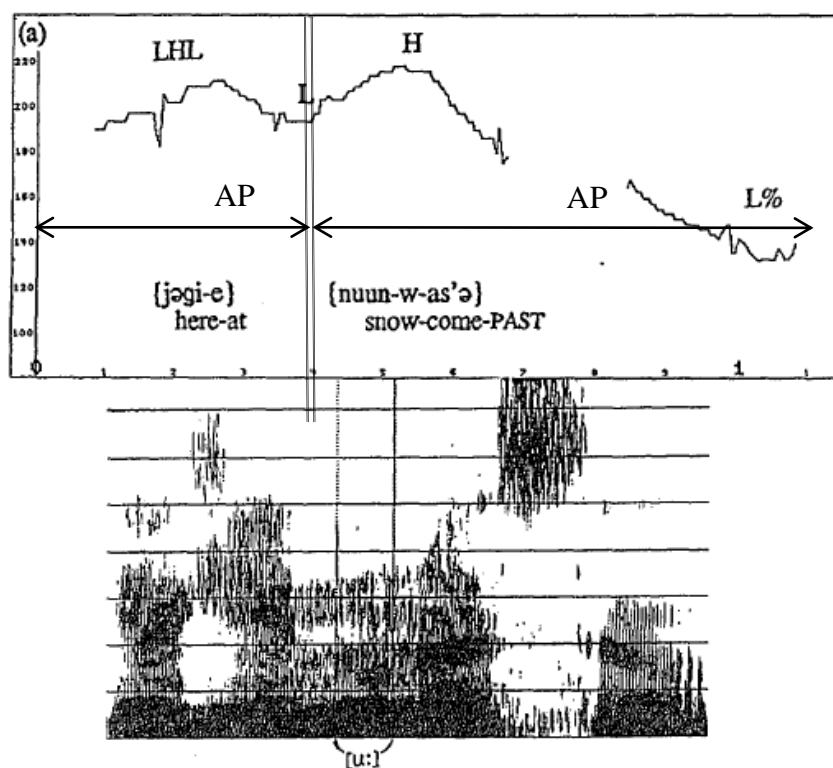


Figure 4. Pitch track and spectrogram of sentence (9) when the target word [nu:n] occurs in AP-initial position, from Jun (1993, p 114).

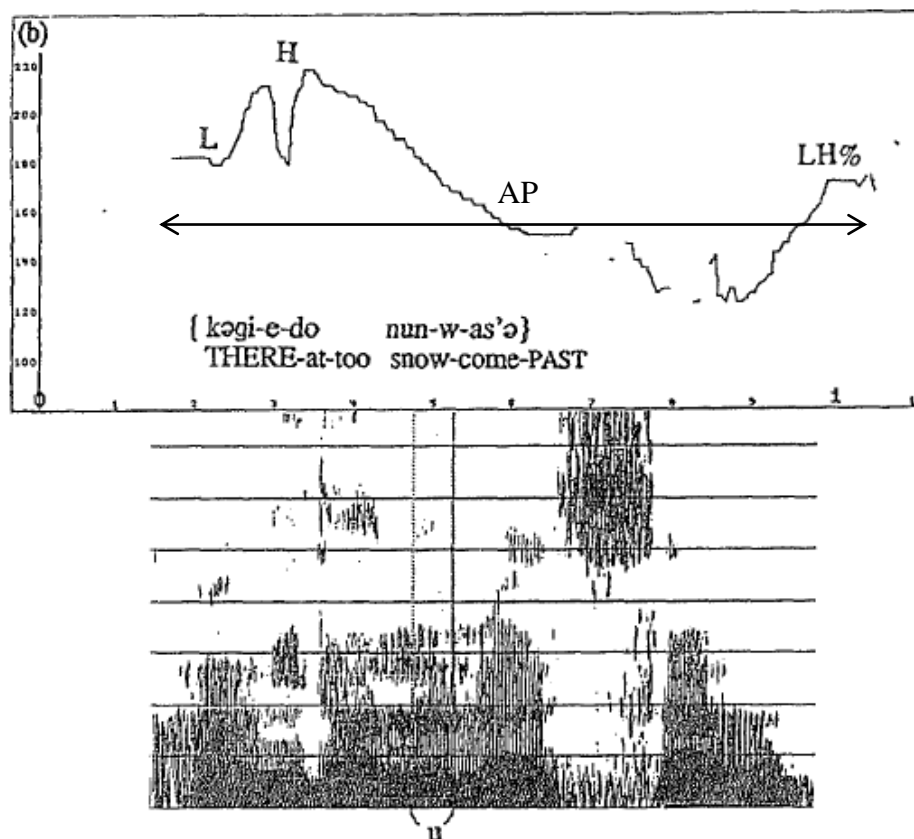


Figure 5. Pitch track and spectrogram of sentence (10) when the target word [nu:n] occurs in the AP-medial position, from Jun (1993, p 114).

Given these findings, Jun (1993) concluded that the long vowel is shortened in AP-medial position, neutralizing the vowel length distinction. However, since her analysis was based on the production of Seoul speakers who do not preserve the vowel length distinction, it is not clear yet whether it is the stress that is neutralized or the vowel length.

In addition to F0, previous studies have found that other cues, such as duration and amplitude, can also characterize the phrasal-level prominence. With respect to duration, phrase-final lengthening can mark IP boundaries in Korean. Jun (1993) and Chung et al. (1996) found that final lengthening does not occur at the AP level, but at the IP level. However, Cho and Keating (2001) and Oh (1998) found a small but significant AP-final lengthening effect compared to non-AP-final words. Although these studies are not consistent regarding AP-final

lengthening in Korean, there is a strong consensus at least that phrase-final lengthening exists in IP-final position. (Cho & Keating, 2001; Chung et al., 1996; Jun, 1993; 2000)

Amplitude can also mark both the AP-initial and -final boundary in Korean. Jun (1995) found that the amplitude of the first syllable was greater than that of the second syllable when a trisyllabic reiterative word like ‘mamama’ was embedded in sentence-medial position. The amplitude of the first syllable was comparable with that of the third syllable, but the third syllable was also marked with low F0 because it was in AP-final position.

Taken together, three acoustic correlates – F0, duration, and intensity – express a higher-level prominence in Korean. High pitch marks AP-final boundary, duration marks IP-final boundary, and high amplitude marks AP-initial and –final boundary. These cues have been found to facilitate Korean listeners’ word segmentation not only in Korean (Kim, 2004; Kim & Cho, 2009), but also in unfamiliar languages (Kim, 2004; Kim, Broersma, & Cho, 2012). Given that it is still unclear whether contemporary Seoul Korean has word-level prominence, the present dissertation aims to investigate whether younger Korean speakers produce word-level prominence in Korean. If there is word-level prominence in Korean and younger speakers can produce it, will younger speakers also perceive it? If not, do they transfer the use of higher-level prosodic cues to the perception of word-level prominence? These two points will be investigated in the first two experiments (Experiment 1 & 2).

In the next section, we will review previous examinations of word-level prominence in Korean, and which acoustic cues have been established as cues to express word-level prominence in Korean.

1.5.2. Word-level prominence in Korean

Historically, Korean has been claimed to have a long and short vowel distinction. The long vowels only appear in the first syllable (Heo, 1965) and are realized with a rising tone.

Although it had been widely accepted that Korean had a vowel length distinction for pairs with identical vowel quality (the IPA manual 1999: 44), most younger speakers have lost this distinction (Kim, 2001; Kim & Han, 1998; Magen & Blumstein, 1993) and only speakers from a few dialects like Chonnam (Ko, 2013) and North Kyungsang (Kenstowicz & Park, 2006) preserve the distinction.

This vowel length distinction has been argued to influence lexical stress in Korean, which is realized as rhythmic shortening or lengthening. The traditional vowel shortening rule takes the long vowel as the underlying form, and posits that the long vowel undergoes vowel shortening. The following example (1) from compound words illustrates the limited realization of the long vowel in syllable-initial position. When a monosyllabic word with a short vowel is combined with a monosyllabic word with a long vowel, the long vowel in the second syllable is shortened in the compound word.

(1) Vowel shortening in the compound word

- a. [cʰʌtʰ] ‘first’ + [nu:n] ‘snow’ → [cʰʌtʰnʌn] ‘first snow’
- b. [nʌn] ‘eye’ + [pjʌ:n] ‘disease’ → [nʌnpjʌn] ‘eye disease’
- c. [pʌm] ‘night’ + [ma:l] ‘words’ → [pʌmmʌl] ‘secret talk’

Similarly, when a monosyllabic word with a long vowel is combined with another monosyllabic word with a long vowel, the vowel in the second syllable is always shortened instead of the initial vowel, as illustrated in example (2).

(2) No vowel lengthening from the short vowel stem in the compound word

[pa:n] ‘half’ + [ma:l] ‘words’ → [pa:nmʌl] ‘casual speech’

The vowel shortening in the second syllable is also found from suffixation, as shown in example (3). When a verb stem with a long vowel is attached to a vowel-initial suffix such as stative (-ə/-a) or effective (-ini) suffix, the long vowel in the verb stem is shortened. However,

when the same vowel stem is attached to a consonant-initial suffix such as declarative (-ta) or connective suffix (-ko), the long vowel in the verb stem is preserved. This vowel-shortening occurs when the Korean long vowel is attached to vowel-initial suffixes (Kim-Renaud, 1974; B.-G. Lee, 1978).

(3) Vowel shortening from suffixation (Kim-Renaud, 1974; B.-G. Lee, 1978).

Stem	Declarative (-ta)	Connective (-ko)	Stative (-ə/-a)	Effective (-ini)	Gloss
a. ta:m	ta:m- ta	ta:m- ko	tam- a	tam- ini	‘put in’
b. a:n	a:n- ta	a:n- ko	an- a	an- ini	‘hug’
c. to:p	to:p- ta	to:p- ko	top- a	top- ini	‘help’

When the same suffix that triggers vowel shortening in example (3) is attached to a short-vowel verb stem, however, vowel lengthening does not occur, as illustrated in (4). Based on this, scholars have claimed that the long vowel is the underlying form of the vowel alternation in Korean.

(4) No vowel alternation in the short-vowel verb stem (Davis & Cho, 1994).

Stem	Declarative (-ta)	Connective (-ko)	Stative (-ə/-a)	Effective (-ini)	Gloss
a. ip	ip- ta	ip- ko	ip-ə	ip- ini	‘wear’
b. kot	kot- ta	kot- ko	kot- a	kot- ini	‘be straight’
c. pəs	pəs- ta	pəs- ko	pəs- a	pəs- ini	‘take off’

Based on this, various researchers have concluded that the Korean long vowel is shortened when attached to a vowel-initial affix instead of the short vowel being lengthened (E. Han, 1990; Kim-Renaud, 1974; Korean Ministry of Education, 1988; B.-G. Lee, 1978; H.-Y. Lee, 1987). However, vowel shortening only applies to monosyllabic verb stems (E. Han, 1990; Kim-Renaud, 1974; Korean Ministry of Education, 1988; B.-G. Lee, 1978, 1986; H.-Y. Lee, 1987). In the following example (5), when the suffixes that trigger vowel shortening in example

(3) (Stative -ə/-a, Effective ‘-ini’) are attached to the long vowel verb stem in polysyllabic words, the vowel shortening does not occur.

(5) Polysyllabic verb stem word (Davis & Cho, 1994).

Stem	Declarative (-ta)	Connective (-ko)	Stative (-ə)	Effective (-ini)	Gloss
a. tə:ləp	tə:ləp- ta	tə:ləp- ko	tə:ləp-ə	tə:ləp- ini	‘be dirty’
b. k’ə:ci	k’ə:ci- ta	k’ə:ci- ko	k’ə:ci-ə	k’ə:ci- ini	‘sink’
c. yo:ŋsəha	yo:ŋsəha- ta	yo:ŋsəha- ko	yo:ŋsəha-ə	yo:ŋsəha- ini	‘forgive’

However, not all the homophonous vowel-initial suffixes trigger vowel shortening in the monosyllabic verb stem. In the following example (6), when the homophonous vowel-initial suffix /-i/ is attached to a long-vowel monosyllabic verb stem, only the nominalizing suffix triggers vowel shortening. Considering that the latter two examples share the identical surface form with the nominalizing suffix, whether the suffix begins with a vowel does not seem to have any impact on vowel shortening.

(6) Different patterns from the attachment of the homophonous suffix ‘-i’ (J.-K. Kim, 2000)

a. nominalizing suffix –i (causes vowel shortening)				
Stem	Gloss	Nominalizing	Gloss	
ki:p ^h	‘be deep’	kip ^h -i	‘depth’	
ki:l	‘be long’	kil-i	‘length’	
b. adverbializing suffix –i (does not cause vowel shortening)				
Stem	Gloss	Adverbializing	Gloss	
ki:p ^h	‘be deep’	kí:p ^h -i	‘deeply’	
ma:n ^h	‘be abundant’	má:n ^h -i	‘abundantly’	
c. nominative case marker –i (does not cause vowel shortening)				
Stem	Gloss	Nominative	Gloss	
ka:m	‘persimmon’	ka:m-i	‘persimmon-NOM’	
pyə:ŋ	‘disease’	pyə:ŋ-i	‘disease-NOM’	

The idiosyncratic pattern of vowel shortening is also observed in consonant-initial suffixes, as shown in (7). This disparate pattern from the homophonous suffix /-ki/ also supports the claim that the vowel-initial suffix cannot be the factor that triggers vowel shortening.

(7) Vowel shortening from Consonant-initial suffixation (Ko, 2002, 2013)

a. passive/causative suffix –ki (causes vowel shortening)

Stem	Gloss	Passive/Causative	Gloss
ta:m	‘put in’	tam- ki -ta	‘be put in’
a:n	‘hug’	an- ki -ta	‘be hugged’

b. nominalizing suffix –ki (does not cause vowel shortening)

Stem	Gloss	Normalizing	Gloss
ta:m	‘put in’	ta:m- ki	‘to put in’
a:n	‘hug’	a:n- ki	‘hugging’

Based on this fact, some scholars (Davis & Cho, 1994) have concluded that the vowel shortening in Korean is triggered by some lexical property of the suffix. The previous traditional point of view was that the stem-final syllable in the verb stem that is adjacent to the vowel-initial suffix undergoes the vowel shortening. Davis & Cho (1994) argued that certain suffixes have the property to erase the moraic structure of the verb stem, and consequently, the vowel is shortened.

Ko (2002, 2010, 2013), on the other hand, proposed that vowel shortening occurs to avoid accent clash. In her analysis, both ‘stress’ and ‘accent’ are used in reference to word-level prominence. Ko (2002) defines ‘stress’ to refer to “the metrical head physically realized on the surface”, and ‘accent’ to refer to “the underlying specification for prominence on a syllable” (Ko, 2002, p 81: line 27-29). ‘Stress’ is the actual location at which physical correlates of word-level prominence are realized with acoustic features such as duration, F0, and amplitude, while ‘accent’ is the potential location of stress. Ko (2013) claimed that the long vowel is realized with the stress on the syllable, and when a syllable is not realized with stress, the vowel remains as a short vowel. Therefore, when a suffix that is carrying an accent is attached to a monosyllabic long vowel verb stem, the stem vowel is shortened in order to avoid the accent clash. However, when the accent-triggering suffix is attached to a disyllabic verb stem, the elongated vowel does not need to undergo vowel shortening. The accent of these suffixes is never realized because

stress in Korean needs to fall on the first two syllables. The stress assignment rules in Korean can be summarized as follows:

(8) Stress Assignment in Korean (Ko, 2013: page 88)

- a. Stress falls on the initial syllable if it is accented; otherwise, on the second syllable.
- b. Two-syllable left edge window :
Stress must be contained within the first two syllables of the stress domain.

In sum, many researchers have tried to analyze the vowel length distinction in Modern Korean. Some scholars have treated it as vowel shortening, others have analyzed it in terms of accent clash.

However, the loss of the vowel length distinction in Modern Korean makes these analyses questionable. Considering that the long vowel is preserved in a few dialects and older Seoul speakers, it might be the case that the lexical stress is diminishing in Seoul Korean.

1.5.3. Phonetic evidence for lexical stress in Korean

Ko (2013) examined whether other acoustic correlates indicating lexical stress are realized along with vowel duration in two dialects of Korean. Since the Chonnam Korean dialect still preserves the vowel length distinction unlike Seoul Korean, Ko (2013) hypothesized that the Chonnam dialect might be more conservative in preserving lexical stress and therefore, the manifestation of the four acoustic correlates of stress will be more apparent compared to Seoul Korean. Two different age groups across two dialects (younger Chonnam speakers vs. older Seoul speakers) were chosen. The reason why different age groups were included is because both the current Chonnam dialect and the traditional Seoul dialect (older Seoul speakers) still preserve the vowel length distinction. Thus, the productions of 4 young Chonnam speakers (1 male, mean age = 34) were compared with those of 4 old Seoul Korean speakers (2 males, mean age = 69). Seventeen stress minimal pairs (e.g., *sákwa* ‘apology’ vs. *sakwá* ‘apple’) were embedded in a

contextually related sentence (e.g., As for **apples**, Taegu is famous for it) and in a contextually neutral sentence (e.g., ‘Please pronounce apple clearly’)³. First, the subjects were asked to read aloud a contextually related sentence so that speakers would know the lexical category of the target word. Immediately after that, the subjects read aloud the same target word in a contextually-neutral sentence. Three acoustic parameters – vowel duration (ms), intensity (dB), and F0 (semitone) – were examined. For vowel duration and intensity, the measurements over the total vowel duration from the stressed syllables (*sá* from *sákwa* ‘apology’) were compared to those of the unstressed syllables (*sa* from *sakwá* ‘apple’). For the F0 values, normalized semitone values were used. First, the F0 range was adjusted to each speaker’s register tone (5th percentile of all F0 values for each subject), and then the adjusted F0 values were normalized on a semitone scale. To avoid any coarticulation effect from neighboring sounds at the beginning and end of the vowel portion, the mean semitone values from the 20% point to the 50% point of the vowel were analyzed. Similarly to vowel duration and intensity, the mean F0 values of the stressed syllable were compared with those of the unstressed syllables.

A series of paired t-tests found that young Chonnam speakers use three acoustic correlates to distinguish the vowel-length minimal pairs. The ‘stressed first syllables’ were produced with 77.7 ms longer duration ($p < .01$), 0.64 semitone higher F0 ($p < .01$), and 2.6 dB greater intensity ($p < .01$) than ‘unstressed first syllables’. The stressed second syllables were produced with 35.72 ms longer duration, 1.51 semitone higher F0, and 1.8 dB greater intensity. On the other hand, older Seoul Korean speakers only used vowel duration in the first syllable and

³ The claims regarding word-level prominence in Korean were made based on cases where the phonological process of vowel shortening occurs, whereas Ko (2013) used words with phonemically long and short vowels for the acoustical analysis.

intensity in the second syllable in expressing vowel-length minimal pairs. The older Seoul speakers produced stressed first syllables with 96.71 ms longer duration ($p < .01$) than unstressed first syllables, and produced stressed second syllables with 1.02 dB greater intensity than unstressed second syllables ($p < .01$). Table 1 represents the mean values and standard deviations of vowel duration, F0, and intensity of the first and second syllables for both dialects.

Table 1. Mean values and standard deviation (in parentheses) of duration, F0, and intensity of two Korean dialects. Adopted from Ko (2013).

		First syllable			Second syllable		
		duration (ms)	F0 (semitone)	intensity (dB)	duration (ms)	F0 (semitone)	intensity (dB)
Chonnam	Word-initial stress	152.6 (50.2)	3.61 (0.66)	66.6 (2.50)	213.79 (51.6)	2.62 (0.69)	63.9 (2.41)
	Word-final stress	75.1 (21.7)	2.97 (0.69)	64 (2.62)	178.07 (48.9)	1.11 (0.72)	62.1 (2.16)
Seoul	Word-initial stress	181.33 (28.43)	3.28 (0.69)	67.72 (1.82)	145.4 (32.57)	1.63 (0.55)	63.26 (3.48)
	Word-final stress	84.62 (21.22)	3.67 (0.81)	67.34 (2.14)	138.47 (35.29)	1.08 (0.74)	62.24 (2.97)

Additionally, two separate models of a mixed effect logistic regression were constructed to examine the relative effects of three acoustic correlates of lexical stress in Korean. Whether stress was on the first syllable or second syllable was entered as the binomial dependent variable. Three acoustic correlates in two different stress locations – first syllable duration, first syllable F0, first syllable intensity, second syllable duration, second syllable F0, and second syllable intensity – were entered as fixed effects. Subjects and items were entered as random effects. This model was conducted separately for Chonnam speakers' data and Seoul speakers' data. The results showed that vowel duration and F0 had a significant effect on expressing stress patterns in the Chonnam dialect. All three correlates – vowel duration, F0, and intensity – showed a

significant effect on predicting stress on the first syllable. However, only vowel duration and F0 showed a significant effect on predicting stress on the second syllable. On the other hand, in the Seoul dialect, vowel duration was found to be the only factor to predict stress on the first syllable. In predicting the stress on the second syllable, both vowel duration and F0 showed a significant effect.

Based on this, Ko (2013) concluded that Chonnam uses vowel duration, F0, and intensity to express lexical stress, while the Seoul dialect is exhibiting a diachronic change from a stress language to a phrasal-accent language, as supported by the limited expression of word-level prominence. Ko (2013) argued that Seoul Korean had a “duration-based prominence system based on a very limited window of initial syllable” (p. 108, line 10), but the stress has eventually been lost in contemporary Seoul Korean. This raises the question how diachronic change in Seoul speakers’ word-level prominence has affected the production and perception of lexical prominence. The first goal of the current dissertation is to investigate which acoustic correlates younger Korean speakers produce instead of vowel duration to indicate word-level prominence. Also, we investigate which acoustic features younger Korean speakers use in perceiving word-level prominence, and how their use of acoustic cues differs from that of older Korean speakers.

1.5.4. A few potential problems

There are a number of issues in the design and interpretation of the Ko (2013) study that warrant a closer look into the notion of stress/word-level prominence in Korean. First, the participants in Ko (2013)’s study were limited to four older Seoul Korean speakers who came to the USA almost 40 years ago. Their exposure to English for this vast period of time could have affected their production of word-level prominence in Korean, and also, their production in L1 might not reflect contemporary Seoul Korean, especially with respect to the ongoing language changes. It has been found that the use of VOT and F0 in indicating the three-way laryngeal

distinction among stops in Korean has changed (Kang & Guion, 2008; Lee & Jongman, 2015; Lee, Politzer-Ahles, & Jongman, 2013; Perkins & Lee, 2010; Silva, 2006; Wright, 2007) and more importantly, the vowel length distinction has been claimed to have disappeared among younger Korean speakers (Kim, 2001; Kim & Han, 1998; Magen & Blumstein, 1993).

Considering that, while living in the USA, Ko's speakers did not get as much L1 input as Korean residents, their productions might not be representative of Seoul Korean speakers. Chang (2012) also found that the Taiwanese attriters, who have lost their L1 (i.e., Taiwanese) due to the dominant use of L2 (i.e., Chinese), produced one of the Taiwanese tone sandhi forms with higher accuracy than non-attriters or bilinguals, indicating that the ongoing change in the Taiwanese tone sandhi system was not reflected in attriters. Similarly, we might find a smaller duration difference in older Seoul Korean speakers, who have been exposed to the ongoing loss of the vowel length distinction, than Ko did for her immigrant speakers.

Second, in order to tease apart the effect of phrasal boundary on lexical stress, we need to examine the productions in two different contexts. Ko (2013) recorded the tokens produced in a carrier sentence, where the target words were embedded in sentence-medial position. However, the carrier sentence that Ko used is unnatural due to the absence of the case marker after the target word. Ko first used a contextually-related sentence in order to prompt the intended word, and then asked the participants to read the target word embedded in a contextually neutral sentence, 'clearly *apple* pronounce' [t'o.bak. t'o.bak. **sa.gwa**. par.im.ha.se.jo.]. However, she deliberately omitted the case marker after the target word, *apple*, since the case marker is an allomorph which will appear as three syllables following a closed syllable (e.g., [**si.dʒaŋ**. i.ra.go]) and as two syllables following an open syllable (e.g., [**sa.gwa**. ra.go]). However, the sentence without a case marker sounds extremely unnatural, which might lead to producing the

words with unnatural F0 patterns. In fact, Ko explained in her earlier study that the same sentence can be used to express two different prosodic frames, depending on how the sentence is parsed, as illustrated below. (Ko, 2002; p 144)

Two possible ways of phrasing the frame sentence from Ko (2002)

- a. Two independent prosodic domains
 {t'obak t'obak} {sa:gwa} {parimhasejo}
 'clearly apple say'
- b. A single prosodic domain from the VP
 {t'obak t'obak} {sa:gwa parimhasejo}
 'clearly apple say'

Moreover, Ko instructed her speakers to produce the sentences with a falling intonation, which also could result in unnatural prosody. Ko (2013) explained that this was done in order to prompt the speakers to read the target words in a citation form and also to avoid a list effect. However, Ko did not provide a clear motivation, or references, to clarify how this procedure would achieve natural speech.

Also, Ko only measured raw values for each syllable and compared the difference between the values from the stressed syllables and unstressed syllables in their respective positions. However, the obtained difference might be misleading, because the same difference can also be found from vowel length minimal pairs. Moreover, a direct comparison between the first syllables of the stress minimal pairs does not provide insight into the relative differences between the syllables within a word. In addition, if the speakers claimed that they pronounced the stress pairs as homophones, Ko eliminated those tokens from the analysis. Thus, it is unclear whether the difference found from Ko (2013) is a fair representation of lexical stress, given the fact that the recording procedure was problematic and the data was subjectively selected.

Lastly, Ko (2013) made claims about the use of perceptual cues based on her analysis of linear mixed logistic regressions on her acoustic findings. Without any perception data, it is hard to conclude which cue(s) Korean listeners use in their perception. To our knowledge, no study has been conducted examining cue weighting for Korean word-level prominence. Thus, by conducting an acoustic study as well as a perception study, this dissertation aims to provide evidence regarding whether Korean indeed has lexical stress or simply has a vowel length distinction. In the acoustic study, we examine whether we can replicate the findings from Ko in two contexts (i.e., at the sentence level, in word-isolation) with speakers of two generations. In the perception study, we examine which acoustic cue(s) Korean listeners weight in identifying Korean stress pairs. The detailed goals of the first part of this dissertation will be listed in the next section.

1.6. Goals of the study (Experiments 1 & 2)

The primary goal of Experiment 1 is to investigate whether contemporary Seoul Korean still retains word-level prominence by conducting an acoustic analysis of productions of older and younger Seoul Korean speakers. Given the claims that contemporary Seoul Korean has lost its vowel length distinction (Kim & Han, 1998; Magen & Blumstein, 1993; Kim, 2001), we also aim to investigate which acoustic correlates younger Korean speakers use instead of duration to indicate word-level prominence. If Korean indeed has stress, we hypothesize that the effect of stress will be observed in two different contexts – at the sentence level and in word-isolation. If Korean indeed has stress, we hypothesize that the effect of stress will be observed in two different contexts – at the sentence level and in word-isolation. If Korean has completely the lost vowel length distinction and also lexical stress as Ko (2013) claims, then, younger Korean speakers will produce stress pairs as homophones. More detailed research questions and hypotheses are listed in Chapter 2.

The primary goal of Experiment 2 is to examine which acoustic cues Korean listeners weight in identifying Korean word-level prominence. We try to answer this question by manipulating duration, F0, and intensity on each syllable. We hypothesize that if Korean has stress, listeners' perception of stress will be shifted depending on which syllable has prominence. It is predicted that if Korean has lexical stress and a vowel length distinction, like K'ekchi, then Korean listeners would not weight duration in their perception. If Korean has only a vowel length distinction, then Korean listeners would only be sensitive to the duration cue in the first syllable. If Korean has stress realized mainly with duration, like Thai, then Korean listeners would use duration in both the first and second syllables. The detailed research questions and hypotheses are listed in Chapter 3.

CHAPTER II.

PRODUCTION OF KOREAN WORD-LEVEL PROMINENCE BY OLDER AND YOUNGER KOREAN SPEAKERS

2.1. Introduction

Korean has been claimed to have both word-level and phrase-level prominence, with the former realized mainly with duration (e.g., Ko, 2013) and the latter with F0 height (e.g., Jun, 1996). Ko (2013) argued that traditional Korean had lexical stress realized with longer vowel duration on the first syllable, but has undergone language change from word-level to phrasal-level prominence when losing the vowel length distinction among younger speakers (Kim & Han, 1998; Magen & Blumstein, 1993; Kim, 2001). However, the question that arises about this claim is that if only one cue, duration, expresses word-level prominence only in limited syllable position, then whether what has been claimed to be stress is indeed stress or a phonemic vowel length contrast. Thus, one of the main foci of the current chapter is to examine whether contemporary Seoul Korean still has word-level prominence or only expresses phrasal-level prominence. We will be comparing younger Korean speakers' production of Korean vowel length pairs (also known as stress pairs) to that of older Korean speakers.

If Korean still has word-level prominence, younger Korean speakers might have traded the duration cue with other cue(s) and still produce a difference between the members of Korean stress minimal pairs. If what has been claimed to be word-level prominence in Korean was just a phonemic vowel length distinction, only the duration cue from older speakers' production will differentiate Korean word pairs. If Korean has undergone a language change from word-level to phrasal-level prominence, the productions of older speakers and younger speakers will differ in terms of duration as well as F0 pattern: older Korean speakers will express word-level prominence with duration, whereas younger speakers will produce the stress pairs as

homophones. However, younger speakers' production will show a consistent LH (or HH) F0 pattern on an accentual phrase, indicating phrasal-level prominence while older speakers' production will not.

2.2. Background

Historically, Korean has been claimed to have a long and short vowel distinction, in which the long vowels only appear in the first syllable (Heo, 1965) with a rising tone. Although it had been widely accepted that Korean had a vowel length distinction for pairs with identical vowel quality (the IPA manual 1999: 44), most younger speakers have lost this distinction (Kim & Han, 1998; Magen & Blumstein, 1993; Kim, 2001) and only speakers from a few dialects like Chonnam (Ko, 2013) and North Kyungsang (Kenstowicz & Park, 2006) preserve it. This vowel length distinction has been analyzed in discussion of lexical stress in Korean, which is realized as rhythmic shortening or lengthening.

For example, Ko (2002; 2010; 2013) claimed that the long vowel is realized as the indicator of stress on the first syllable. When the first syllable has a short vowel, the syllable is not stressed. Based on her analysis, Ko (2013) examined how other acoustic correlates indicating lexical stress in addition to duration are realized in two dialects of Korean. Ko (2013) examined production of Chonnam younger speakers, who still preserve the vowel length distinction, and compared it to that of older Seoul speakers. When examining three acoustic measurements – duration, F0, and intensity – of Korean vowel-length minimal pairs, Ko (2013) found that the stressed syllables produced by Chonnam speakers have longer duration, higher F0, and greater intensity than the unstressed syllables, whereas older Seoul Korean speakers expressed stress only with duration on the first syllable. Based on this, Ko (2013) concluded that Chonnam dialect is using the acoustic manifestation of vowel duration, F0, and intensity to express lexical stress, while Seoul dialect is exhibiting a diachronic change from a stress language to a phrasal-

accent language, as supported by the limited expression of word-level prominence on the first syllable. Ko (2013) argued that Seoul Korean had a “duration-based prominence system based on a very limited window of initial syllable” (p. 108, line 10), but the stress has eventually been lost in contemporary Seoul Korean.

However, Ko (2013)’s data is not enough to support the claim that Seoul Korean has indeed undergone a language change from word-level to phrasal-level prominence. First, phrasal-level prominence in Korean is primarily expressed with F0 pattern: when the initial consonant of the first syllable in an accentual phrase begins with a lenis consonant, the first syllable is delimited with a low tone, resulting in LH pattern. However, when the initial consonant of the first syllable is either fortis or aspirated, the initial tone is raised, resulting in HH F0 pattern (Jun, 1993; 1995). Since the F0 pattern clearly demonstrates the phrasal accent in Korean, without comparing F0 patterns of initial consonants between older and younger Seoul Korean speakers, evidence so far is inconclusive as to whether traditional Korean had only word-level prominence or both word-level and phrasal-level prominence.

Second, Ko (2014)’s claim that traditional Seoul Korean had word-level prominence is based on her comparison between Seoul and Chonnam dialects. Chonnam speakers used duration, F0, and intensity dynamically in indicating word-level prominence in Korean, while older Seoul Korean speakers only used duration in the first syllable to indicate word-level prominence. However, given that both Chonnam and Seoul Korean have phrasal prominence (Jun, 1993), it is unclear why only Seoul Korean changed to a language with phrasal-level prominence while losing intensity and F0 to express word-level prominence. Moreover, instead of examining the relative difference between syllables, Ko (2013) compared acoustic correlates of the stressed and unstressed first syllables (e.g., SAkwa vs saKWA; Uppercase indicates stress)

and stressed and unstressed second syllables (e.g., SAkwa vs. saKWA). However, without comparing the relative difference between the first and second syllable, it is hard to tease apart whether Korean has vowel duration contrasts or word-level prominence.

Previous studies have suggested that when the functional load of one cue is preempted by other phonological features, such as lexical tone or phonemic vowel length, the function of the cue does not seem to be extended to the lexical level in expressing stress. For example, in Thai, stress is only expressed with duration, presumably because F0 is preempted by lexical tone; therefore, F0 is not a reliable cue to stress (Potisuk et al., 1996). Also, in K'ekchi, a Mayan language with fixed syllable-final stress and with a phonemic vowel length distinction, only intensity and F0 were used to indicate stress, but not duration, in production (Berinstein, 1979). Thus, according to the Functional load hypothesis (Berinstein, 1979; Potisuk et al., 1996), we will be able to tease apart whether Korean has 1) word-level prominence, 2) only a vowel length distinction, or 3) both word-level prominence and vowel length contrasts.

Ko (2013) discussed the relation between duration and stress in terms of a weight-to-stress effect (Myers, 1987; Prince, 1991): if the first syllable is long, then it is stressed. Therefore, if Seoul Korean has word-level prominence realized by duration, then duration will mark the difference both in the first and the second syllable. If Seoul Korean has only a vowel length distinction, then the duration difference will only appear on the first syllable. If Seoul Korean has both word-level prominence as well as a vowel length contrast, then the prominence of the syllables will be realized with duration only in the first syllable, but the second syllable will be marked by F0 and intensity, because the functional load of duration as a cue to a vowel length contrast would prohibit duration from being used as a cue to stress. Therefore, duration

will only be realized in the first syllable as a cue to vowel length, while other cues such as intensity and duration will be realized in the second syllable as cues to stress.

Third, it is possible that the effect of lexical stress found by Ko (2013) is confounded with the effect of phrasal accent. Since all three acoustic cues expressing word-level prominence in Korean are also used to express higher-level prosody, it is essential to examine whether any stress cues that were found by Ko (2013) derived from the fact that the cues in higher-level prosody were imposed onto the target words. Thus, this research examines the acoustic correlates of Korean stress pairs in different contexts – when produced in sentences vs. when produced in isolation. When the target words are produced in sentence-medial position, where the target words are located in AP-initial position, F0 and intensity will be affected by the AP-initial boundary by having lower F0 values (for words beginning with lenis consonants) and higher intensity values in the first syllable. When the target words are produced in isolation, on the other hand, F0 and intensity will be affected by the effect of sentence-final position: the second syllable will be lengthened while having lower F0 and higher intensity values when produced in isolation as compared to when produced in a sentence. Thus, the effect of word-level prominence is expected to be weaker in word isolation than at the sentence level. Nevertheless, observation of a similar pattern of the stress cues in the tokens produced in word isolation to those in sentence condition would allow us to conclude that the cues that Ko (2013) found indicate word-level prominence in Korean. By comparing acoustic correlates in two different contexts, we will be able to disentangle the effect of word-level prominence and the effect of phrasal prosody.

Lastly, considering that none of the previous studies have provided detailed acoustic evidence on the production of Korean (so-called) stress minimal pairs by Seoul Korean speakers,

we do not know yet whether younger Korean speakers have completely lost the vowel length distinction in their speech or still retain the length distinction with small acoustic differences.

Taken together, the current chapter will provide a detailed acoustic analysis of word-level prominence in contemporary Seoul Korean, and the most comprehensive comparison regarding language change as it relates to prominence in Korean between two generations.

2.3. Goal

The goal of this chapter is to investigate whether contemporary Seoul Korean still retains word-level prominence, and if so, which acoustic correlates younger Korean speakers produce instead of, or in addition to, vowel duration to indicate word-level prominence. The primary focus of this chapter is to examine the acoustic correlates of Korean word-level prominence by two different Seoul speaker groups in two different contexts. More specifically, we examine whether traditional Seoul Korean indeed had word-level stress and whether contemporary Seoul Korean has changed to a phrasal-accent language from a word-level prominence language. There are four research questions that we aim to answer in this chapter:

- 1) Have younger Korean speakers completely lost the vowel length distinction in their production as previous studies have suggested? How different or similar is the production of younger Korean speakers to that of older Korean speakers in terms of duration?
- 2) If younger Korean speakers have completely lost the vowel length distinction, do they produce Korean stress pairs as homophones? Or do younger Korean speakers use other cues that they have traded with duration to differentiate Korean stress pairs?
- 3) Did traditional Seoul Korean change from word-level prominence to phrasal-level prominence? Will we see a different F0 pattern as a function of initial consonants between older and younger Korean speakers?

- 4) Did traditional Seoul Korean indeed have lexical stress? That is, will the acoustic cues indicating word-level prominence in words in isolation also be found in the production in the sentence condition (e.g., AP-initial position)?

2.4. Methodology

2.4.1. Participants

Twenty-one male native speakers of Korean participated in a production study (ten older and eleven younger Korean speakers). All subjects were born and raised in Seoul or Suwon, Kyunggi area where the standard Korean dialect is spoken. The mean age of older Korean speakers was 71.9 years (sd = 1.52) and 23.5 years (sd = 3) for the younger Korean speakers. None of the subjects lived in any other region where a different dialect is spoken, except for the older Korean speakers during the Korean war from 1951-1953. All subjects were literate in Korean, and none of the subjects reported any hearing or speech disorder.

2.4.2. Stimuli

Seventeen minimal pairs that were used by Ko (2013) were adopted for the production study. These word pairs are traditionally considered as minimal pairs with phonemic vowel length, which Ko (2013) treated them as minimal pairs in terms of stress. For example, for the minimal pair /sa:kwa/ ‘apology’ and /sakwa/ ‘apple’, Ko (2013) treated /sa:kwa/ ‘apology’ as the word with first-syllable stressed and /sakwa/ ‘apple’ as having second-syllable stressed. These word pairs were first embedded in contextually related sentences in order to cue the semantic meaning of the target word to the participants, and then presented in a contextually neutral sentence as well as in isolation. The number of syllables of the contextually related sentences was balanced (See Appendix A for the stimulus list). Examples of semantically-related sentences and neutral sentences for the word pair /sakwa/ are as follows:

(1) Examples for ‘apology’

- a. Semantically-related sentence for ‘*apology*’
[dʒal.mo.sil. ha.mjøn. **sa:gwa**.ha.go. mʌn.dʒʌ. joŋ.sʌ.lil. pin.da.] (16 syllables)
*‘If you do wrong, you should give an **apology** first and ask for forgiveness.’*
- b. Semantically neutral sentence for ‘*apology*’
[i. dan.ʌ.nin. **sa:gwa**. im.ni.da.]
*‘This word is **apology**’*

(2) Examples for ‘apple’

- a. Semantically-related sentence for ‘*apple*’
[dʒɛ.sa. gwa.il.lo. **sa:gwa**.wa. pɛ.ga. dʒa.dʒu. sa.joŋ.dwen.da.] (16 syllables)
*‘For fruits to use at ancestor veneration ceremonies, **apples** and pears are often used.’*
- b. Semantically neutral sentence for ‘*apple*’
[i. dan.ʌ.nin. **sa:gwa**. im.ni.da.]
*‘This word is **apple**’*

Only the tokens that were produced in neutral sentences (e.g., critical words produced in AP-initial position) and isolated words (e.g., critical words produced in word-isolation condition) were examined for the acoustic analysis. All stimuli were presented in Korean orthography in a randomized order, without any indication of the vowel length or stress location. In total, 714 tokens were recorded in a contextually neutral sentence (17 pairs x 2 repetitions x 21 speakers), and 357 tokens in word isolation (17 pairs x 21 speakers). Tables 2 and 3 represent IPA symbols for each stressed vowels for the 14 target word pairs as a function of vowel height and frontness, respectively.

Table 2. IPA symbols for each stressed vowel of the 17 Korean stress minimal pairs from Ko (2013) as a function of vowel height. The numbers in parentheses next to the IPA symbols indicate the number of words corresponding to the symbol.. Stimulus list of the Korean stress minimal pairs.

	Vowel Height	IPA when stressed	Words
First-syllable stressed	High vowels	[i:] (1)	[si:caŋ] ‘market’
		[u:] (2)	[pu:ca] ‘rich man’ [su:tʃi] ‘number’
	Mid vowels	[o:] (5)	[ko:de] ‘prehistoric’ [ko:caŋ] ‘malfunction’ [co:gi] ‘flag’ [co:li] ‘strainer’ [so:gim] ‘short flute’
		[ʌ:] (4)	[cʌ:ŋdo] ‘straight path’ [cʌ:li] ‘low interest’ [cʌ:ŋgi] ‘electricity’ [ʌ:mi] ‘suffix’
	Low vowels	[a:] (5)	[ka:caŋ] ‘head of family’ [ka:cʌŋ] ‘hypothesis’ [ca:ŋsa] ‘strong man’ [sa:gi] ‘morale’ [sa:gwa] ‘apology’
	Second-syllable stressed	High vowels	[i] (7)
[ɨ] (1)			[sogim] ‘salt’
Mid vowels		[o] (1)	[cʌŋto] ‘degree’
		[ʌ] (1)	[kacʌŋ] ‘family’
		[ɛ] (1)	[kodɛ] ‘Korea university’
Low vowels		[a] (6)	[sicaŋ] ‘hunger’ [kocaŋ] ‘town’ [pu:ca] ‘father and son’ [kacaŋ] ‘most’ [caŋsa] ‘business’ [sakwa] ‘apple’

Table 3. IPA symbols for each stressed vowel of the 17 Korean stress minimal pairs from Ko (2013) as a function of vowel frontness. The numbers in parentheses next to the IPA symbols indicate the number of words corresponding to the symbol. Syllables with uppercase indicate stressed syllables.

	Vowel Height	IPA when stressed	Words
First-syllable stressed	Front vowels	[i:] (1)	[si:caŋ] ‘market’
	Back vowels	[u:] (2)	[pu:ca] ‘rich man’ [su:tʃi] ‘number’
		[o:] (5)	[ko:de] ‘prehistoric’ [ko:caŋ] ‘malfunction’ [co:gi] ‘flag’ [co:li] ‘strainer’ [so:gim] ‘short flute’
		[ʌ:] (4)	[cʌ:ŋdo] ‘straight path’ [cʌ:li] ‘low interest’ [cʌ:ŋgi] ‘electricity’ [ʌ:mi] ‘suffix’
		[ɑ:] (5)	[ka:caŋ] ‘head of family’ [ka:cʌŋ] ‘hypothesis’ [ca:ŋsa] ‘strong man’ [sa:gi] ‘morale’ [sa:gwa] ‘apology’
Second-syllable stressed	Front vowels	[i] (7)	[sagi] ‘china’ [sutʃi] ‘humiliation’ [cogi] ‘yellow croaker’ [coli] ‘cooking’ [cʌli] ‘there’ [cʌŋgi] ‘biography’ [ʌmi] ‘mother’
		[ɛ] (1)	[kode] ‘Korea university’
	Central vowels	[i] (1)	[sogim] ‘salt’
	Back vowels	[o] (1)	[cʌŋdo] ‘degree’
		[ʌ] (1)	[kacʌŋ] ‘family’
		[ɑ] (6)	[sicaŋ] ‘hunger’ [kacaŋ] ‘most’ [caŋsa] ‘business’ [sakwa] ‘apple’ [puca] ‘father and son’ [kocaŋ] ‘town’

2.4.3. Procedure

The recordings were conducted in Suwon and Seoul. For older Korean speakers, the recording was made in a quiet room in a local hotel, and for younger Korean speakers, the recording was made in a seminar room at Sungkyunkwan University in Seoul, Korea. A Marantz Digital Recorder (PMD 671) and a SHURE head-mounted microphone were used for the recording of both groups. The subjects were asked to read the stimulus sentences where the target words were embedded in different carrier sentences. First, the subjects read the target words embedded in contextually related sentences. Immediately after that, the subjects read the same target words embedded in the contextually neutral sentences with two repetitions. Then, the speakers read the same target word in isolation with one repetition. The sampling rate of the recording was 22050 Hz and these recordings were analyzed using the speech analysis program Praat (version 5.4.03).

2.4.4. Measurements

Duration, intensity, F0, F1 and F2 values were measured for each vowel from the first and second syllable of the target words. The duration values were measured from the onset of F1 to the offset of the F2 of each syllable. When a nasal stop followed the vowel, the vowel duration was measured from the onset of F1 to the onset of the oral closure of the nasal stop, as marked by an abrupt change in the high frequencies. If segmentation of a sonorant from the vowel was not possible based on F1 and F2 from the spectrogram, the duration of the sonorant was included for both members of the minimal pair. When the second syllable ended in [i], we took vowel offset as the point where the stop closure of the carrier sentence began, since the target words always preceded the vowel [i] from the carrier sentence (e.g., [i. dan.ʌ.nin. **co:.ki.** im.ni.da.] ‘this word is flag’). When the second syllable of the target word ended in a mid or low vowel (e.g., [o, e, a]) (e.g., [i. dan.ʌ.nin. **sa:.gwa.** im.ni.da.] ‘this word is apology’), vowel duration was

measured from the point at which F1 started going down and F2 started going up, where the articulators started to move to produce the high front vowel [i] from the carrier sentence. Since some target words exhibited devoicing of high vowels between two voiceless consonants, these tokens were eliminated from the analysis. This applied to both members of the minimal pairs. For example, if the first-syllable stressed word, /'si:.caŋ/ 'market' underwent vowel devoicing, we also eliminated its second-syllable stressed counterpart, /si. 'caŋ/ 'hunger' from the analysis. A total of 102 tokens (47 from the older speakers' productions) were eliminated from the productions recorded at the sentence level, and 58 tokens (28 from older speakers' productions) were eliminated from the productions recorded in word-isolation.

The intensity values were averaged over each vowel. For F0, the F0 values from 20% to 80% of the duration of each vowel were averaged to avoid perturbation effects from the preceding consonant. F1 and F2 were measured across 25 ms at the midpoint of each vowel. Thus, a total of 3060 measurements (612 tokens x 5 measurements) were taken from the tokens produced in contextually neutral sentences, and 1495 measurements (299 tokens x 5 measurements) were taken from the tokens produced in word-isolation.

To control for differences across speakers in terms of duration, F0, and amplitude of the target syllable, second-to-first syllable ratios for the three suprasegmental measurements (i.e., F0, duration, and intensity) are also used, in addition to the raw values of each measurement, by using Beckman (1986)'s formulas.

$$\text{F0 ratios (in semitone)} = 17.31 \ln[\text{Hz}(S2)/\text{Hz}(S1)]$$

$$\text{Average intensity ratio} = \text{dB}(S2) - \text{dB}(S1)$$

$$\text{Log duration ratio} = \ln[\text{ms}(S2)/\text{ms}(S1)].$$

Thus, it is expected that first-syllable stressed words (e.g., [sa:gwa] ‘apology’) have a negative value of each ratio, and second-syllable stressed words will result in a positive value (e.g., [sagwa] ‘apple’).

2.4.5. Data analysis

For the statistical analysis, factorial repeated measures ANOVAs were conducted to analyze the acoustic parameters. For the suprasegmental cues (intensity, duration, and F0), mean values of each measurement were entered as dependent variable. Stress (first syllable vs. second syllable) and Syllable (first vs. second) were entered as within-subjects independent variables, and Group (older vs. younger) was entered as a between-subjects independent variable. For second-to-first-syllable ratios, Stress (first syllable vs. second syllable) and Group (older vs. younger) were entered as independent variables. For F1 and F2 values, repeated measures ANOVAs on F1 values of the first and second syllable were separately conducted with Stress (first syllable vs. second syllable), Vowel Height (high vs. mid vs. low), and Group (older vs. younger) as independent variables. ANOVAs on F2 values of the first and second syllable were separately conducted with Stress (first syllable vs. second syllable), Vowel Frontness (front vs. central vs. back), and Group (older vs. younger) as independent variables.

When comparing the production contexts (sentence level vs. Isolation), we conducted factorial repeated measures ANOVAs for each of the three suprasegmental second-to-first syllable ratios as the dependent variable, and Stress (first syllable vs. second syllable), Context (sentence vs. isolation), and Group (older vs. younger) as independent variables.

2.5. Results

2.5.1. Results of tokens produced in sentences

2.5.1.1. Duration

Repeated measures three-way ANOVAs found main effects of Stress [$F(1, 19) = 6.212, p < .01$], Syllable [$F(1, 19) = 16.04, p < .01$], and Group [$F(1, 19) = 23.88, p < .01$] for Duration. The main effect of Stress indicates that the average duration of both syllables was greater for first-syllable stressed words (96 ms) than second-syllable stressed words (92 ms). In addition, the second syllables were longer (102 ms) than the first syllables (86 ms), and the older speakers produced a statistically longer average duration of both syllables (107 ms) than younger speakers (81 ms). There was also a significant interaction between Stress and Syllable [$F(1, 19) = 27.01, p < .01$], indicating that the duration difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = 8$ ms) than second-syllable stressed words ($S2 - S1 = 23$ ms). We also found a statistically significant three-way interaction among Stress, Syllable, and Group [$F(1, 19) = 11.24, p < .01$], indicating that while younger speakers always produced the second syllable longer than the first syllable, older speakers produced a second syllable longer than the first syllable only for the second-syllable stressed words.

In order to further examine the three-way interaction, we stratified the data for each group, and ran two-way ANOVAs independently for each group's data with Syllable and Stress as independent variables. The analysis of the older speakers' productions found a two-way interaction between Stress and Syllable, [$F(1, 9) = 20.464, p < .01$], indicating that the duration difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = -2$ ms) than second-syllable stressed words ($S2 - S1 = 22$ ms). The analysis of the younger speakers' productions only found a main effect of Syllable [$F(1, 10) = 35.42, p < .01$], indicating that younger speakers produced longer second syllables (91 ms) than first syllables (71 ms).

Figure 6 illustrates the duration values of the first and second syllables of Korean minimal pairs between older and younger speakers.

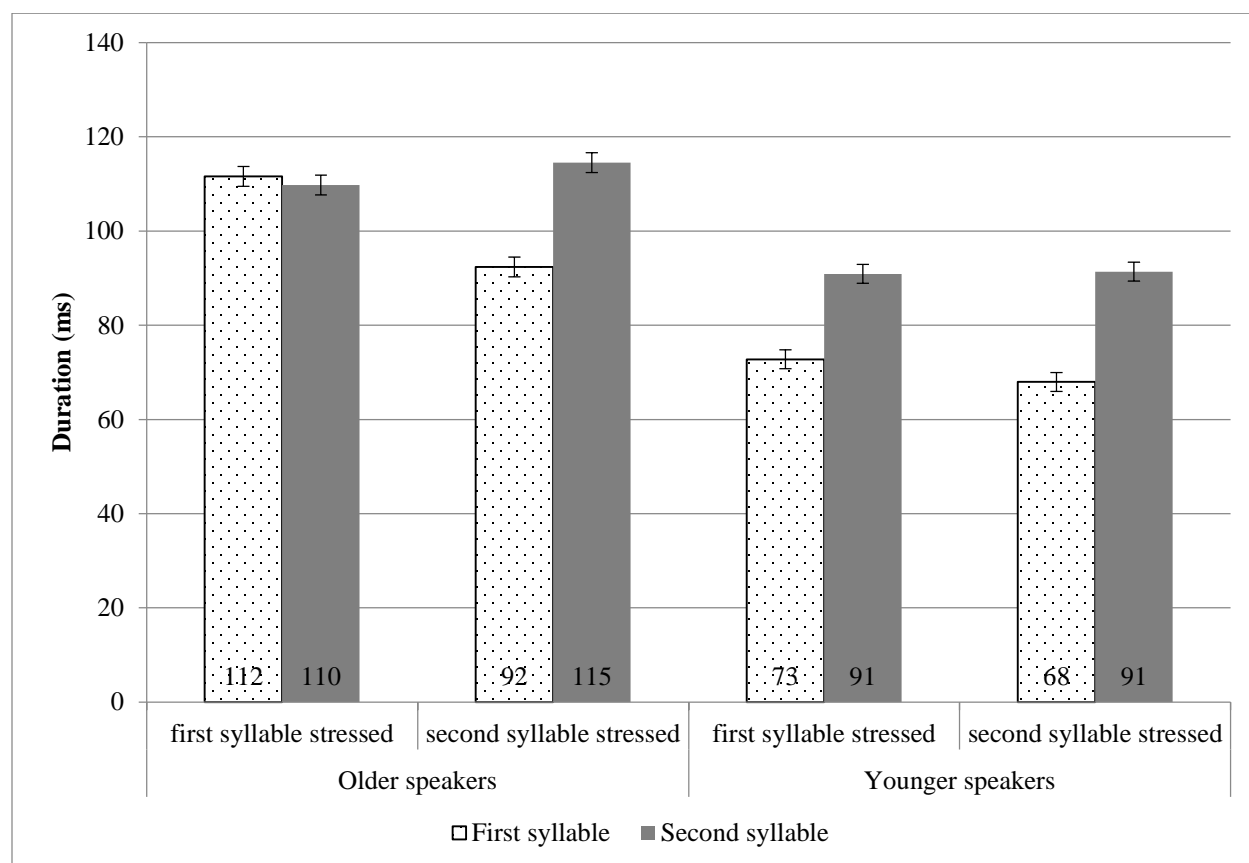


Figure 6. Duration of first and second syllable of Korean stress pairs produced in sentences between older and younger speakers.

With respect to the second-to-first syllable duration ratios, repeated measures 2 x 2 ANOVAs found a significant main effect of Stress [$F(1, 19) = 27.54, p < .01$]. The first-syllable stressed words were produced with smaller second-to-first duration ratio (0.11) than the second syllable stressed words (0.27). We also found a significant interaction between Stress and Group [$F(1, 19) = 7.64, p < .001$], indicating that the duration ratio difference between the stress pairs was greater for the older speakers than the younger speakers.

In order to further examine the two-way interaction, we stratified the data for each group, and ran one-way ANOVAs independently for each group's data with Stress as the independent

variable. A main effect of Stress was found for both older [$F(1, 9) = 20.99, p < .01$] and younger speakers' productions [$F(1, 10) = 5.53, p = .05$]. Figure 7 illustrates second-to-first syllable duration ratios of the Korean stress pairs produced at the sentence level.

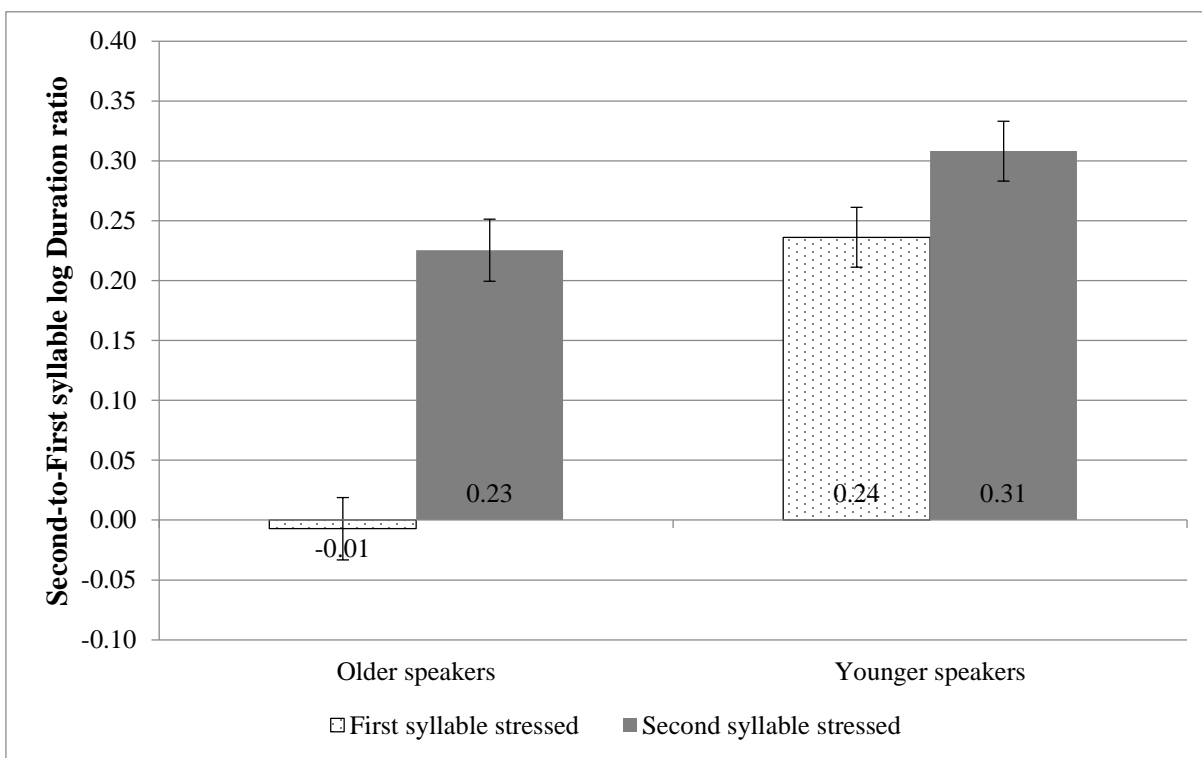


Figure 7. Second-to-first syllable log duration ratio for Korean stress pairs produced in sentences between older and younger speakers.

2.5.1.2. Intensity

Regarding Intensity, repeated measures three-way ANOVAs found main effects of Syllable [$F(1, 19) = 47.52, p < .01$] and Group [$F(1, 19) = 14.72, p < .01$]. The main effect of Syllable indicates that the intensity of the first syllable is lower (64.25 dB) than that of the second syllable (66.27 dB), and the main effect of Group indicates that older speakers produced Korean stress minimal pairs with lower intensity values (61.84 dB) than younger Korean speakers (68.68 dB). There was also a significant interaction between Stress and Syllable [$F(1, 19) = 17.20, p < .01$], indicating that the first-syllable stressed words have a smaller intensity

difference between the first and second syllable ($S2 - S1 = 1.67$ dB) than the second-syllable stressed words ($S2 - S1 = 2.37$ dB). Also, the significant interaction between Syllable and Group [$F(1, 19) = 7.58, p < .01$] indicates that the intensity difference between the first and second syllable was greater for the younger speakers ($S2$ stressed words – $S1$ stressed words = 2.83 dB) than the older speakers ($S2$ stressed words – $S1$ stressed words = 1.21 dB). We also found a significant three-way interaction among Stress, Syllable, and Group [$F(1, 19) = 4.74, p = .01$], indicating that the intensity difference between the first and second syllable as a function of stress pattern was greater for younger speakers than older speakers.

In order to further examine the three-way interaction, we stratified the data for each group, and ran two-way ANOVAs independently for each group with Syllable and Stress as independent variables. The analysis of the older speakers' productions found a main effect of Syllable [$F(1, 9) = 17.45, p = .02$], indicating that the first syllable was produced with a lower intensity value (61.23 dB) than the second syllable (62.44 dB). Also, we found a two-way interaction between Stress and Syllable, [$F(1, 9) = 17.45, p < .01$], indicating that the intensity difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = 0.66$ dB) than second-syllable stressed words ($S2 - S1 = 1.75$ dB). The analysis of the younger speakers' productions only found a main effect of Syllable [$F(1, 10) = 81.82, p < .01$], indicating that younger speakers produced the second syllable with higher intensity values (70.1 dB) than the first syllable (67.26 dB). Figure 8 illustrates the intensity values of the first and second syllables of Korean minimal pairs between older and younger speakers.

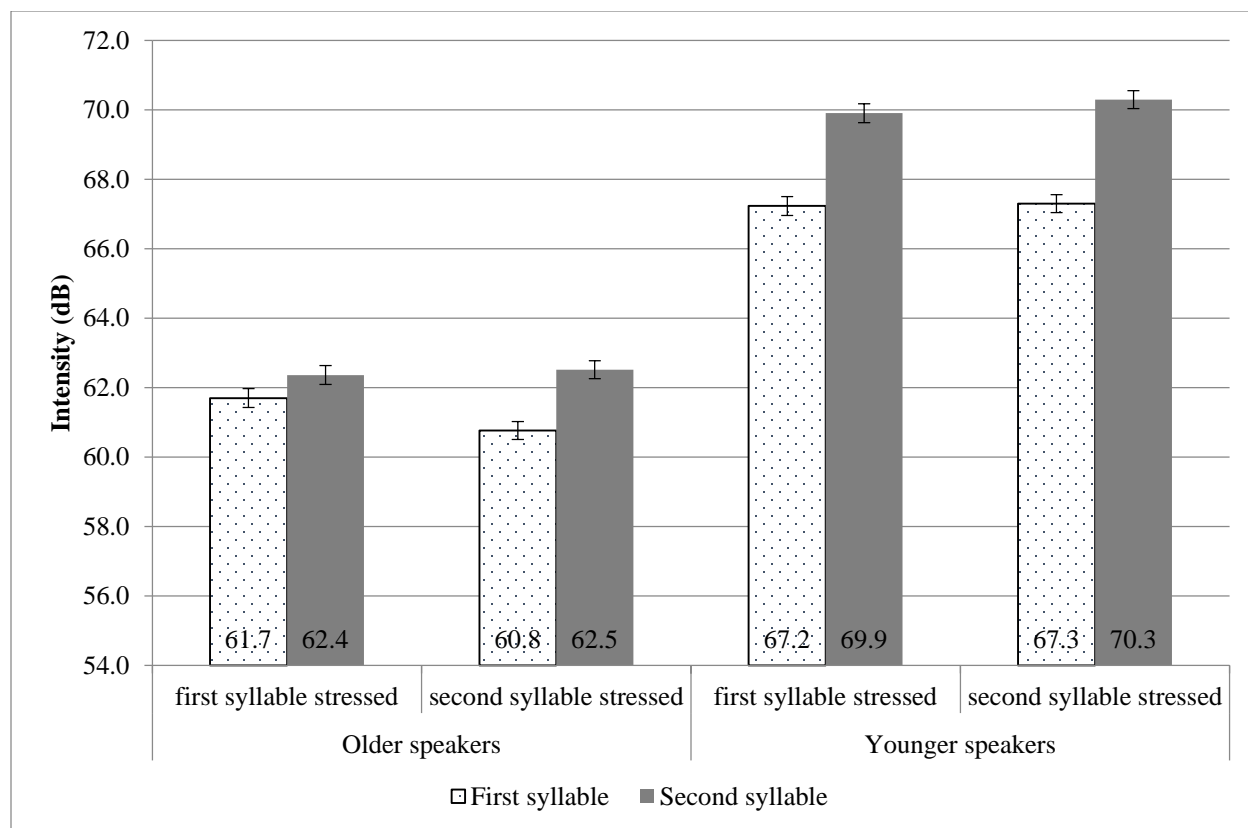


Figure 8. Intensity of first and second syllable of Korean stress pairs produced in sentence between older and younger speakers.

With respect to the second-to-first syllable intensity ratio, repeated measures 2 x 2 ANOVAs found significant main effects of Stress [$F(1, 19) = 17.20, p < .01$] and Group [$F(1, 19) = 7.58, p < .01$]. The first-syllable stressed words were produced with smaller second-to-first syllable intensity ratios (1.67) than the second-syllable stressed words (2.37), and duration ratios were smaller for older speakers (1.21) than younger speakers (2.83). We also found a significant interaction between Stress and Group [$F(1, 19) = 4.74, p = .001$], indicating that the intensity ratio difference between first-syllable stressed words and second-syllable stressed words was greater for the older speakers than the younger speakers.

In order to further examine the two-way interaction, we stratified the data for each group, and ran one-way ANOVAs independently for each group's data with Stress as the independent variable. A main effect of Stress was found only for older speakers' productions [$F(1, 9) =$

17.454, $p < .01$]. Figure 9 illustrates the second-to-first syllable intensity ratio of Korean stress pairs by older and younger speakers.

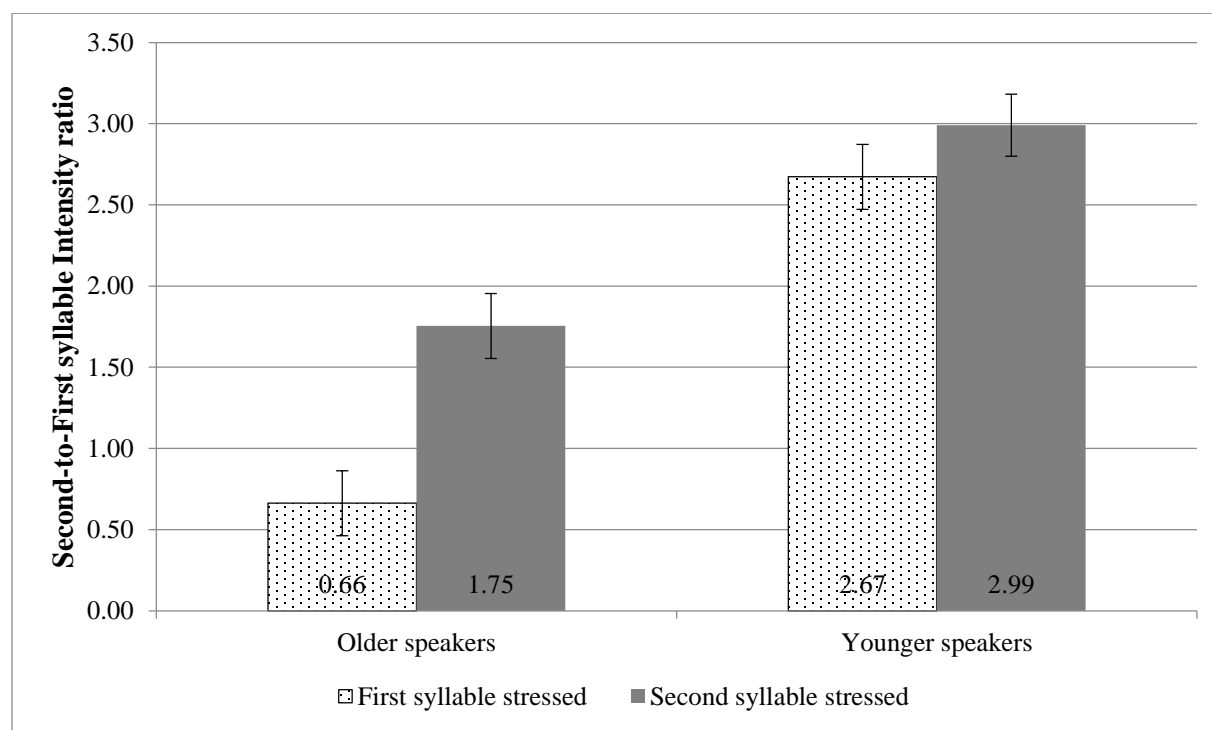


Figure 9. Second-to-first syllable intensity ratio of Korean stress pairs produced in sentence between older and younger speakers.

2.5.1.3. F0 values

With respect to F0, repeated measures ANOVAs found a significant main effect of Syllable [$F(1, 19) = 13.49, p < .01$], indicating that the first syllable was produced with a lower F0 (123 Hz) than the second syllable (129 Hz). We also found a significant interaction between Syllable and Group [$F(1, 19) = 4.88, p < .01$], indicating that the younger speakers produced the second syllable with significantly higher F0 values (134 Hz) than the first syllable (124 Hz) as compared to the older speakers (first syllable: 122 Hz, second syllable: 125 Hz). Figure 10 illustrates the F0 values of first and second syllable of Korean minimal pairs between older and younger speakers.

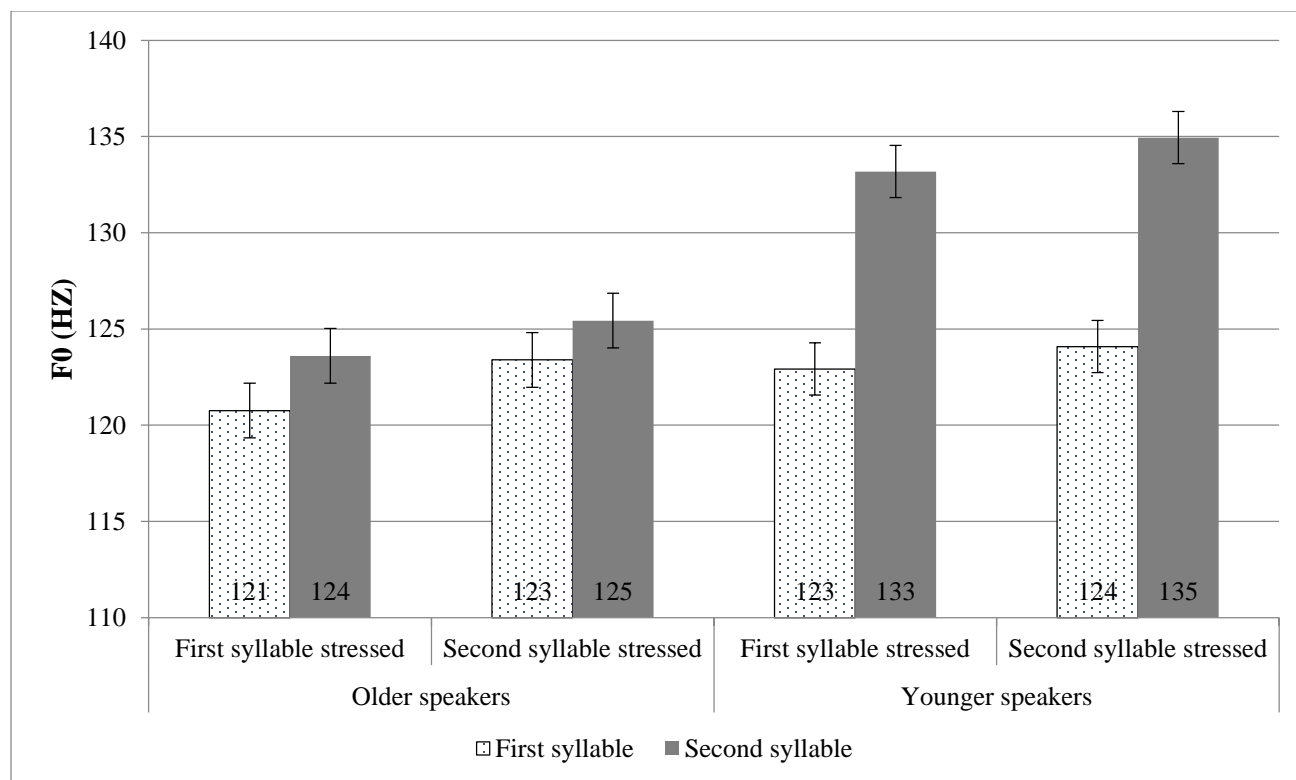


Figure 10. F0 values of first and second syllable of Korean stress pairs produced in sentence between older and younger speakers.

With respect to the second-to-first syllable F0 ratio, 2 x 2 repeated measures ANOVAs found a significant main effect of Group [$F(1, 19) = 4.48, p < .01$] only, indicating that the younger group produced target words with a greater F0 ratio (1.60) than the older speakers (0.33). Figure 11 illustrates the second-to-first syllable F0 log ratio of Korean stress pairs by older and younger speakers.

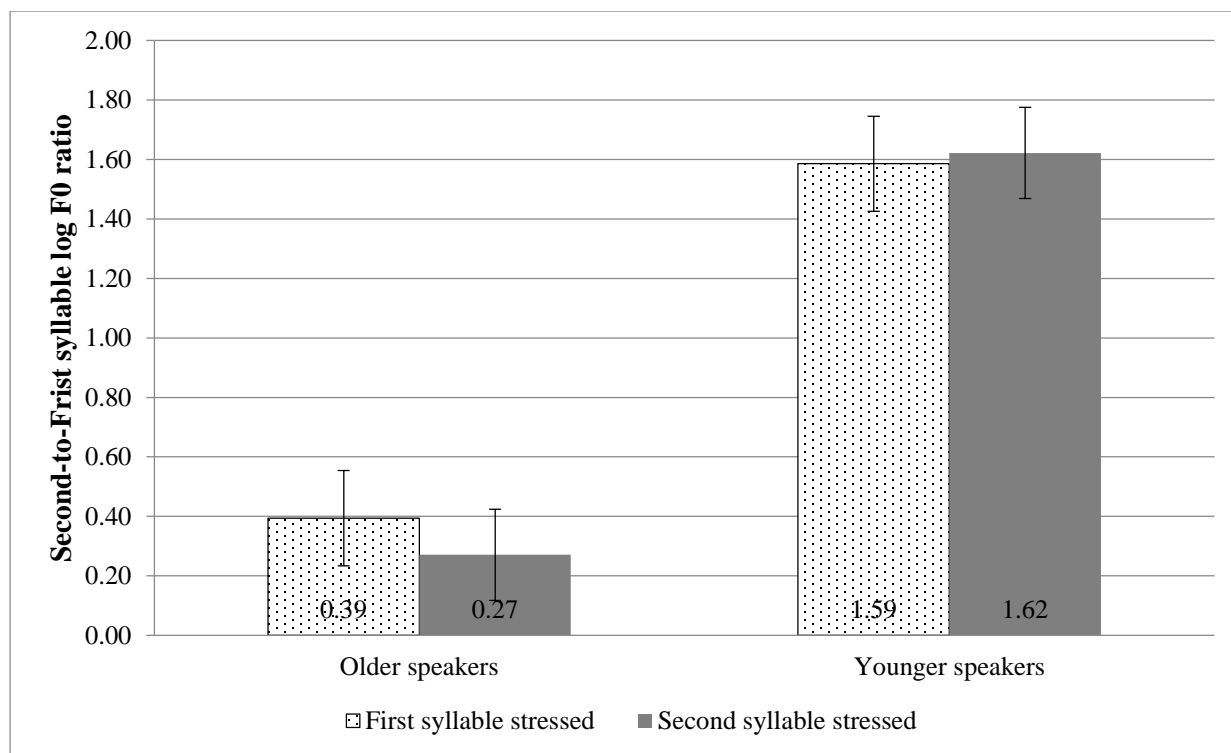


Figure 11. Second-to-first syllable F0 ratio for Korean stress pairs produced in sentences between older and younger speakers.

2.5.1.4. F1 and F2 values

In order to examine vowel reduction by stress location, repeated measures ANOVAs were conducted separately for F1 values and F2 values of first syllable and second syllable. For F1 values, Vowel Height (high vs. mid vs. low) was also considered as one of the independent factors, since vowel height is inversely correlated with F1 values: the higher the vowel, the lower the F1 value. Thus, repeated measures three-way ANOVAs were conducted with Stress (first, second), Group (younger, older), and Vowel Height (high vs. mid vs. low) as independent variables. For the F1 values of the first syllable, we found statistically significant main effects of Vowel Height [$F(2, 18) = 33.31, p < .001$] and Group [$F(1, 17) = 6.09, p = .025$]. These results indicate the F1 values decreased as vowel height increased (high: 453 Hz, mid: 514 Hz, low: 653 Hz), and also that the F1 values produced by the older Korean speakers were lower (520 Hz) than those of the younger Korean speakers (579 Hz). Tukey post hoc comparisons reported that

F1 values of high vowels in the first syllable were significantly different from those of low vowels, and F1 values of mid vowels were significantly different from those of high and low vowels at $p < .005$.

For the F1 values of the second syllable, main effects of Vowel Height [$F(2, 18) = 414.79, p < .001$] and Group [$F(1, 19) = 12.95, p = .002$] were found. These results also indicate that the F1 values decreased as vowel height increased (high: 317 Hz, mid: 427 Hz, low: 563 Hz), and also the F1 values from the productions of older Korean speakers were lower (425 Hz) than those of younger Korean speakers (476 Hz). Tukey post hoc comparisons reported that F1 values of high vowels in the second syllable were significantly different from those of mid and low vowels, and F1 values of mid vowels were also significantly different from those of low vowels at $p < .005$.

For F2 values, Vowel Frontness (front vs. back) was considered as one of the independent factors as well, since F2 values correspond to the frontness of the vowel: the more fronted the vowel, the higher its F2 value. Thus, we conducted repeated measures three-way ANOVAs with Stress (first, second), Group (younger, older), and Vowel Frontness (front vs. central vs. back) as independent variables. We found a significant main effect of Frontness on the F2 values of the first syllable [$F(2, 12) = 104.70, p < .001$], indicating that the F2 values decreased as a function of vowel frontness in the first syllable (front: 2095 Hz, back: 1277 Hz).

For F2 values in the second syllable, we found a main effect of Frontness [$F(2, 18) = 201.60, p < .001$], indicating that F2 values decreased as a function of Vowel Frontness as well (front: 2138 Hz, central: 1243 Hz, back: 1390 Hz). Tukey post hoc comparisons reported that F2 values of front vowels in the second syllable were significantly different from those of central

and back vowels, and the F2 values of mid vowels were significantly different from those of back vowels at $p < .005$.

Taken together, the results of F1 and F2 in the first and second syllable suggest that there is no vowel reduction in Korean stress pairs, based on the absence of two-way interactions between Stress and Vowel Height for F1 or Stress and Vowel Frontness for F2 for both first (F1 values: $[F(2, 16) = 1.57, p = .24]$; F2 values: $[F(1, 12) = .014, p = .91]$) and second syllables (F1 values: $[F(2, 18) = 0.24, p = .79]$; F2 values: $[F(2, 18) = 1.04, p = .37]$). The absence of any three-way interactions among Stress, Vowel Height, and Group for F1 and F2 for first (F1 values: $[F(2, 16) = 1.92, p = .18]$; F2 values: $[F(1, 12) = .007, p = .93]$) and second syllables (F1 values: $[F(2, 18) = .69, p = .52]$; F2 values: $[F(2, 18) = 1.62, p = .23]$) also supports the lack of vowel reduction in Korean. Figure 12 represents the vowel distribution of the first syllable from the two different stress conditions (e.g., first-syllable stressed vs. second-syllable stressed) produced at the sentence level by two speaker groups.

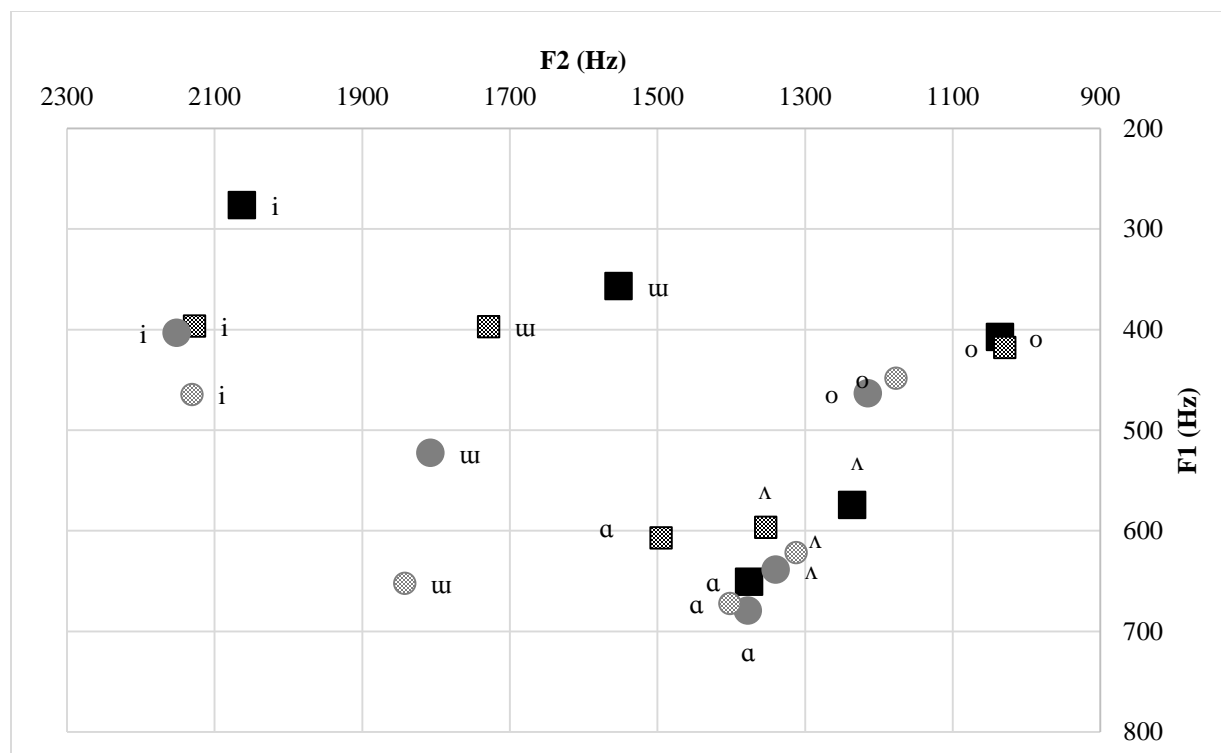


Figure 12. Scatterplot of vowel productions of the first syllable produced in sentences. Black squares represent productions by older Korean speakers, and gray dots represent productions by younger Korean speakers. Solid colors represent productions of the stressed syllables (e.g., first-syllable stressed words) and the patterned colors represent productions of the unstressed syllables (e.g., second-syllable stressed words).

Figure 13 represents the vowel distribution of the second syllable from the two different stressed conditions (e.g., first-syllable stressed vs. second-syllable stressed) produced at the sentence level by two speaker groups.

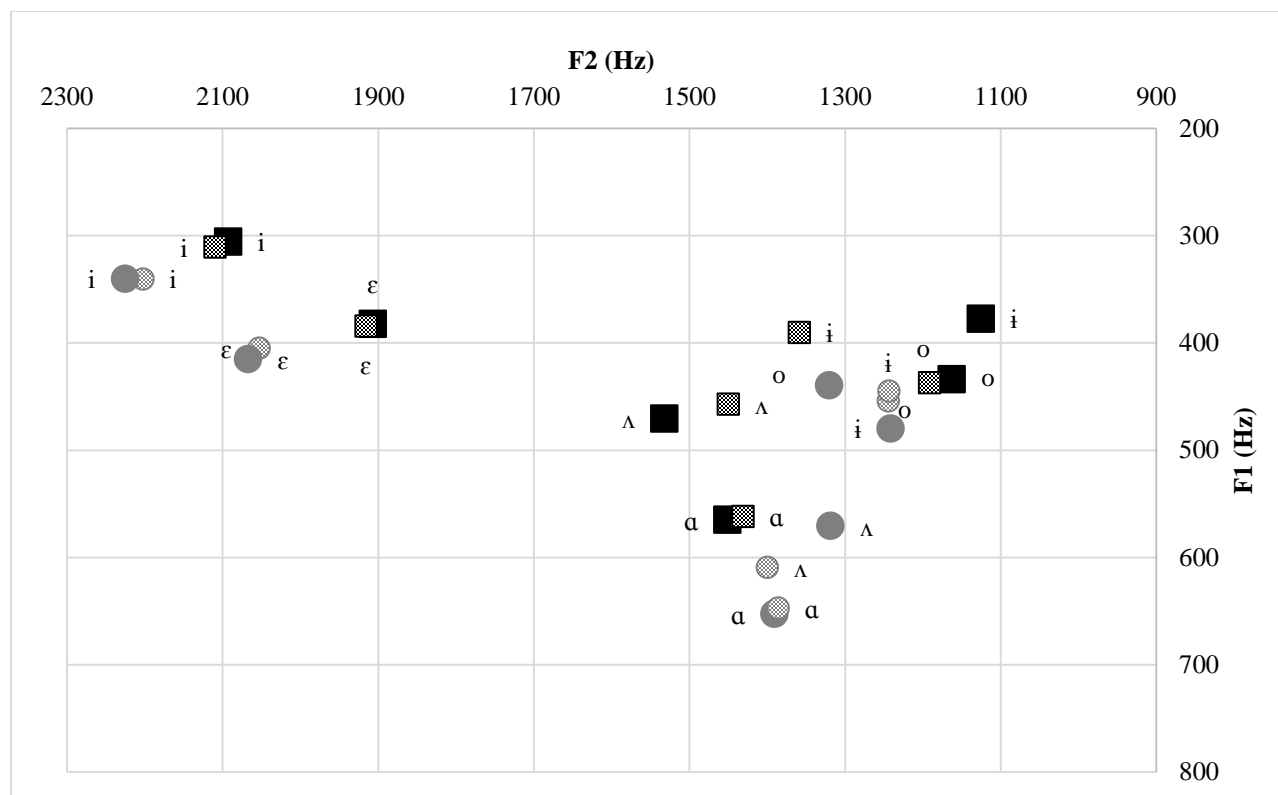


Figure 13. Scatterplot of vowel productions of the second syllable produced in sentences. Black squares represent productions by older Korean speakers, and gray dots represent productions by younger Korean speakers. Solid colors represent productions of the stressed syllables (e.g., second-syllable stressed words) and the patterned colors represent productions of the unstressed syllables (e.g., first-syllable stressed words).

2.5.2. Results of tokens produced in word-isolation

In order to investigate how phrase-final effects influence production of Korean stress word pairs, we also examined 5 acoustic measurements of the same words produced in isolation. Similarly to previous analyses, we conducted repeated measures three-way ANOVAs with Stress (first, second), Syllable (first, second), and Group (younger, older) as independent variables while having the raw values of intensity, duration, F0, F1, and F2 values as dependent variables. Repeated measures two-way ANOVAs with Stress (first, second) and Group (younger, older) as independent variables and ratios of duration, intensity, and F0 ratios as dependent variables were also conducted. Results of raw values and ratios of each measurement will be reported as follows.

2.5.2.1. Duration

Two by two by two factorial repeated measures ANOVAs found main effects of Stress [$F(1, 19) = 6.05, p < .001$], Syllable [$F(1, 19) = 41.72, p < .001$], and Group [$F(1, 19) = 13.21, p < .001$]. These results indicate that the first-syllable stressed words were produced with a longer mean syllable duration (110 ms) than the second-syllable stressed words (104 ms), and both groups of speakers produced the second syllable with longer duration (124 ms) than the first syllable (91 ms). Also, the older speakers produced both syllables with longer duration (128 ms) than the younger speakers (87 ms). Figure 14 illustrates the duration values of first and second syllables produced in isolation of Korean minimal pairs between older and younger speakers.

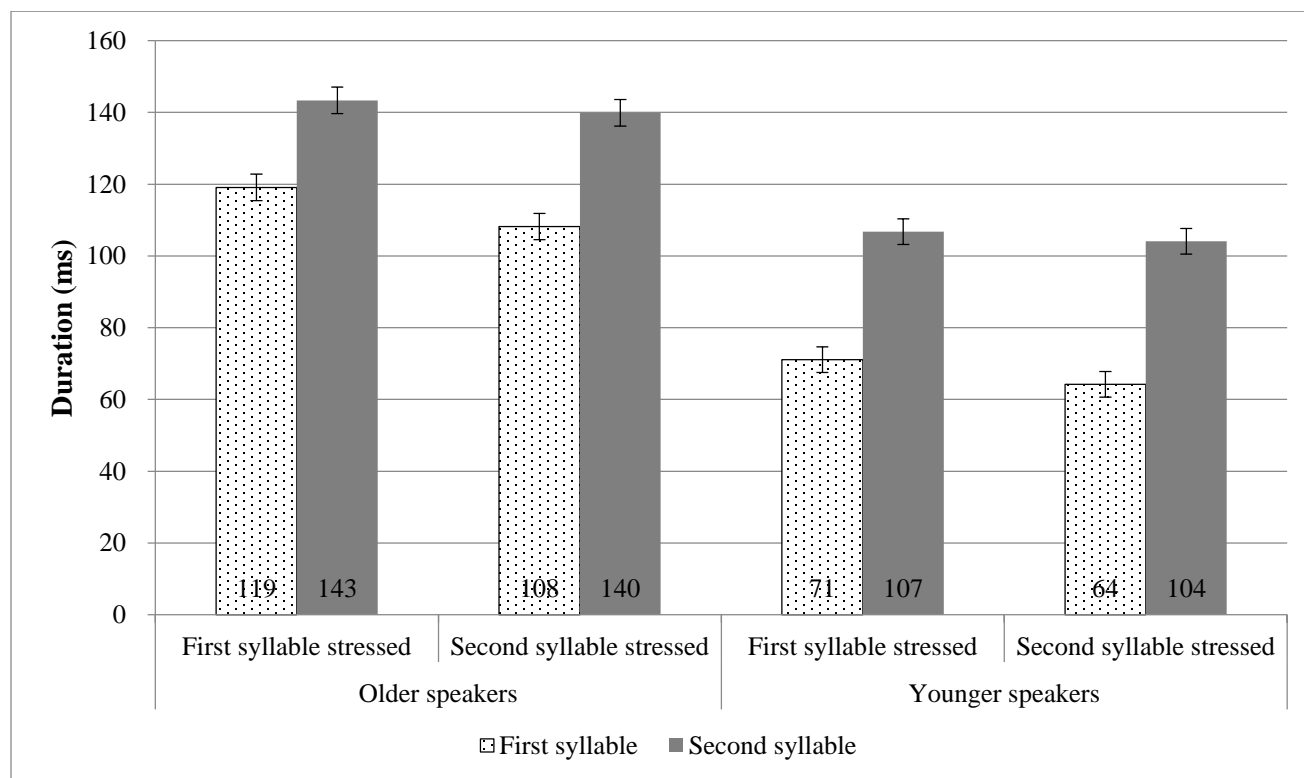


Figure 14. Duration of first and second syllable of Korean stress pairs produced in word-isolation between older and younger speakers.

When conducting 2 by 2 repeated measures ANOVAs on second-to-first syllable duration ratios, we found no significant main effects or interactions. Figure 15 illustrates second-to-first syllable log duration ratios of the Korean stress pairs produced in isolation.

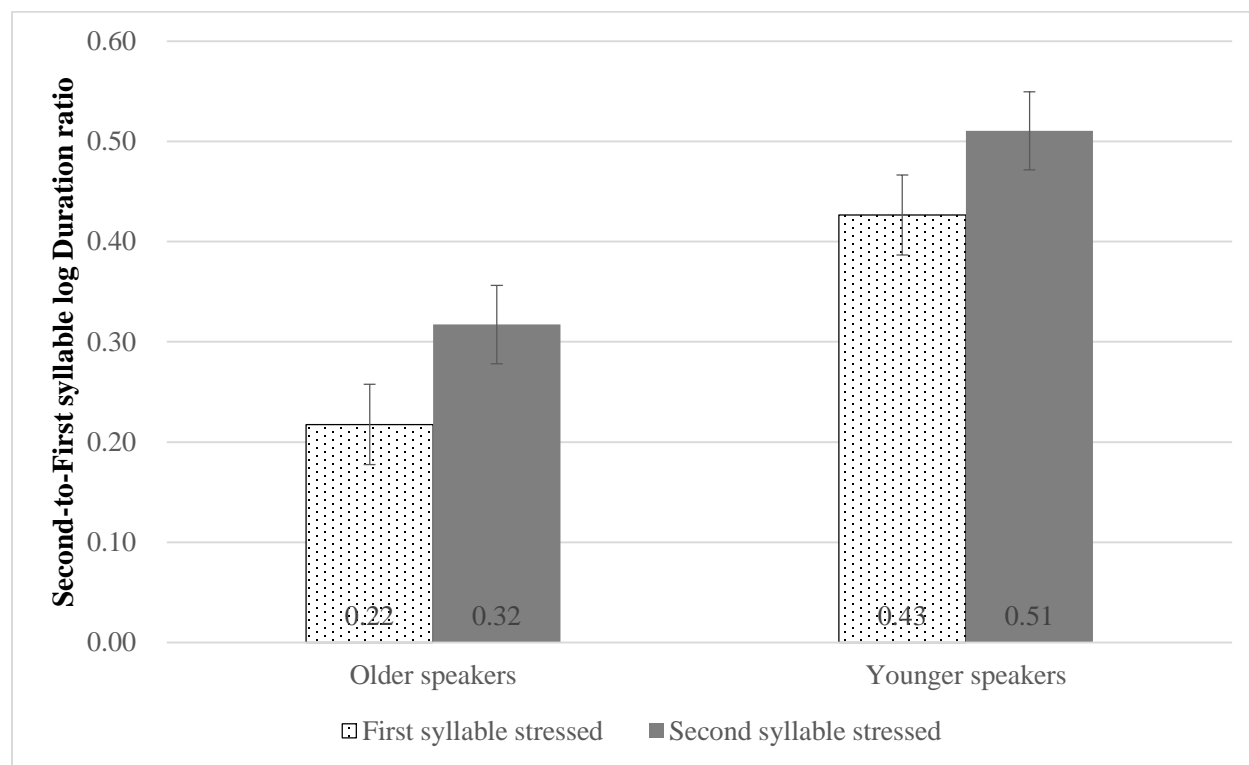


Figure 15. Second-to-first syllable log duration ratio of Korean stress pairs produced in word-isolation between older and younger speaker.

2.5.2.2. Intensity

Two by two by two repeated measures ANOVAs found a main effect of Syllable [$F(1, 19) = 9.19, p < .001$] and Group [$F(1, 19) = 14.14, p < .001$], indicating that the first syllable was produced with greater intensity (63 dB) than the second syllable (61 dB), and younger speakers produced Korean minimal pairs with greater intensity values (59 dB) than older speakers (54 dB). Figure 16 illustrates the intensity values of the first and second syllable produced in isolation of Korean minimal pairs between older and younger speakers.

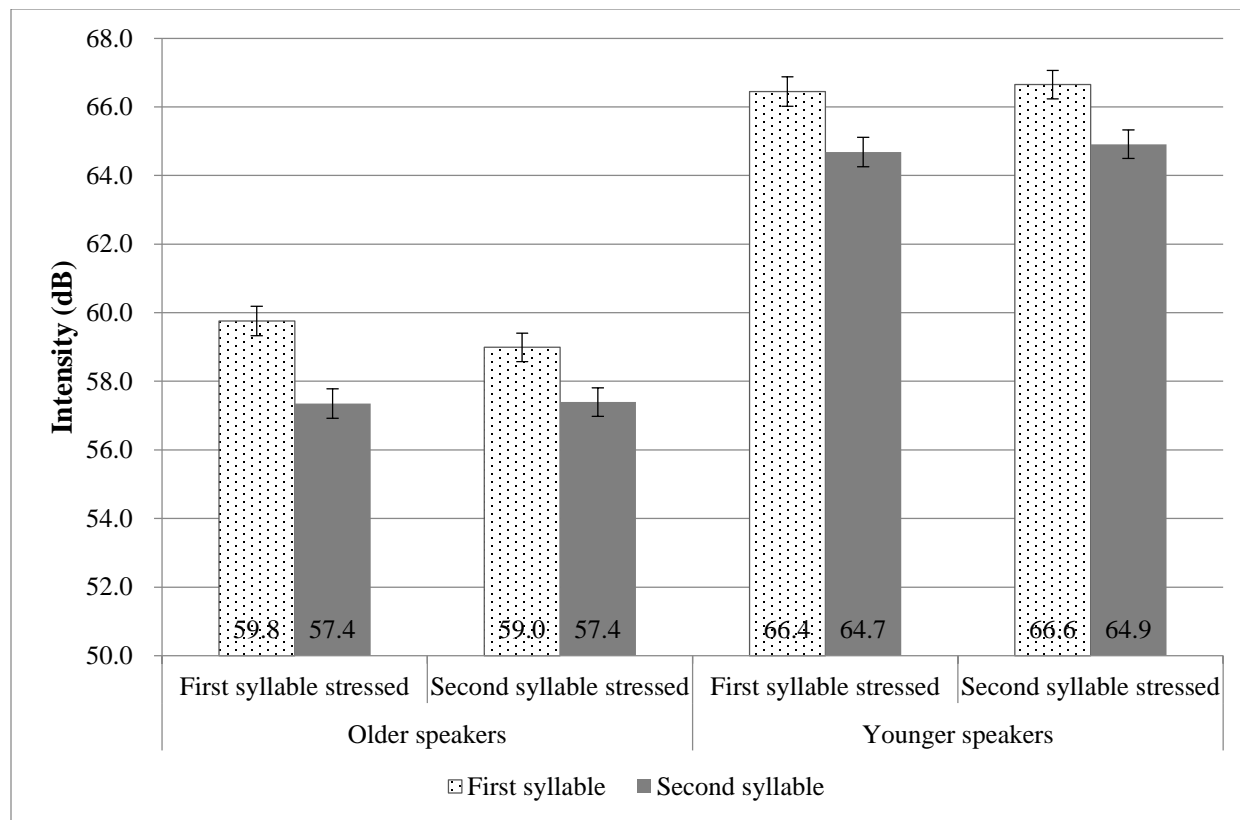


Figure 16. Intensity of first and second syllable of Korean stress pairs produced in word-isolation between older and younger speakers.

When conducting 2 by 2 repeated measures ANOVAs on second-to-first syllable intensity ratios, no significant main effects nor interactions were found. Figure 17 illustrates second-to-first syllable intensity ratios of the Korean stress pairs produced in isolation between the two speaker groups.

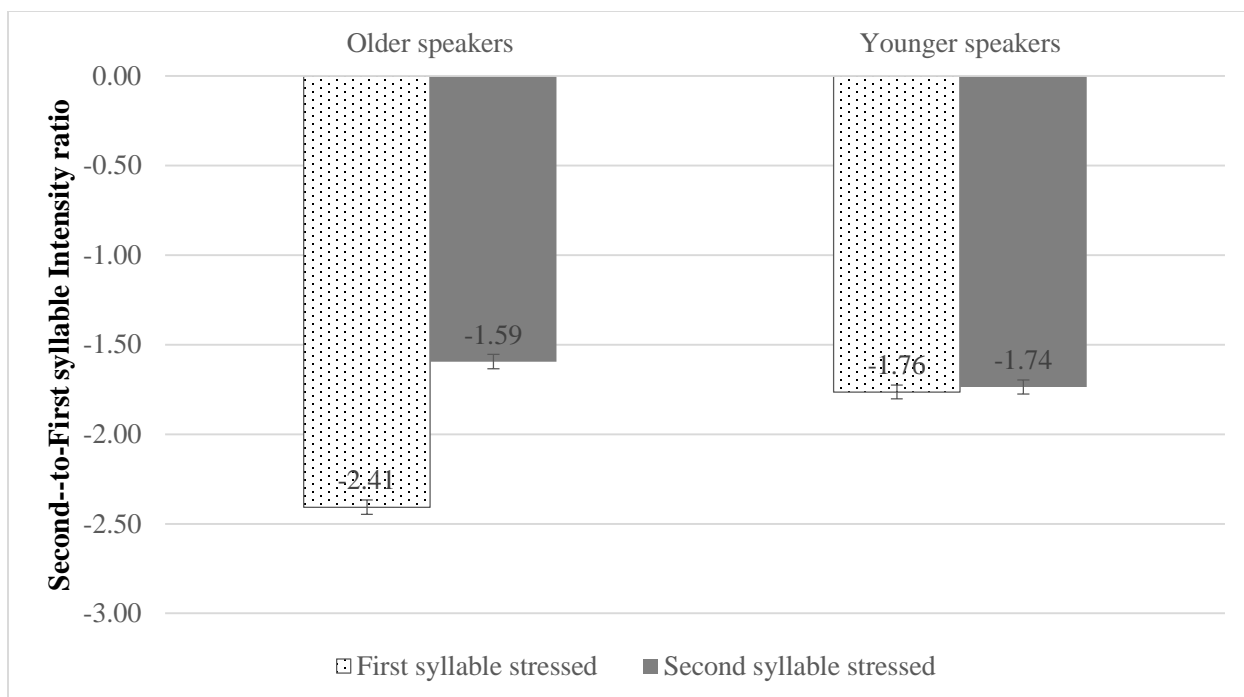


Figure 17. Second-to-first syllable intensity ratio of Korean stress pairs produced in word-isolation between older and younger speakers.

2.5.2.3. F0 values

With respect to F0, repeated measures ANOVAs found a significant main effect of Syllable [$F(1, 19) = 58.67, p < .01$] only, indicating that the first syllable was produced with higher F0 values (116 Hz) than the second syllable (102 Hz) by both groups. Figure 18 illustrates the F0 values of first and second syllable of Korean minimal pairs produced in isolation between older and younger speakers.

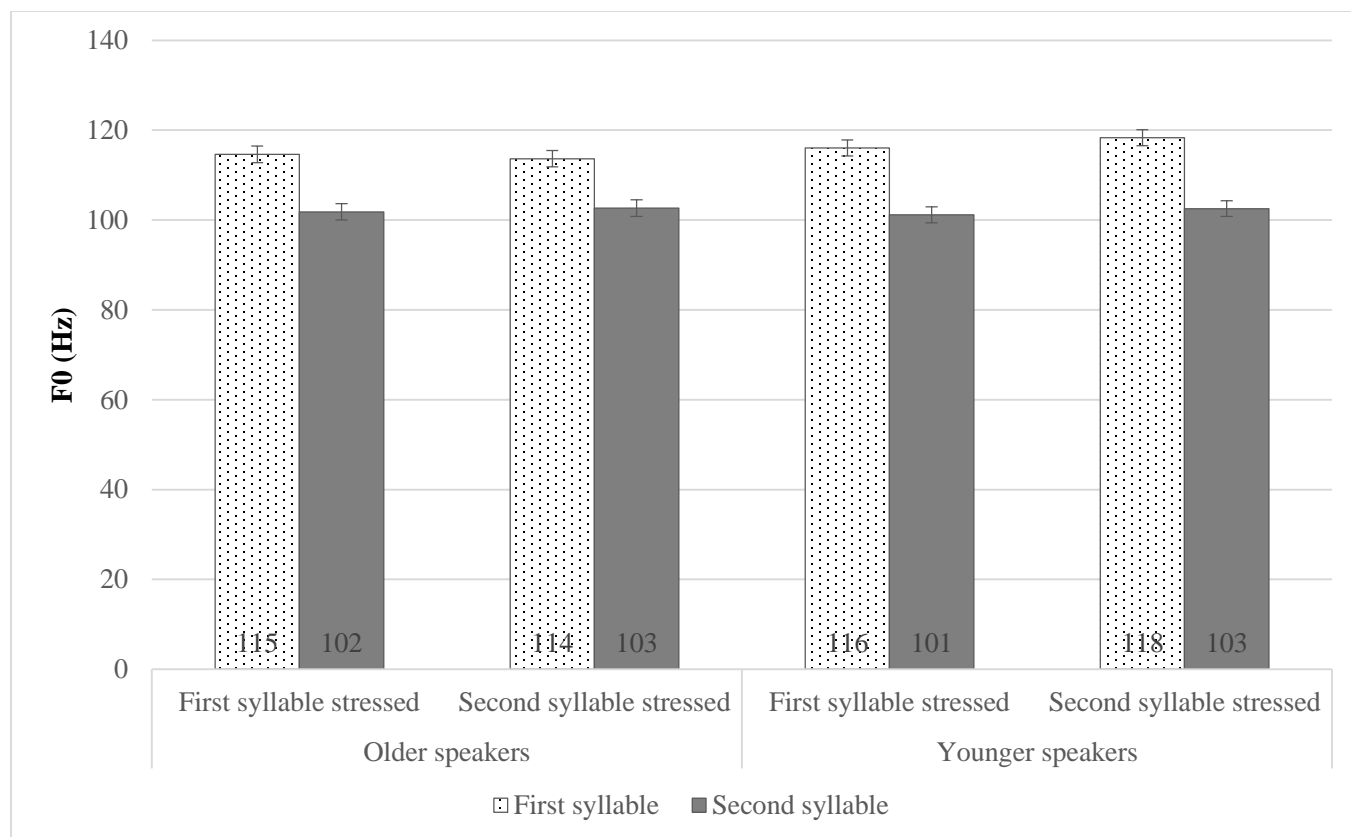


Figure 18. F0 values of first and second syllable of Korean stress pairs produced in word-isolation between older and younger speakers.

With respect to the second-to-first syllable F0 ratio, neither significant main effects nor interactions were found. Figure 19 represents second-to-first syllable F0 ratio difference between two groups.

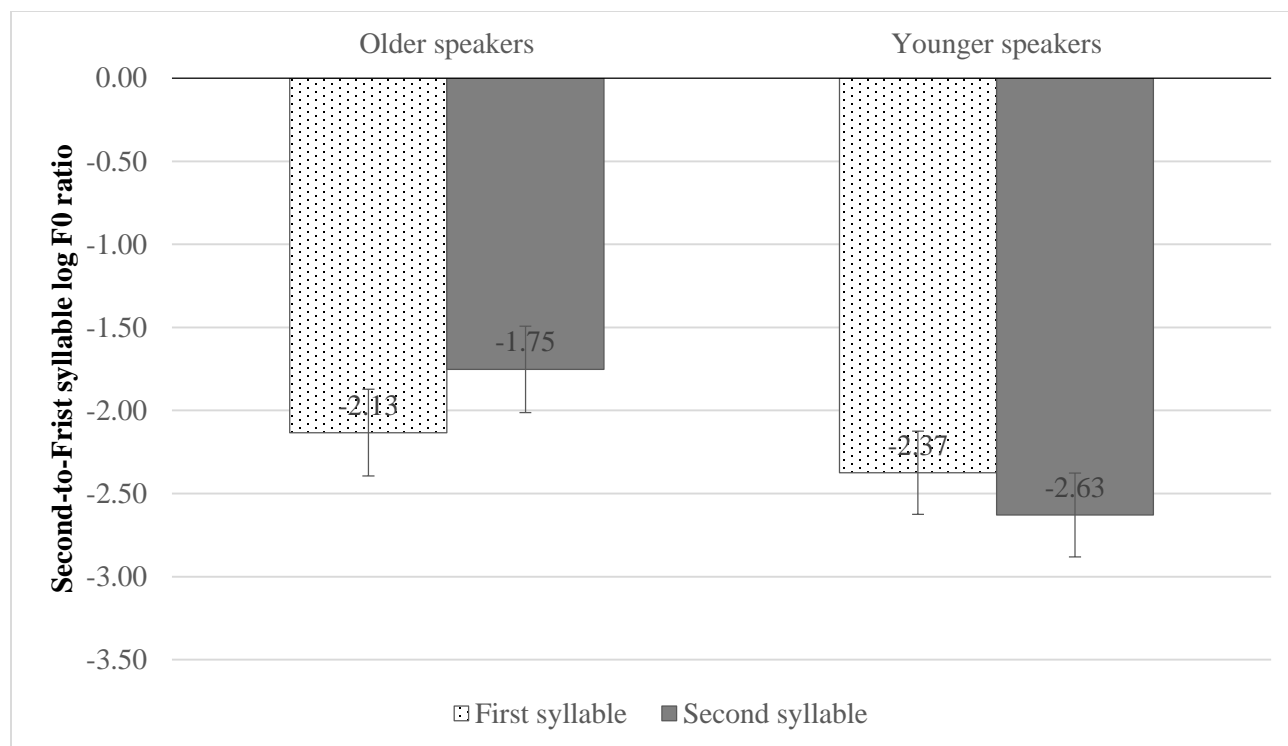


Figure 19. Second-to-first syllable F0 ratio of Korean stress pairs produced in word-isolation between older and younger speakers.

2.5.2.4. F1 and F2 values

In order to examine vowel reduction by stress location, repeated measures ANOVAs were conducted separately for F1 values and F2 values of first syllable and second syllable. For F1 values, three-way repeated measures ANOVAs were conducted with Stress (first, second), Vowel Height (high vs. mid vs. low), and Group (younger, older) as independent variables. For the F1 values of the first syllable, we found a statistically significant main effect of Vowel Height [$F(2, 18) = 33.31, p < .001$], indicating that the F1 values decreased as vowel height increased (high: 509 Hz, mid: 506 Hz, low: 645 Hz). Tukey post hoc comparisons also reported that F1 values of high vowels in the first syllable were significantly different from those of low vowels, and also F1 values of mid vowels were significantly different from those of low vowels at $p < .005$.

For the F1 values of the second syllable, we also found a significant main effect of Vowel Height [$F(2, 18) = 190.79, p < .001$], indicating that F1 values decreased as Vowel Height increased (high: 348 Hz, mid: 543 Hz, low: 703 Hz). Tukey post hoc comparisons also reported that F1 values of high vowels in the first syllable were significantly different from those of mid and low vowels, and also F1 values of mid vowels were significantly different from those of low vowels at $p < .005$.

For F2 values, we conducted three-way repeated measures ANOVAs with Stress (first, second), Vowel Frontness (front vs. central vs. back), and Group (younger, older) as independent variables. We found a significant main effect of Frontness on the F2 values in the first syllable [$F(2, 12) = 68.90, p < .001$] only, indicating that the F2 values decreased as a function of Vowel Frontness on the first syllable (front: 2148 Hz, back: 1331 Hz).

For F2 values on the second syllable, we found a main effect of Frontness [$F(2, 18) = 163.80, p < .001$], indicating that the F2 values decreased as a function of Vowel Frontness in the second syllable (front: 2099 Hz, central: 1213 Hz, back: 1358 Hz). Tukey post hoc comparisons reported that F2 values of front vowels in the first syllable were significantly different from those of central and back vowels, and F2 values of central vowels were also significantly different from those of back vowels at $p < .005$.

Figure 20 represents the vowel distribution of the first syllable of the two different stress conditions (e.g., first-syllable stressed vs. second-syllable stressed) produced in word-isolation by the two speaker groups.

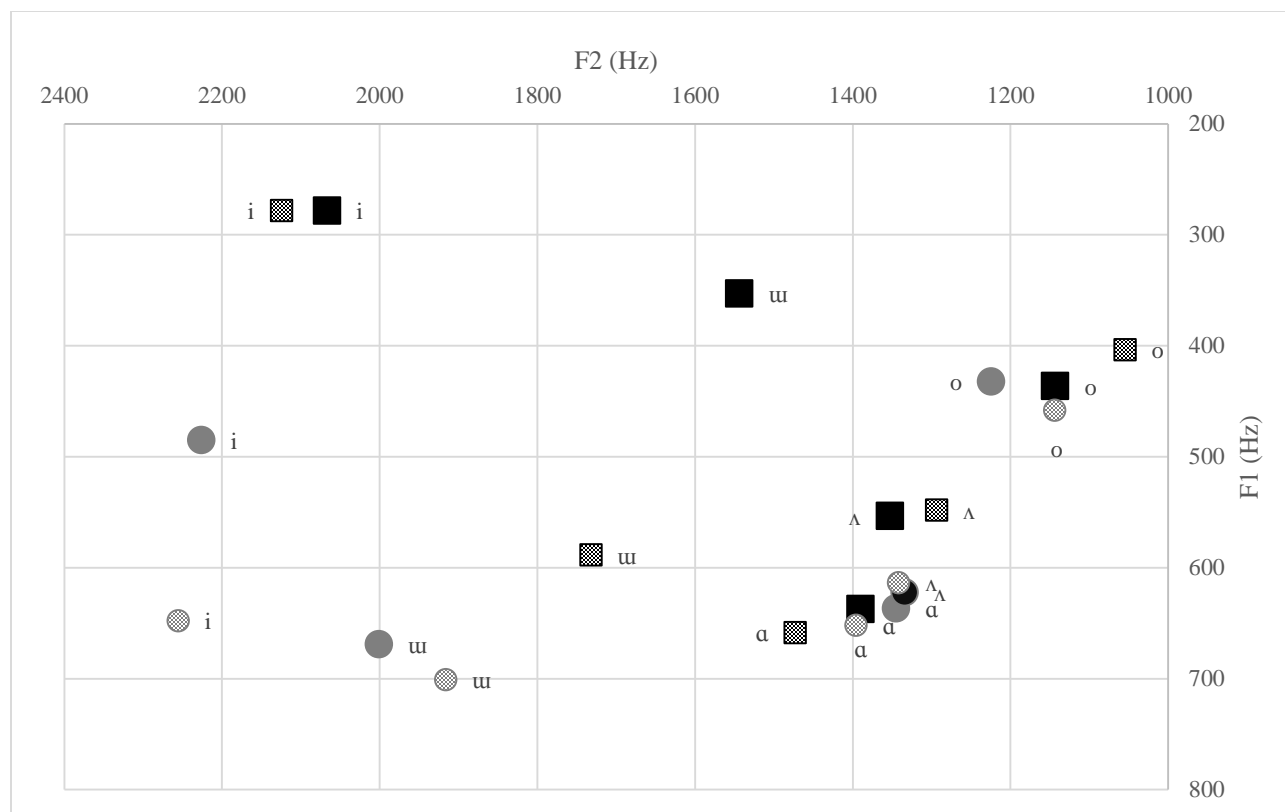


Figure 20. Scatterplot of vowel productions of the first syllable in isolated words. Black squares represent productions by old Korean speakers, and gray dots represent productions by younger Korean speakers. Solid colors represent productions of the stressed syllables (e.g., first-syllable stressed words) and the patterned colors represent productions of the unstressed syllables (e.g., second-syllable stressed words).

Figure 21 represents the vowel distribution of the second syllable from the two different stressed conditions (e.g., first-syllable stressed vs. second-syllable stressed) produced in word-isolation by the two speaker groups.

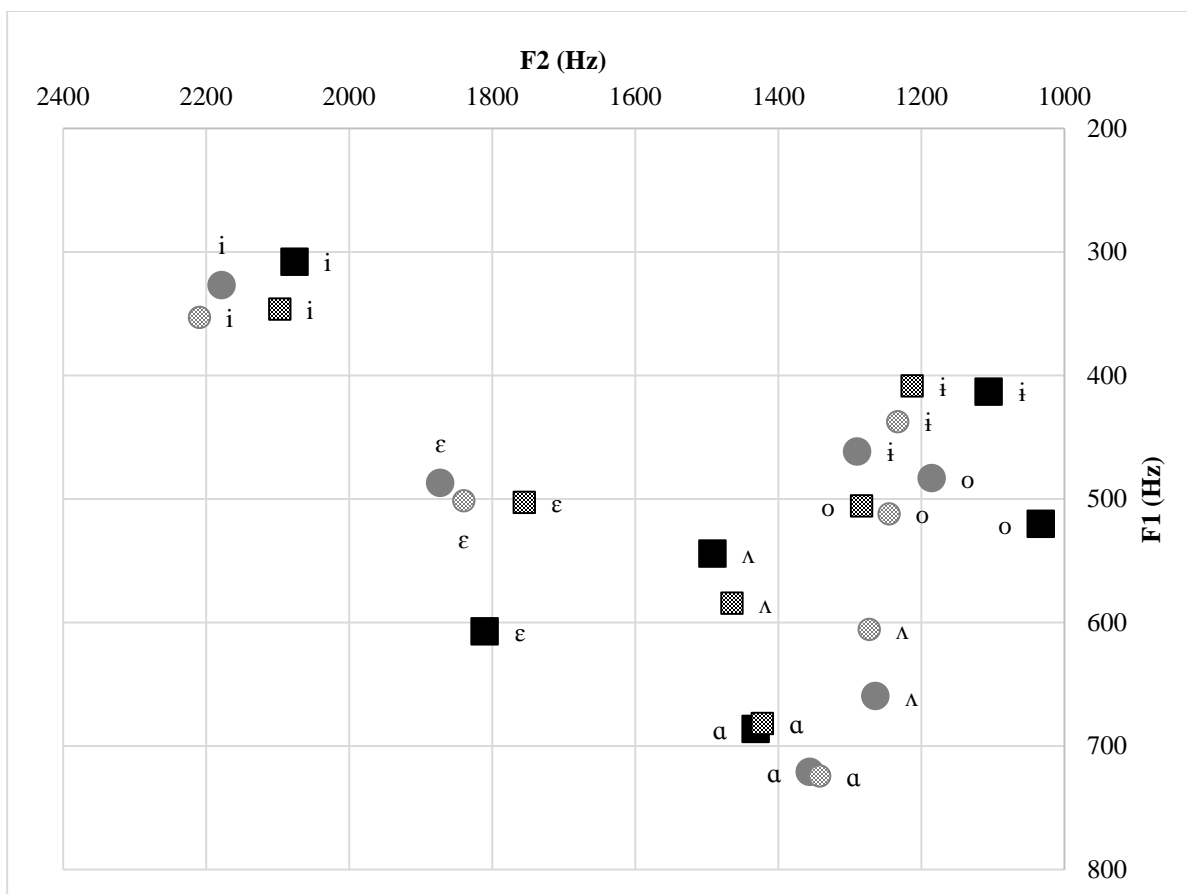


Figure 21. Scatterplot of vowel productions of the second syllable in isolated words. Black squares represent productions by old Korean speakers, and gray dots represent productions by younger Korean speakers. Solid colors represent productions of the stressed syllables (e.g., second-syllable stressed words) and the patterned colors represent productions of the unstressed syllables (e.g., first-syllable stressed words).

Taken together, the results of the F1 and F2 analysis for the first and second syllable suggest that there was no vowel reduction in the production of Korean stress pairs produced in isolation, given the fact that no two-way interactions between Stress and Vowel Height for F1 or Stress and Vowel Frontness for F2 in both first (F1 values: $[F(2,18) = 1.20, p = .33]$; F2 values: $[F(1,12) = 1.35, p = .27]$) and second syllable (F1 values: $[F(2,18) = 1.31, p = .29]$; F2 values: $[F(2,18) = 0.02, p = .98]$) were found, as well as no three-way interactions among Stress, Vowel Height, and Group for F1 and F2 in first (F1 values: $[F(2,18) = .94, p = .41]$; F2 values: $[F(1,12) = .04, p = .85]$) and second syllable (F1 values: $[F(2,18) = .30, p = .75]$; F2 values: $[F(2,18) = 1.15, p = .34]$).

2.5.3. Results of comparison between the two production contexts

In this section, results of ratios between two production contexts are compared. In doing so, we follow Beckman (1986) who argued that the relative weight of the phonetic characteristics expressing the phonological feature of a language needs to be considered rather than the absolute differences, because how much a cue is utilized in expressing a phonological feature varies by language. Since one of the purposes of this chapter is to examine whether the phonetic realization of cues to stress in Korean appears in both contexts, we focus on the results of the ratios in the two production contexts.

2.5.3.1. Second-to-first syllable duration ratio

When conducting 2 by 2 by 2 repeated measures ANOVAs for second-to-first syllable duration ratios, main effects of Condition [$F(1, 19) = 10.60, p = .004$], Stress [$F(1, 19) = 11.92, p = .003$], and Group [$F(1, 19) = 4.51, p = .005$] were found. These results indicate that speakers produced the stress pairs with smaller duration ratio values at the sentence level (0.19) than in isolation (0.36), and first-syllable stressed words had smaller duration ratio values (0.21) than second-syllable stressed words (0.34). Also, older Korean speakers produced stress pairs with smaller ratio values (0.19) than the younger Korean speakers (0.37). We also found a marginally significant three-way interaction among Condition, Stress, and Group [$F(1, 19) = 3.78, p = .067$], indicating that the duration ratio by stress between the two speaker groups was marginally affected by Condition. The duration ratio difference between the first- and second-syllable stressed words as a function of Condition was greater for the older speakers (S2-S1 at sentence: 0.24, S2-S1 in word-isolation: 0.1) than for the younger speakers (S2-S1 at sentence: 0.07, S2-S1 in word-isolation: 0.08). Figure 22 illustrates the second-to-first duration ratio values of the first- and second-syllable stressed words in two different contexts between the two speaker groups.

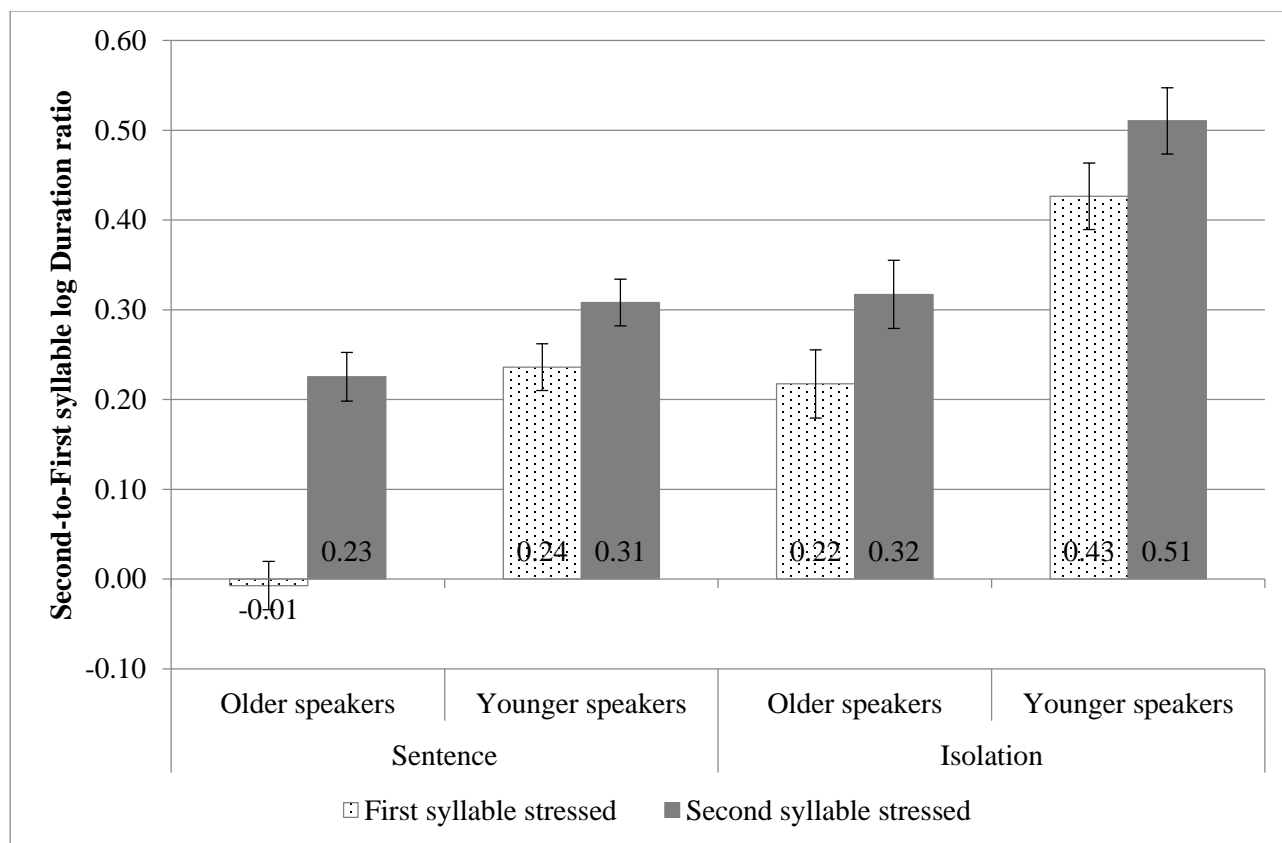


Figure 22. Second-to-first syllable log duration ratio values of the first- and second-syllable stressed words in two different contexts between two speaker groups.

2.5.3.2. Second-to-first syllable intensity ratio

When conducting 2 by 2 by 2 repeated measures ANOVAs on second-to-first syllable intensity ratios, main effects of Condition [$F(1, 19) = 46.50, p < .001$] and Stress [$F(1, 19) = 10.64, p < .001$] were found. These results indicate that the intensity ratio values were greater for the productions from the sentence level (2.10) than those from isolation (-1.92), and the first-syllable stressed words had a smaller intensity ratio (-0.19) than the second-syllable stressed words (0.37). We also found a two-way interaction between Group and Stress [$F(1, 19) = 4.85, p < .001$], indicating that the intensity ratio difference between the stress pairs was greater for the older speakers than the younger speakers. Figure 23 illustrates the second-to-first syllable intensity ratio values of the first- and second-syllable stressed words in two different contexts between the two speaker groups.

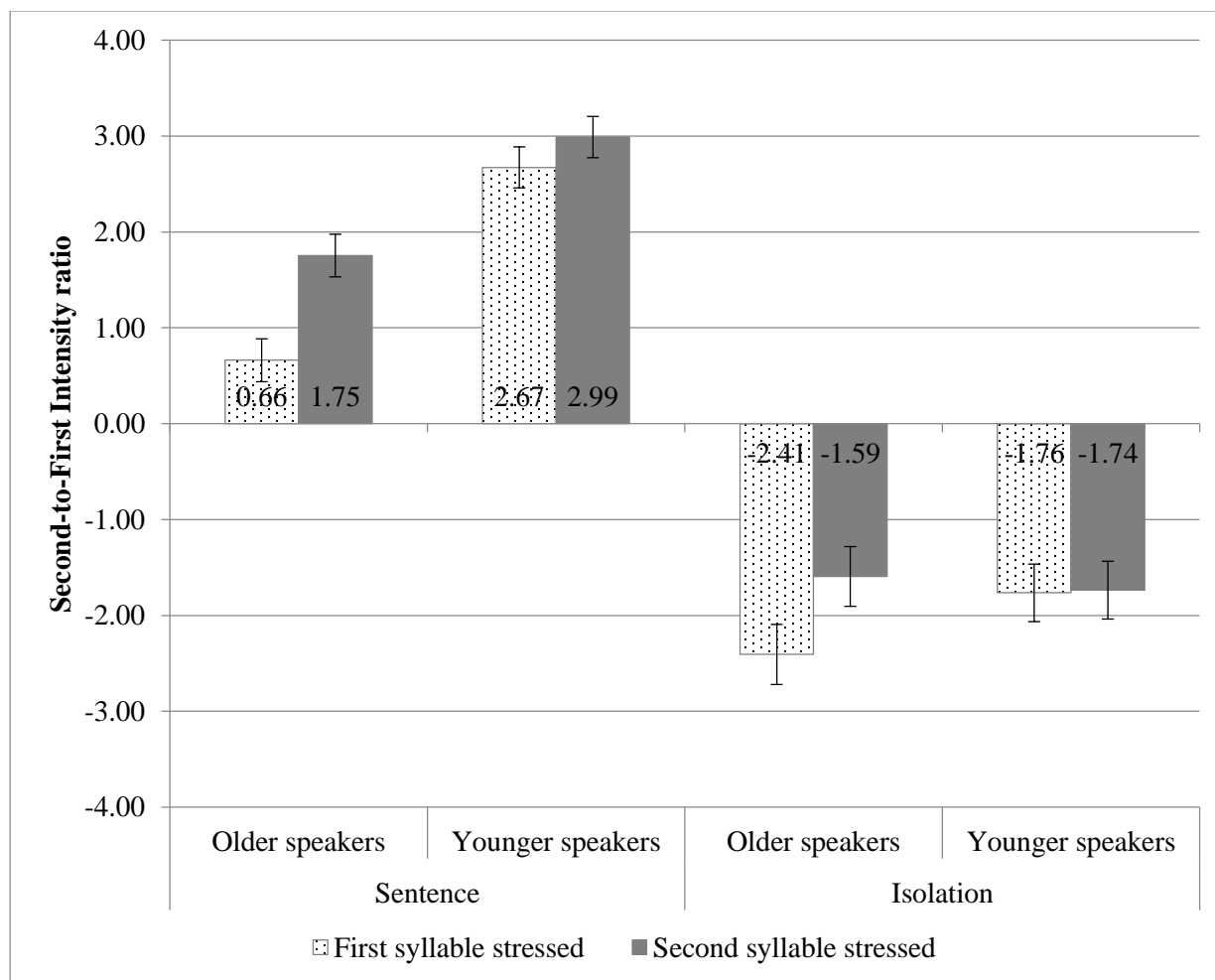


Figure 23. Second-to-first syllable intensity ratio values of the first- and second-syllable stressed words in two different contexts between two speaker groups.

2.5.3.3. Second-to-first syllable F0 ratio

When conducting 2 by 2 by 2 repeated measures ANOVAs on second-to-first syllable F0 ratios, a main effect of Condition [$F(1, 19) = 81.50, p < .001$] was found, indicating that the F0 ratio was greater in the productions at the sentence level (0.98) than the productions in isolation (-2.21). We also found a significant interaction between Condition and Group [$F(1, 19) = 6.23, p < .001$], indicating that the F0 ratio difference between the two contexts was greater for the younger speakers (1.85) than the older speakers (1.62). Figure 24 illustrates the second-to-first syllable F0 ratio values of the first- and second-syllable stressed words in two different contexts between the two speaker groups.

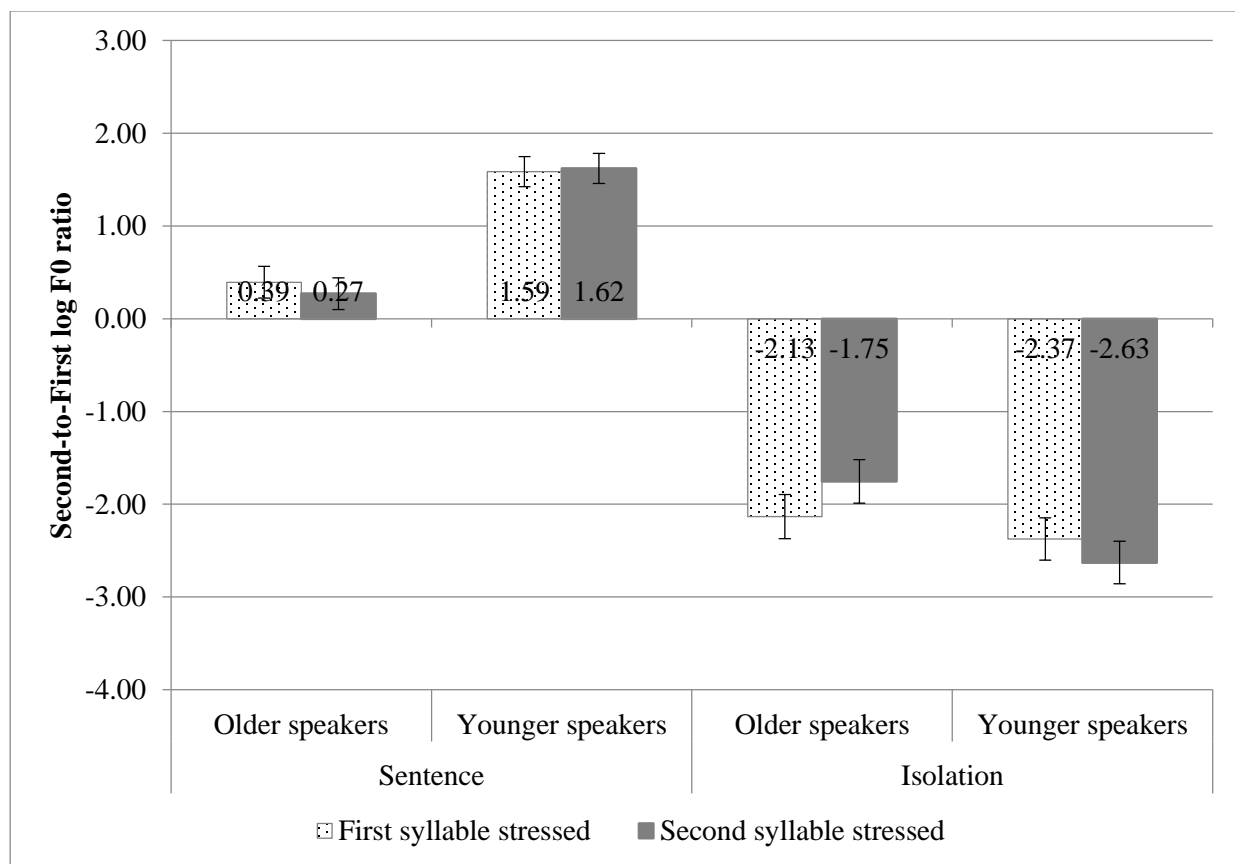


Figure 24. Second-to-first syllable F0 ratio values of the first- and second-syllable stressed words in two different contexts between two speaker groups.

2.5.4. Results of the effect of phrasal accent on F0

This analysis was conducted to investigate how phrasal prominence affected the production of the initial tone. AP theory predicts that F0 values in the first syllable will vary as a function of initial consonant: Syllables beginning with lenis consonants will have lower F0 values than syllables beginning with plain fricative regardless of the condition. If Korean had undergone a language change in expressing phrasal-level prominence, a group difference would be expected in the production of the AP-initial boundary tone. This will be examined in section 2.5.4.1. Also, AP theory predicts that in AP-initial position, F0 patterns of two syllables will either be LH/HH (HH pattern when the first syllable begins with a non-lenis consonant). However, when the target words are located in IP-final position, the F0 values of the second

syllable will be lowered, resulting in LL/HL pattern. Thus, positive values are predicted for words beginning with a plain fricative, whereas values close to zero are predicted for words beginning with lenis consonants. If Korean has undergone a language change in expressing phrasal-level prominence, the F0 difference between the first and second syllable will be similar across initial consonant types. This is examined in section 2.5.4.2.

2.5.4.1. F0 values as a function of initial consonant in the first syllable

In order to examine the effect of phrasal accent on F0 values between the two groups, we conducted a separate three-way ANOVA with Initial Consonant (lenis vs. plain fricative), Condition (sentence vs. isolation), and Group (older vs. younger) as independent variables and F0 values in the first syllable as dependent variable. Vowel-initial tokens were not included for the analysis since only one token began with a vowel (e.g., /ʌ.mi/).

A repeated measures ANOVA found significant main effects of Initial Consonant [$F(1, 19) = 48.84, p < .01$] and Condition [$F(1, 19) = 130.91, p < .01$]. These results indicate that words beginning with a plain fricative had a higher F0 (137 Hz) than words beginning with lenis consonants (113 Hz). Also, first syllables produced at the sentence level had a higher F0 (130 Hz) than first syllables produced in isolation. We also found significant two-way interactions between Initial Consonant and Group [$F(1, 19) = .324, p < .001$], between Condition and Group [$F(1, 19) = 46.33, p < .001$], and Initial Consonant and Condition [$F(1, 19) = 20.38, p < .001$]. These results indicate that the F0 differences between the syllables beginning with a lenis consonant and plain fricative were smaller for the older speakers (Plain fricative: 125 Hz, Lenis consonant: 116 Hz) than younger speakers (Plain fricative: 148 Hz, Lenis consonant: 111 Hz). Also, the F0 differences between the syllables beginning with lenis consonant and plain fricative were smaller for the productions at the sentence level (Plain fricative: 129 Hz, Lenis consonant: 111 Hz) than in word-isolation (Plain fricative: 145 Hz, Lenis consonant: 115 Hz).

We also found a significant three-way interaction among Initial Consonant, Condition, and Group [$F(1, 19) = 7.48, p = .013$]. In order to further examine the three-way interaction, we conducted two-way ANOVAs independently for each condition with Initial Consonant and Group as independent variables. The analysis of the F0 values at the sentence-level found a main effect of Initial Consonant [$F(1, 19) = 198.18, p < .01$] and a two-way interaction between Initial Consonant and Group [$F(1, 19) = 70.64, p < .01$]. When conducting one-way ANOVAs independently for each speaker group, main effects of Initial Consonant were found for both older [$F(1, 9) = 23.29, p = .01$] and younger speakers [$F(1, 10) = 203.115, p < .01$], indicating that both speaker groups produced first syllables beginning with a plain fricative with significantly higher F0 values than syllables beginning with lenis consonants. The analysis of the F0 values of isolated words found a similar result: a main effect of Initial Consonant [$F(1, 19) = 42.88, p < .01$] as well as a two-way interaction between Initial Consonant and Group [$F(1, 19) = 15.00, p = .01$] were found. When conducting one-way ANOVAs independently for each speaker group, main effects of Initial Consonant were found for both older [$F(1, 9) = 6.79, p = .028$] and younger speakers [$F(1, 10) = 39.40, p < .01$], indicating that both speaker groups produced first syllables beginning with a plain fricative with significantly higher F0 values than syllables beginning with lenis consonants. Table 4 presents the F0 values as a function of Initial Consonant in both contexts.

Table 4. F0 values of first syllable as a function of initial consonant type in both contexts by two speaker groups. Standard errors are indicated in parentheses.

	At sentence level		In isolation	
	Older speakers	Younger speakers	Older speakers	Younger speakers
Plain fricative (5 pairs)	130 Hz (5.89)	158 Hz (5.62)	119 Hz (7.07)	138 Hz (6.75)
Lenis (11 pairs)	119 Hz (5.18)	112 Hz (4.94)	112 Hz (4.76)	111 Hz (4.54)

2.5.4.2. F0 patterns as a function of initial consonant

In order to examine the effect of phrasal accent on F0 pattern between the two speaker groups, we conducted a three-way ANOVA with Initial Consonant (lenis vs. plain fricative), Condition (at sentence vs. in-isolation), and Group (older vs. younger) as independent variables. F0 differences between the first and second syllable (S1-S2) were entered as dependent variables.

A repeated measures ANOVA found significant main effects of Initial Consonant [$F(1, 19) = 44.32, p < .01$] and Condition [$F(1, 19) = 69.38, p < .01$]. These results indicate that F0 differences of the words beginning with a plain fricative (9.50 Hz) were greater than those of words beginning with a lenis consonant (1.42 Hz). Also, F0 differences between the first and second syllable were greater in isolated words (15.45 Hz) than at the sentence level (-4.53 Hz). We also found significant two-way interactions between Initial Consonant and Group [$F(1, 19) = .21.37, p < .001$] and between Condition and Group [$F(1, 19) = 7.43, p = .013$]. These results indicate that the F0 differences between two syllables as a function of Initial Consonant were greater for younger speakers (Plain fricative: 12.21 Hz, Lenis consonant: -1.03 Hz) than older speakers (Plain fricative: 6.51 Hz, Lenis consonant: 4.12 Hz). Also, the F0 difference between the first and second syllable was greater in isolated words than words produced at the sentence-level. However, younger speakers showed a greater difference as a function of condition (at sentence-level: 18.65 Hz, isolated words: -7.46 Hz) than older speakers (at sentence-level: 11.93, isolated words: -7.46)

We also found a significant three-way interaction among Initial Consonant, Condition, and Group [$F(1, 19) = 4.61, p = .045$]. In order to further examine the three-way interaction, we conducted two-way ANOVAs independently for each condition with Initial Consonant and Group as independent variables. The analysis for sentence-level found a main effect of Initial

Consonant [$F(1, 19) = 43.13, p < .01$] and a two-way interaction between Initial Consonant and Group [$F(1, 19) = 10.35, p = .05$]. When conducting one-way ANOVAs independently for each speaker group, main effects of Initial Consonant were found for both older [$F(1, 9) = 5.99, p = .037$] and younger speakers [$F(1, 10) = 45.92, p < .01$]. The analysis for isolated words found an interesting result: a main effect of Initial Consonant [$F(1, 19) = 25.34, p < .01$] as well as a two-way interaction between Initial Consonant and Group [$F(1, 19) = 20.69, p = .01$] were found. However, when conducting one-way ANOVAs independently for each speaker group, main effects of Initial Consonant were only found for younger speakers [$F(1, 10) = 48.99, p < .01$]. The absence of a main effect of Initial Consonant for older speakers [$F(1, 9) = .11, p = .747$] indicates that older speakers did not show LL/HL pattern as a function of Initial Consonant. Table 5 represents the F0 values as a function of Initial Consonant in both contexts.

Table 5. F0 difference between first and second syllable as a function of initial consonant in both contexts by two speaker groups. Standard errors are indicated in parentheses.

	At sentence level		In isolation	
	Older speakers	Younger speakers	Older speakers	Younger speakers
Plain fricative (5 pairs)	0.71 (2.46)	-1.58 (2.35)	12.30 (3.5)	26.00 (3.31)
Lenis (11 pairs)	-3.32 (2.67)	-13.35 (2.55)	11.56 (2.31)	11.3 (2.21)

2.6. Summary of results

The current chapter examined acoustic characteristics of Korean stress minimal pairs produced in two different contexts. Not only did we replicate previous studies, but we also obtained a number of new findings. First, we will discuss the results of the acoustic measurements taken from the sentence level.

First, consistent with previous studies (e.g., Ko, 2013), we found that older Korean speakers use duration to distinguish Korean stress pairs in their production, as suggested by two-

way interactions between stress and syllable for both raw duration values and second-to-first syllable duration ratios. Subsequent two-way ANOVAs for each speaker group for raw duration values revealed that only older speakers preserve a duration difference in their production of Korean stress, supported by a significant interaction between stress and syllable for older speakers.

With respect to intensity, we found a similar result to duration: significant two-way interactions between stress and syllable for raw intensity value as well as for the second-to-first syllable intensity ratio were found. Subsequent two-way ANOVAs for each speaker group for raw intensity values revealed that only older speakers use intensity as a cue to stress, supported by a significant two-way interaction between stress and syllable only for older speakers. The results of duration and intensity seem to suggest that older Korean speakers at least use both cues to stress while younger speakers have completely lost duration and intensity in their production of stress. Along with duration, intensity was previously found to express word-level prominence, although it has been argued that intensity is a weak cue to Korean stress (Ko, 2013). The present study also found a similar result, at least from the tokens produced at the sentence level.

With respect to F0, no effect of stress was found for either speaker group for raw F0 values or second-to-first syllable F0 ratios, indicating that F0 is not a reliable parameter to indicate Korean stress. Also, when separating out the groups and testing the effect of initial consonant on the F0 values, we found main effects of initial consonants for both groups, but only the younger speakers showed a main effect of syllable and a two-way interaction between initial consonant and syllable. As Korean AP boundary theory suggests, Tukey *post hoc* analyses revealed that the F0 values were boosted for both groups when the initial consonant of the target word was a plain fricative.

Lastly, the absence of significant effects of stress or group on F1 and F2 values for tokens produced at the sentence level suggests that there is no vowel reduction. Taken together, the acoustic evidence taken from the sentence level seems to suggest that only duration and intensity cue stress in older Korean speakers' productions. Tables 6 and 7 represent a summary of main effects and interactions of raw values of the five acoustic measurements (duration, intensity, F0, F1, and F2) as well as ratio values of the three acoustic measurements (duration ratio, intensity ratio, and F0 ratio) from the productions at the sentence level.

Table 6. Summary of statistical results for the raw values of the five acoustic measurements from the productions at the sentence level.

Acoustic Cue	Main analysis (Sentence level)	Post-hoc analysis	
		Older speakers	Younger speakers
Duration	Main effect of Stress Main effect of Syllable Main effect of Group Stress * Syllable Stress * Syllable * Group	Syllable * Stress	Main effect of Syllable
Intensity	Main effect of Syllable Main effect of Group Stress * Syllable Syllable * Group Stress * Syllable * Group	Main effect of Syllable Stress * Syllable	Main effect of Syllable
F0	Main effect of Syllable Syllable * Group	Main effect of Initial Consonant	Main effect of Initial Consonant Main effect of Syllable Initial Consonant * Syllable
Acoustic Cue	Analysis of the first syllable	Analysis of the second syllable	
F1	Main effect of Vowel Height Main effect of Group	Main effect of Vowel Height Main effect of Group	
F2	Main effect of Frontness	Main effect of Frontness	

Table 7. Summary of statistical results for the ratio values of the three acoustic measurements from the productions at the sentence level.

Acoustic Cue	Main analysis (Sentence level)	Post-hoc analysis	
		Older speakers	Younger speakers
Duration ratio	Main effect of Stress Stress * Group	Main effect of stress	Main effect of stress
Intensity ratio	Main effect of Stress Main effect of Group Stress * Group	Main effect of stress	n.s.
F0 ratio	Main effect of Group	n.a.	n.a.

We also examined the same acoustic measurements for the tokens produced in isolation in order to investigate the effect of a phrase-final boundary on the production of Korean word-level prominence. For duration, we found inconsistent results between raw values and ratios: we found a main effect of stress for raw duration values but no significant effect was found for ratio values, suggesting that duration is not a cue to stress for words in isolation. The inconsistent results between raw duration values and ratios suggest that the final lengthening effect in the second syllable from the productions in isolation partially neutralized the effect of the vowel length distinction in the first syllable.

Regarding intensity, a main effect of stress was not found either for raw intensity values nor second-to-first syllable intensity ratios. This again suggests that intensity is not a strong indicator of stress in words in isolation.

With respect to F0, we also found an effect of phrasal boundary on the F0 pattern. Unlike the results for the sentence level, we found a main effect of syllable for both older and younger speakers, suggesting that the F0 of the second syllable was lowered due to the effect of the phrasal-final tone. However, a two-way interaction between initial consonant and syllable was only found for the younger speakers' production, indicating the possibility of a diachronic language change in phrasal-level prominence in Korean.

Lastly, the lack of significant main effects of stress or group on F1 and F2 values for the tokens produced in isolation suggests there is no vowel reduction in Korean. Tables 8 and 9 represent a summary of main effects and interactions of raw values of the five acoustic measurements (duration, intensity, F0, F1, and F2) as well as ratio values of the three acoustic measurements (duration ratio, intensity ratio, and F0 ratio) from the production in word-isolation.

Table 8. Summary of statistical results for the raw values of the five acoustic measurements from the productions in word-isolation

Acoustic Cue	Main analysis (In isolation)	Post-hoc analysis	
		Older speakers	Younger speakers
Duration	Main effect of Stress Main effect of Syllable Main effect of Group	n.a.	n.a.
Intensity	Main effect of Syllable Main effect of Group	n.a.	n.a.
F0	Main effect of Syllable	Main effect of Initial Consonant Main effect of Syllable	Main effect of Initial Consonant Main effect of Syllable Initial Consonant * Syllable
Acoustic Cue	Analysis of the first syllable	Analysis of the second syllable	
F1	Main effect of Vowel Height	Main effect of Vowel Height	
F2	Main effect of Frontness	Main effect of Frontness	

Table 9. Summary of statistical results for the ratio values of the three acoustic measurements from the productions in word-isolation

Acoustic Cue	Main analysis (Sentence level)	Post-hoc analysis	
		Older speakers	Younger speakers
Duration ratio	n.s.	n.a.	n.a.
Intensity ratio	n.s.	n.a.	n.a.
F0 ratio	n.s.	n.a.	n.a.

When comparing the ratio values in the two different contexts, we also found several interesting facts. First, we found duration ratio cues to stress only in the sentence condition. Since younger speakers have lost the phonemic vowel length distinction, it was predicted that the difference in duration ratio between the two conditions would be smaller for the younger speakers than the older speakers. This was supported by a marginally significant three-way interaction among Condition, Stress, and Group.

Second, intensity is used as a cue to stress only by older speakers, as supported by a two-way interaction between Stress and Group. The ratio analysis for each condition revealed that intensity ratio only cues stress for older speakers at the sentence level. However, how intensity expresses prominence within a word varied as a function of context: intensity ratio values in isolation consistently showed negative values, while intensity ratio values at the sentence level consistently had positive values. This result indicates that at the sentence level, the second syllable had higher intensity values than the first syllable, whereas in isolation, the first syllable had higher intensity values than the second syllable. The different intensity pattern between the two syllables across different contexts, therefore, suggests that intensity is strongly affected by the phrasal-boundary effect, resulting in higher intensity at the boundary-initial position in isolation than at the boundary-initial position in sentence-medial position.

Also, we found that younger speakers were more strongly affected by the accentual phrase than older speakers, as supported by the two-way interaction between Condition and Group on F0 ratio. Table 10 represents a summary of main effects and interactions found in this chapter, comparing the three suprasegmental ratio values in two different conditions.

Table 10. Summary of main effects and interactions found in this chapter, comparing the three suprasegmental ratio values in two different conditions.

Acoustic cues	Analysis for Condition
Second-to-first syllable duration ratio	Main effect of Condition Main effect of Stress Main effect of Group (Marginal) Condition * Stress * Group
Second-to-first syllable intensity ratio	Main effect of Condition Main effect of Stress Stress * Group
Second-to-first syllable F0 ratio	Main effect of Condition Condition * Group

In terms of the effect of phrasal prominence on the target words, we found that in both conditions both younger and older speakers showed an effect of F0 boost in the first syllable when the target words started with non-lenis consonants. However, the F0 difference as a function of consonant type was greater at the sentence level than in word-isolation, as supported by a three-way interaction among Initial Consonant, Condition, and Group. With respect to the F0 patterns, however, we found a different pattern between the two speaker groups in two conditions: both speaker groups showed a LL/HH F0 pattern as a function of consonant type at the sentence-level, whereas only younger speakers showed a clear LL/HH F0 pattern in word-isolation. The lack of a main effect of Initial Consonant in older speakers' isolated words indicates that older speakers produced target words with LL F0 pattern, whereas younger speakers produced target words either with LL or HL pitch pattern. These results suggest that Korean is undergoing a language change in expressing phrasal-level prominence, although the F0 results do not support the claim that Korean has word-level prominence. Tables 11 and 12 present a summary of main effects and interactions of F0 values in the first syllable as well as F0

difference between first and second syllable as a function of initial consonant types between the two speaker groups in both conditions.

Table 11. Summary of main effects and interactions found in this chapter, comparing F0 values in the first syllable as a function of initial consonant between two speaker groups in two different contexts.

		Main analysis			
F0 on S1	Main effect of Initial Consonant				
	Main effect of Condition				
	Initial Consonant * Group				
	Initial Consonant * Condition				
	Condition * Group				
	Initial Consonant * Condition * Group				
	Post-hoc analysis				
	F0 at the sentence level		F0 in word-isolation		
Main effect of Initial Con		Main effect of Initial Con			
Initial Con * Group		Initial Con * Group			
Older speakers	Younger speakers	Older speakers	Younger speakers		
Main effect of Initial Con	Main effect of Initial Con	Main effect of Initial Con	Main effect of Initial Con		

Table 12. Summary of main effects and interactions found in this chapter, comparing F0 differences between first and second syllables of the target words as a function of initial consonant between two speaker groups in two different contexts.

		Main analysis			
F0 pattern (S1-S2)	Main effect of Initial Consonant				
	Main effect of Condition				
	Initial Consonant * Group				
	Condition * Group				
	Initial Consonant * Condition * Group				
	Post-hoc analysis				
	F0 at the sentence level		F0 in word-isolation		
	Main effect of Initial Con		Main effect of Initial Con		
Initial Con * Group		Initial Con * Group			
Older speakers	Younger speakers	Older speakers	Younger speakers		
Main effect of Initial Con	Main effect of Initial Con	n.s.	Main effect of Initial Con		

2.7. Discussion

One of the purposes of this chapter was to examine whether word-level prominence in Korean exists in contemporary Seoul Korean, and if it does, which acoustic correlates are expressed by speakers of Korean. We examined how older speakers of Seoul Korean produce Korean stress pairs and compared this to younger speakers' production by using detailed acoustic analysis. Previous studies have claimed that younger Korean speakers have completely lost the vowel length distinction, which is presumed to be the main cue to express word-level prominence. Accordingly, this chapter explored how younger speakers produce Korean stress pairs and examined if they produce the member of these pairs identically or not.

Consistent with previous studies, our findings show that older Korean speakers still preserve the vowel length distinction, while younger speakers have lost the distinction, as indicated by the three-way interaction between stress, syllable, and group for duration. In addition to duration, intensity was also found to indicate word-level prominence for older speakers at the sentence level. However, given that intensity was not used to cue to stress in words in isolation, the effect that was found at the sentence level seems to suggest that intensity cannot be a cue to word-level prominence in Korean. Also, we observed a generational difference in the way the two groups of speakers used other cues such as intensity and F0 in producing Korean stress pairs. Younger speakers always produced the second syllable with longer duration than the first syllable, regardless of the stress position. The intensity value was always greater for the second syllable than the first syllable at the sentence level; however, the opposite pattern was found for the productions in isolation. F0 clearly indicates the phrasal domain in younger Korean speakers' productions. Based on these results, we conclude that traditional Seoul Korean has a vowel length distinction, not word-level prominence, given that

none of the acoustic correlates related to stress were consistently found to indicate word-level prominence across the two conditions.

The question then arises whether duration was ever used as a primary cue to lexical stress in the Korean language. In order to answer this question, we contrasted the productions taken from the sentence level to productions recorded in isolation. Since all cues expressing word-level prominence – duration, intensity, and F0 – also express phrasal-level prominence in Korean, we hypothesized that if we find the same effect of stress on duration in tokens across different phrasal boundaries, we would be able to conclude that Korean had lexical stress expressed with duration. We predicted that all three acoustic cues would be affected by the phrasal-boundary effect in the word-isolation context: the second syllable will be elongated due to the final lengthening, F0 of the second syllable will be lowered, and the intensity will be raised. However, if Korean indeed had lexical stress, older speakers should still produce stress pairs with a longer duration on the first syllable in the word-isolation context.

The findings from words in isolation were very interesting. First, the effect of duration for older speakers were only found in the productions at the sentence level. Both raw duration values and the second-to-first syllable duration ratio were significant cues to stress at the sentence level only for the older speakers. Although we predicted that the duration effect would be weakened in isolation due to the final-lengthening effect, if Korean indeed had lexical stress, multiple cues in the first syllable should still indicate lexical stress. However, such a pattern was not found in the current study. Even though both duration and intensity (both raw values and ratios) were significant cues to stress at the sentence-level, consistent results were not found in isolated words. If Korean had lexical stress expressed with duration and intensity, as found by Ko (2013), both cues should pattern similarly in the two contexts. However, such a pattern was

not found. Note that while the ratio values consistently showed positive values in both contexts, intensity ratios were either positive (at the sentence) or negative (in isolation). Therefore, the absence of consistent results across two contexts seems to suggest that duration could not be a cue to stress, and the effect of intensity was due to the effect of phrasal-level prominence.

Taken together, with the phonetic evidence that we have collected, we can conclude that it is not the case that Korean had lexical stress that was only expressed by duration. This chapter was successful in providing evidence suggesting that duration is only used to indicate phonemic vowel length in Seoul Korean.

The secondary purpose of this chapter was to examine whether Korean had undergone a diachronic change from word-level prominence to phrasal-level prominence. The evidence supporting this claim was not compelling. On the other hand, our findings suggest that Korean had undergone a diachronic change in how Korean expresses phrasal-level prominence. First, when we ran separate ANOVAs on F0 values of older and younger speakers' productions at the sentence level, a significant interaction between initial consonant and group was found for both conditions for both speaker groups. Note that AP-theory for Korean predicts that words beginning with lenis consonants and vowels will have an LH F0 pattern, and an HH pattern for words beginning with plain fricatives. Although older speakers' productions showed an effect of initial consonant, the effect of F0 boost by non-lenis initial consonants was greater for younger speakers. When examining the F0 difference between the first and second syllable, however, we found a different F0 pattern between the two conditions. Both older and younger speakers produced a LH/HH F0 pattern as a function of initial consonant type at the sentence level. However, in word-isolation, while younger speakers produced target words with HL/LL pitch pattern, older speakers produced the two syllables of the target words with the LL F0 pattern, as

opposed to what AP theory predicts. The second syllable was lowered due to the IP-final boundary tone. However, while younger speakers still showed an effect of F0 difference between the two syllables, older speakers did not show such an effect. Thus, these results for F0 between older and younger speakers seem to suggest that there were at least some changes in the ways speakers of Seoul Korean express phrasal-level prominence.

The differences in the use of F0 between the two groups examined here suggest two possibilities: First, it could be the case that in traditional Seoul Korean, lexical stress was expressed with duration and F0, and the F0 cue was lost in expressing lexical stress as Korean changed to a phrasal prominence language, since F0 is more frequently used than duration at the phrasal-level. If the older Korean speakers are the generation who are in the middle of the ongoing language change, and the language change has been completed with the younger Korean speakers, the assertion that traditional Korean had word-level prominence is plausible. However, this claim loses its validity when considering how the lexical stress contrast is created by using multiple cues. For example, in a stress-timed language, more than one acoustic manifestation dynamically expresses word-level prominence (e.g., Beckman, 1986). In English, for example, a primary stressed syllable within a word is realized with multiple cues: the stressed syllable has longer duration, higher intensity, higher F0, and reduced vowel quality (Gay, 1978) than the unstressed syllable (Fry, 1955; 1958), while also having a phrasal-level prominence. Also, the Chonnam dialect, which has been claimed to still have word-level prominence, has phrasal-level prominence that is realized with F0 (Ko, 2014). However, Chonnam speakers have not lost the F0 cue to express word-level prominence (Jun, 1993). Thus, without any explanation of why only Seoul Korean has lost F0 to express word-level prominence, it is hard to conclude that F0 used to be used as a cue to stress in traditional Seoul Korean.

Then, why do we see different phrasal tone patterns between the two groups? It might be because the Korean consonant system has been undergoing a change. Numerous previous studies have reported changes in the weighting of VOT and F0 in the Korean three-way distinction among stop consonants (Kang & Guion, 2008; Lee & Jongman, 2015; Lee et al., 2013; Perkins, J., Lee, 2010; Silva, 2006; Wright, 2007). In addition to the stop consonants, it seems that the use of F0 in distinguishing plain fricatives from fortis fricatives has also changed. For example, inconsistent findings were reported in regard to the use of F0 in categorizing Korean fricatives, implying that there is an arbitrary use of F0 in distinguishing fricatives. Cho, Jun, and Ladefoged (2002) reported a marginally lower F0 in the plain than in the fortis fricative, whereas Yoon (2002) reported higher F0 values in the plain fricative than in the fortis fricative. Moreover, other studies have reported no significant difference between plain and fortis fricatives (C. B. Chang, 2008; Holliday, 2012; G. Lee & Jongman, n.d.; G. Lee, 2011). Even though there is no solid claim on language change in the use of F0 in categorizing Korean fricatives, the inconsistent results reported so far indirectly suggest speaker variability in F0 usage to categorize Korean fricatives. If the Korean consonant phonetic inventory has been continuously developing to date, we might be able to conclude that the effect of Initial Consonant on phrasal tone has been affected as well.

The next question that we want to investigate, then, is whether Korean speakers will only be sensitive to duration in differentiating Korean phonemic vowel length pairs, or will they use other cues as well. For example, will older Korean speakers use intensity as well as F0 cues in distinguishing Korean vowel length pairs, as we found in their productions? Will younger listeners be only sensitive to duration or will they also be sensitive to other cues? Considering that the second-to-first syllable duration ratio that we found in this chapter was rather small,

albeit significant, to indicate lexical stress, younger listeners may not be sensitive to duration at all in their perception, given the fact that the phonemic vowel length distinction has disappeared. In the next chapter, these issues will be addressed in a perception study with more detailed research questions.

CHAPTER III.
PERCEPTION OF KOREAN WORD-LEVEL PROMINENCE BY KOREAN
LISTENERS

3.1. Introduction

In Experiment 1, we examined acoustic evidence to determine whether Korean had word-level prominence, mainly realized by duration, and provided acoustic evidence supporting the claim that Korean does not have word-level prominence. That being said, duration is used to express a phonemic vowel length distinction and F0 and intensity are used to indicate phrasal-level prominence. However, whether intensity is used as a cue to stress or to phrasal-level prominence was not so clear. When examining the effect of stress on duration and intensity for the older speakers in two different contexts, we found that only duration consistently cued stress, while intensity did not. Moreover, how intensity expresses prominence between two syllables varied as a function of context. Recall that the second syllable always had a greater intensity value than the first syllable at the sentence level, while the first syllable always had a greater intensity value than the second syllable in isolation. Based on this, we concluded that intensity seems to indicate phrasal-level prominence rather than word-level prominence.

However, there are still unsolved questions. First, does the fact that speakers do not use a cue in production mean that they will not use it in their perception as well? Second, given the fact that stress is realized by means of multiple cues, will listeners show a sensitivity to word-level prominence only when both duration and intensity indicate prominence? If Korean listeners show a perceptual sensitivity to both cues together, we can claim that Korean has word-level prominence that is realized by duration and intensity. On the other hand, if listeners can identify Korean stress pairs with only a single cue (e.g., duration), independently from other cues (e.g.,

intensity), then we would be able to conclude that Korean does not have stress. Furthermore, we would be able to conclude that the effect of intensity on stress, which was found in Experiment 1, is due to the phrasal-level prosody, not to the word-level prominence. In order to answer these questions, this chapter will investigate the identification of a Korean stress pair by older and younger Korean listeners.

3.2. Background

To date, a large number of studies have focused on acoustic characteristics of different languages with free or fixed stress, and investigated which cues listeners exploit in perceiving lexical stress. For example, Fry (1955; 1958) conducted an acoustic study in which he measured the duration and peak amplitude of stressed and unstressed syllables of English minimal pairs produced in isolation (e.g., **OB**ject vs. ob**J**ECT; upper case indicates stressed syllable) and found that the stressed syllables have a longer duration and higher peak amplitude than the unstressed syllables. Then, in a perception experiment, Fry investigated how English native listeners perceive synthesized stimuli in which amplitude, duration, and F0 are independently manipulated. The results showed that native English listeners put more weight on duration than amplitude, and used F0 only when F0 on the stressed syllables had a noticeably higher peak than the unstressed syllables, or when F0 had a clear movement between the syllables. Based on these results, Fry (1955; 1958) concluded that F0 as well as duration are the two most important perceptual cues in perceiving English stress, while intensity has a small effect on stress perception in English.

However, Fry implied the significance of vowel reduction in the perception of English stress as well. In later studies, vowel quality was also found as an important cue to English stress (e.g., Lehiste & Peterson, 1959, among many others), and native English listeners weighted vowel quality more than suprasegmental cues (e.g., intensity, duration, and F0) in perceiving

lexical stress in English (Zhang & Francis, 2010). For example, when these 5 steps of systematically manipulated vowel quality cues from DEsert to deSERT were orthogonally manipulated with one of the suprasegmental cues, English listeners relied on vowel quality more than the suprasegmental cues, suggesting that vowel reduction is the most important cue in perceiving English unstressed syllables.

Likewise, there seems to be a hierarchical order of cues to perceive stress; however, stress is not only realized with a single cue (Ladefoged et al., 1958; Lehiste & Peterson, 1959; Lieberman, 1960). Intrinsic characteristics of stressed syllables – longer duration, higher F0, and greater intensity – are strongly correlated with the perception of stress, and when one of these parameters is not in the predicted direction, there is always a trade-off effect for other cues (Lieberman, 1960). That is, when one acoustic parameter (e.g., F0) does not contribute to the perception of stress, other cues (e.g., amplitude) may compensate for the lack of differentiation of F0 and take on a greater role. This pattern was found not only in free-stress languages, such as English and Dutch, but also in fixed-stress languages such as Spanish and Arabic. In Arabic, the relation between duration and F0 is very similar to that in English (de Jong & Zawaydeh, 1999), with the stressed vowel /a/ having a longer duration, higher F0, and higher F1 than its unstressed counterpart (but see also Zuraiq (2005) who found no effect of stress on F1). Also, in Spanish, at least two cues – F0 combined either with duration or intensity – need to signal stress location for native Spanish listeners to perceive stress (Llisterri, Machuca, de la Mota, Riera, & Ríos, 2003). These results suggest that stress is conveyed by multiple cues, and different languages use these acoustic cues with different degrees of saliency in indicating stress.

Taken together, it is clear that indicating stress requires the manifestation of multiple cues. Based on this, we will re-examine whether Korean has a truly lexical stress that is mainly

realized with duration or whether Korean only has a phonemic vowel length distinction. If Korean has both lexical stress and phonemic vowel length, then Korean listeners would be sensitive to duration in the first syllable and weight intensity in the second syllable in distinguishing Korean stress pairs. If Korean has only phonemic vowel length, but not lexical stress, then Korean listeners may only be sensitive to duration in the first syllable. Thus, one of the goals of this chapter is to examine whether Korean has lexical stress or a phonemic vowel length distinction by means of a perception study, and, if Korean has lexical stress, which cue(s) Korean listeners use in perceiving word-level prominence.

The second goal of this chapter is to investigate if older and younger Korean listeners differ in their use of acoustic cues in processing stress contrasts in Korean. Even if younger Korean speakers have lost the vowel length contrast (or lexical stress) in their production, they might still have a perceptual distinction, since they are exposed to the duration distinction in the speech of their elders. In addition, we also aim to investigate whether Korean listeners will distinguish the stress pairs with the same cue(s) in their perception as they used in their production. For example, will they only use duration and intensity in perceiving word-level prominence, as we found in their production at the sentence-level, or will they weight F0 cues as well when F0 cues are available?

Taken together, the main purpose of this chapter is to find perceptual evidence for the claim that Korean has lexical stress, and also to investigate which cue(s) Korean listeners use in perceiving word-level prominence in Korean.

3.3. Goals

The main goal of this chapter is to investigate whether contemporary Seoul Korean still has word-level prominence, and if so, if perception of this prominence is based on multiple cues, such as duration and intensity, or on duration only. Also, we examine whether different

generations of Korean listeners show different perceptual sensitivity to the manipulation of acoustic cues to stress. More specifically, we examine whether Korean listeners' perception will change from a first-syllable-stressed word (e.g., /'sa:kwa/ 'apology') to a second-syllable stressed word (e.g., /sa.'kwa/ 'apple') as acoustic cues vary. Secondly, we also examine which cue will be weighted the most in perceiving Korean lexical stress between the two Korean listener groups. For older Korean listeners, we examine whether they will also be sensitive to F0 and intensity in addition to duration, and which cue will be the strongest cue for them to identify Korean (so-called) stress pairs. For younger Korean listeners, we examine whether they will perceptually weight duration, given the fact that the duration cue has disappeared in contemporary Seoul Korean. The three research questions investigated in this chapter are listed below:

- 1) Is Korean a language that has word-level prominence mainly realized with duration? Will Korean listeners show a perceptual shift from a word with first-syllable prominence to second-syllable prominence only when duration varies, or when multiple acoustic cues change?
- 2) If there is word-level prominence in Korean, which acoustic cues do Korean listeners use in perceiving it? Will younger Korean listeners show a similar perceptual sensitivity to duration as much as older Korean listeners? Will both listener groups show a similar perceptual pattern to all cues?
- 3) Do Korean listeners use the same cue(s) in their perception and production? In other words, will all cues found to be significant from the production be used in perception as well?

3.4. Methodology

3.4.1. Participants

The same 10 older Korean speakers and 12 younger Korean speakers who participated in the Korean production study (See Chapter 2) also took part in the perception study on Korean word-level prominence.

3.4.2. Stimuli

3.4.2.1. Original base token

A Korean stress pair ‘sakwa’ was chosen as the stimulus token based on the frequency of occurrence between the first-syllable (frequency 48) and the second-syllable stressed words (frequency 63) as provided by the National Institute of Korean Corpus (2002). These tokens were produced by an older Korean male speaker (Speaker A, age 68) who did not participate in the production study. We selected the production of the first-syllable stressed word, /sa:kwa/ ‘apology’, as the baseline token in order to preserve possible acoustic information in the long vowel and also to minimize any possibility of losing acoustic information by lengthening the short vowel to a long vowel. The manipulation range was based on the minimum and maximum value of three acoustic parameters – duration, F0, and intensity – of both younger and older speakers’ productions of the /sakwa/ pair from Chapter 2.

Stimulus manipulation

All stimuli were manipulated from the single token /sa:kwa/, so that we could control any unintended changes in phonation type or vowel quality. The stimuli were first produced in semantically-related sentences (e.g., ‘*If you do wrong, you should give an **apology** first and ask for forgiveness.*’), and then produced in a semantically neutral carrier sentence (i.e., [i. dan.ʌ.nin. **sa:gwa.** im.ni.da.] ‘*This word is apology*’). The token that was produced in the neutral sentence was used as the baseline token. For the stimulus manipulation, the maximum and minimum

values of F0, intensity, and duration across all the older and younger speakers were used as endpoints. For each condition, two parameters (e.g., duration x F0) were orthogonally manipulated to signal the stress pattern while the other cue (e.g., intensity) was controlled to be ambiguous. Each cue had 5 steps from unstressed to stressed syllable based on the acoustic data that we gained from the production study in Chapter 2. We also controlled the minimum value of each step to be greater than the Just Noticeable Difference (JND) (Flanagan, 1955; Flanagan & Saslow, 1958; Klatt, 1973; Fujisaki, Nakamura, & Imoto, 1975; Klatt & Cooper, 1975; Nishinuma, Di Cristo, & Espesser, 1983; Turk & Sawusch, 1996) for each cue, so that the listeners can perceive the differences between each step. When the first syllable was manipulated, the second syllable was controlled to be ambiguous (at step 3) between a stressed and an unstressed syllable, and the first syllable was controlled to be ambiguous (at step 3) when the second syllable was manipulated. These manipulated tokens were then embedded in a semantically neutral carrier sentence (e.g., This words is ____ . [i. dan.ʌ.nin. _____ im.ni.da.]) produced by Speaker A, and presented as the auditory stimuli in the perception experiment.

3.4.2.2. Vowel duration manipulation

Five steps of the first and second syllable were created based on the maximum (when the syllable is stressed) and minimum (when the syllable is unstressed) mean values of the vowel duration from our acoustic data for the /sakwa/ pair. For the first syllable, 5 steps were created in 29 ms increments from the minimum duration (56 ms) to the maximum duration (172 ms). And 5 steps of the second syllable were created with a 2.25 ms increment from the minimum (87 ms) to the maximum value (96 ms). This duration range of the first and second syllable was based on the acoustic results by taking the maximum and minimum ranges of the /sakwa/ token across all speakers, gained from Experiment 1. When the first syllable was varied, the second syllable was

controlled to be constant at the midpoint (step 3) throughout the 5 steps of the first syllable continuum, so that listeners would identify the syllable prominence based on the acoustic cues contained in the first syllable. The same was done for the second syllable: after creating a 5-step continuum for the second syllable, each step was concatenated with the midpoint of the first syllable (step 3). The duration manipulation was conducted by setting the onset and offset of periodicity of the vowels in the *Duration manipulation tier* of Praat to extract the *Duration Tier*. Then, the vowel duration was with a manipulation factor for each step. For example, a manipulation factor of 0.663 was used when shortening the vowel duration of the original token (172 ms) to the duration of 114 ms (for step 3). Then, a new token with manipulated vowel duration was synthesized by replacing the original duration tier with the new tier.

3.4.3. F0 manipulation

F0 had 5 steps from the maximum to the minimum F0 value both for the first and the second syllables. Interestingly, since the unstressed first syllable had the highest overall F0 value. Five steps of the first syllable were created with a 7.25 Hz decrease from the maximum F0 value (step 1: 216.32 Hz) to the minimum F0 value (step 5: 187.33 Hz). The second syllable also had 5 steps of a 3.99 Hz decrease from the maximum F0 value (step 1: 186.26 Hz) to the minimum F0 value (step 5: 170.30 Hz) from unstressed to stressed syllables. This F0 manipulation was done after manipulating the vowel duration of each step. F0 values for each step were manipulated by using the *Pitch Manipulation Tier* of Praat by either lowering or raising the F0 point of each tier. For example, to increase the F0 of the baseline token (98.95 Hz) to the F0 of the neutral token (107.69 Hz), we first removed all the pitch points shown on the *Pitch Tier*, and then recreated an initial and a final pitch point at 107.69 Hz. The remaining

points between the initial and final points were interpolated in Praat after resynthesizing the token.

3.4.4. Intensity manipulation

After both duration and F0 manipulation were conducted, manipulation of the intensity was also done, using a Praat script (Vicenik). Intensity had 5 steps in increments of 2.75 dB for the first syllable from the minimum (60.00 dB) to the maximum intensity values (71.00 dB). For the second syllable, the intensity value incrementally increased from the minimum value (60.00 dB) to the maximum value (65.00 dB) in 1.25 dB steps. Table 13 represents the manipulation values of the five steps for first and second syllables for duration, F0, and intensity.

Table 13. Five steps of manipulation values of first and second syllable for duration, F0, and intensity.

	First syllable					Second syllable				
	Unstressed		Stressed			Unstressed		Stressed		
Step	1	2	3	4	5	1	2	3	4	5
Duration (ms)	56	85	114	143	172	87	89.25	91.5	93.75	96
F0 (Hz)	98.95	103.32	107.69	112.06	116.43	112.63	117.02	121.41	128.80	130.19
Intensity (dB)	60.00	62.75	65.5	68.25	71.00	60.00	61.25	62.50	63.75	65.00

Thus, 25 tokens were created for each manipulation condition (e.g., 5 steps of duration x 5 steps of intensity; 5 steps of intensity by 5 steps of F0; 5 steps of F0 by 5 steps of duration) for each syllable. Three pairs of cues were manipulated: F0 & intensity; F0 & duration; duration & intensity. The 5 steps of both cues in each pair were crossed to form 25 stimuli, while the third cue was controlled to be neutral at step 3. For example, we created 25 stimuli by manipulating F0 and duration, while keeping intensity at step 3. In all, we defined 75 stimuli in this way. However, this procedure resulted in repeating conditions with two cues at level 3 twice, and

three cues at level 3 three times for a total of 14 repetitions. Therefore, 61 unique stimuli were created with this procedure at each syllable level for a total of 122 stimuli. These were each repeated 3 times for a total of 366 tokens for each subject.

3.4.5. Procedure

Before the stress perception test, a pure tone threshold test was conducted only for the older Korean listeners in order to examine listeners' hearing sensitivity using manual audiometry. We controlled the frequency, stimulus level, and presentation of test signals and made the determination as to when the threshold was identified. A series of tones was presented in each of the two ears monaurally, close to the threshold (the loudness that the person can just barely detect), and the intensity was continuously decreased in 10 dB steps until the listener stopped responding. When there was no response, we increased intensity in 5 dB steps and presented the signal until the tone was again perceived by the listener. Using this up-5, down-10 procedure, 6 octaves were tested in total: 250, 500, 1000, 2000, 4000, and 8000 Hz. Normal-hearing thresholds were defined as thresholds which are better (or less) than 20 dB. All older listeners passed the threshold of the hearing acuity test.

Next, a word identification task was employed to examine which suprasegmental cue(s) Korean listeners are sensitive to in perceiving Korean stress contrasts, and whether there is a generational difference between older and younger Korean listeners. First, participants saw a screen where two pictures of a Korean stress pair were presented, associated with either number key [1] (first-syllable stressed word, /sa:kwa/ 'apology') or [0] (second-syllable stressed word, /sakwa/ 'apple') on the keyboard. And then, they were asked to identify the auditorily presented word by clicking either the [1] or [0] key. The position of the pictures and the numbers associated with them were counterbalanced. For example, half of the participants saw a picture

of the first-syllable stressed word (e.g., ‘apology’) on the left side of the screen and a picture of the second-syllable stressed word (e.g., ‘apple’) on the right side of the screen, in which [1] was associated with ‘apology’ and [0] was associated with ‘apple’. The other half of the participants saw the pictures associated with the stress pattern in the reversed order, and the numbers were reversed as well. Figure 25 is an example of the screen of the two pictures that the participants saw before making a perceptual judgment on the auditory stimuli.

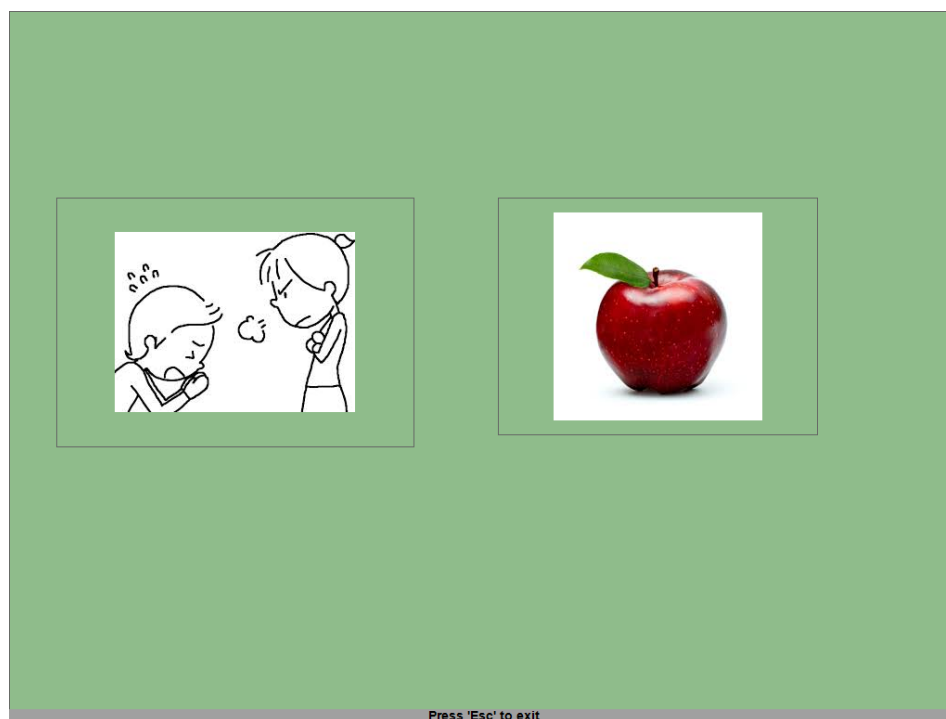


Figure 25. Response screen of the word identification task showing the two pictures of the Korean stress pair in which the first-syllable stressed word, /sa:kwa/ ‘apology’, was associated with [1] and the second-syllable stressed word, /sakwa/ ‘apple’, was associated with [0].

The experiment was conducted with three different blocks of 122 trials in a randomized order. Thus, the experiment consisted of a total of 366 tokens (122 stimuli x 3 repetitions). The intertrial interval (ITI) was 1500 ms from the offset of the response to the onset of the presentation of the following trial. A practice session with 12 trials was conducted before the main experiment to ensure that the participants were familiar with the task. The subjects were allowed to take a short break between the blocks.

3.4.6. Data analysis

We conducted a binomial logistic regression to examine the effect of three acoustic parameters (duration, intensity, and F0) on the perception of the first and second syllable between the two listener groups, using the lme4 package (Bates & Maechler, 2010; Bates, 2005) in the R statistical environment (R development Core Team, 2012, Version 3.1.2). The model had Choice (/sa:kwa/ ‘apology’ vs. /sakwa/ ‘apple’) as a dependent variable, and Group (younger vs. older), Syllable (first vs. second), Intensity manipulation (steps 1-5), Duration manipulation (steps 1-5), and F0 manipulation (steps 1-5) as fixed effects and Participants as random effect. The word with second-syllable prominence, /sakwa/ ‘apple’, was coded as ‘1’ based on the higher frequency of occurrence (/sakwa/ ‘apple’: 63 vs. /sa:kwa/ ‘apology’: 43). The model tested main effects of the independent variables, two-way interactions between the cues (Duration by Intensity, Intensity by F0, F0 by Duration), two-way interactions between Group and Syllable, and three-way interactions among Group and two of the cues (e.g., Group by Duration by Intensity). When there was a significant interaction between the independent variables, we stratified the data by Syllable and Group to probe the interaction between the variables. The older speaker group was used as a baseline against the performance of younger listeners for the comparison, since using the performance of older listeners would allow us to see whether younger Korean listeners have decreased perceptual sensitivity to Korean stress. Thus, the baseline in the model was the older group’s performance on words with second syllable prominence (e.g., /sakwa/ ‘apple’) with intensity 1, duration 1, and F0 1.

3.5. Results

A linear mixed-effects model was conducted on all participants’ responses in identifying the Korean stress pairs. A series of fitted mixed-effects regression models were tested in a

stepwise analysis to find the most parsimonious model. Table 14 presents the result of the logistic regression on both syllables.

Table 14. Summary of results of the optimal model from the logistic regression examining responses at both syllable levels.

Variable	Estimate (SE)	Z	p
(intercept)	7.02 (1.82)	3.85	< .01
Groupyoung	-4.54 (2.29)	-1.98	= .05
Syllable	-4.03 (1.15)	-3.50	< .01
Duration	-2.25 (0.51)	-4.43	< .01
Intensity	0.21 (0.47)	0.45	= .65
F0	0.57 (0.46)	1/23	= .22
Groupyoung:Syllable	2.51 (1.44)	1.74	= .08
Duration:Intensity	0.004 (0.12)	0.04	= .97
Duration:F0	0.02 (0.12)	0.18	= .85
Intensity:F0	-0.16 (0.10)	-1.65	= .10
Groupyoung:Duration	1.24 (0.63)	1.98	= .05
Groupyoung:Intensity	-0.003 (0.59)	-0.01	= .996
Groupyoung:F0	1.18 (0.32)	3.73	= .39
Syllable:Duration	1.18 (0.32)	3.73	< .01

Syllable:Intensity	-0.27 (0.30)	-0.90	= .37
Syllable:F0	-0.31 (0.30)	-1.04	= .30
Groupyoung:Duration:Intensity	-0.06 (0.14)	-0.40	= .67
Groupyoung:Duration:F0	0.10 (0.14)	0.69	= .49
Groupyoung:Intensity:F0	0.18 (0.13)	1.43	= .15
Syllable:Duration:Intensity	-0.01 (0.07)	-0.06	= .95
Syllable:Duration:F0	-0.02 (0.07)	-0.32	= .75
Syllable:Intensity:F0	0.10 (0.07)	1.27	= .14
Groupyoung:Syllable:Duration	-0.74 (0.39)	-1.88	= .06
Groupyoung:Syllable:Intensity	0.10 (0.38)	0.26	= .80
Groupyoung:Syllable:F0	0.42 (0.38)	1.11	= .27
Groupyoung:Syllable:Duration:Intensity	0.06 (0.09)	0.65	= .51
Groupyoung:Syllable:Duration:F0	-0.05 (0.09)	-0.56	= .58
Groupyoung:Syllable:Intensity:F0	-0.14 (0.08)	-1.62	= .11

The results revealed significant main effects of Group ($p = .05$), Syllable ($p < .01$), and Duration ($p < .01$). These results indicate that older listeners' responses were more biased toward the first-syllable stressed word /sa:kwa/ (68 %) than those of younger listeners (57 %), and the listeners' response was biased toward the first-syllable stressed word (74%) when the second syllable was

manipulated, as compared to the tokens for which the first syllable was manipulated (50%). Also, the probability of responding to the second-syllable stressed word was 53 % when the duration step was at 1, and decreased to 45%, 37%, 30%, and 27% when the duration step was at 2, 3, 4, and 5, respectively. We also found significant interactions between Group and Duration ($p = .05$), and Syllable and Duration ($p < .01$). In order to have a better understanding of these interactions, we stratified the data by Syllable, and then ran two separate models at each syllable level.

In order to understand the interactions between Syllable and cues, we conducted separate linear mixed-effects models examining all participants' responses to the tokens for which the first syllable was manipulated. The main effects of Group ($p < .01$) and Duration ($p < .01$) indicate that older listeners gave more initial prominence responses (54 %) than younger listeners (47 %), and as the duration on the first syllable increased, listeners' responses shifted from words with second-syllable prominence to first-syllable prominence. The second-syllable prominence response rate was 78 % when the duration step was at 1, and decreased to 65%, 48%, 34%, and 27% when the duration step was at 2, 3, 4, and 5, respectively. Table 15 presents a summary of results of the model at the level of the first syllable.

Table 15. Summary of results of the logistic regression examining responses at the first syllable level

Variable	Estimate (SE)	Z	P
(intercept)	2.80 (0.28)	9.85	< .01
Groupyoung	-1.40 (0.37)	-3.76	< .01
Duration	-1.00 (0.57)	-17.83	< .01
Groupyoung:Duration	0.59 (0.07)	8.50	< .01

Figure 26 presents the probability of second-syllable stressed responses between the two groups for the tokens for which three acoustic cues of the first syllable were manipulated, showing the different use of the duration cue (red lines) between the two listener groups (old: dashed lines; younger: solid lines) in perceiving Korean stress pairs.

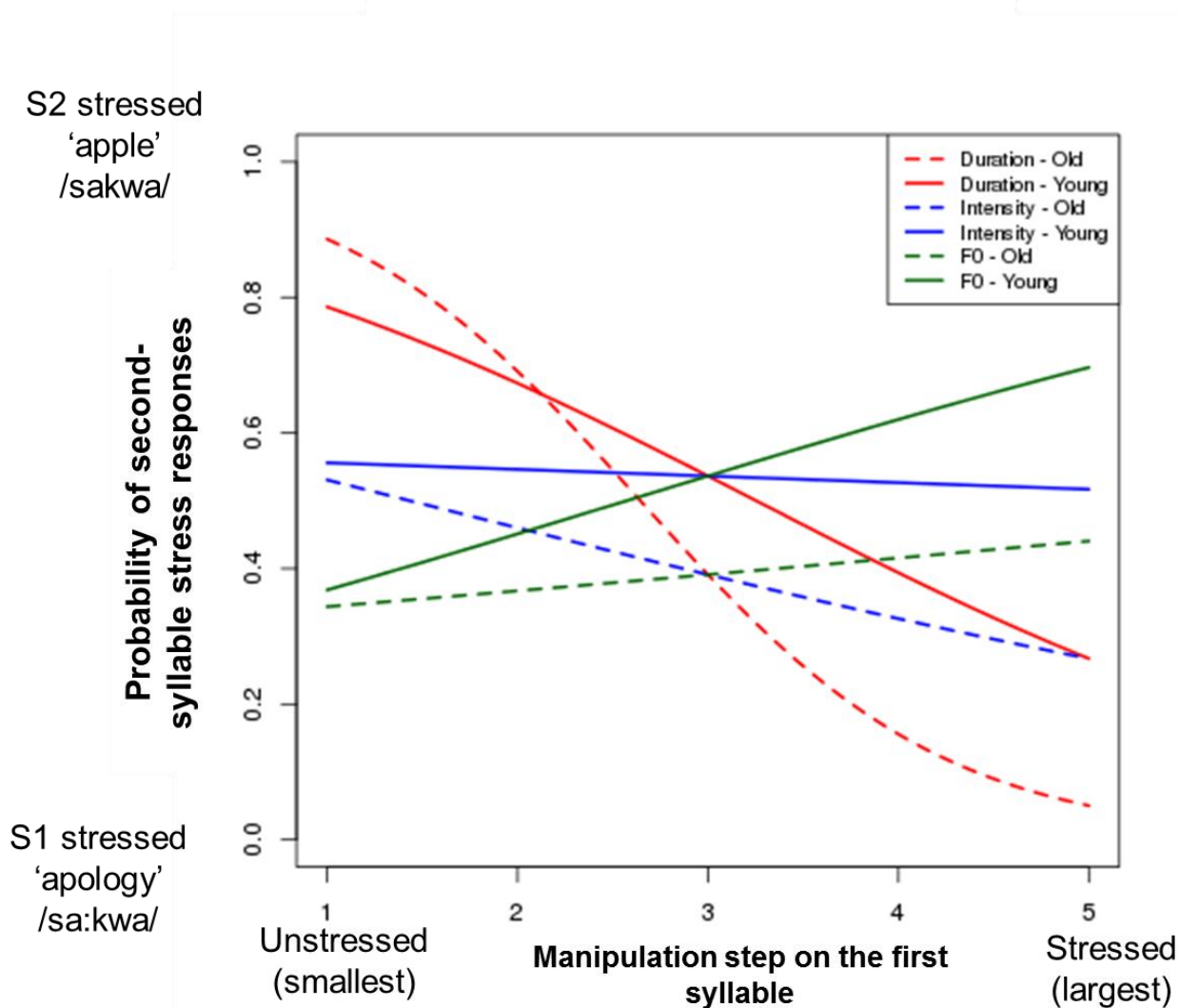


Figure 26. Probability of second-syllable stressed responses, /sakwa/, between the two listener groups. X-axis indicates the manipulated steps of each cue. 1 indicates that duration values were at the minimum endpoint, expressing first-syllable unstressed; and 5 indicates that duration values were at the maximum endpoint, expressing first-syllable stressed. Dotted lines indicate older Korean listeners' responses, and solid lines indicate younger Korean listeners' responses. Listeners' responses for each cue are illustrated with different colors: red, blue, green lines indicate listeners' responses for duration, intensity, and F0, respectively.

In order to find out the interactions between Group and Duration, we further conducted a separate linear mixed-effects model examining participants' responses to the tokens for which the first syllable was manipulated as a function of the listener groups (see Table 16). For the older listeners, we found a main effect of Duration ($p < .01$), indicating that older listeners' second-syllable stressed responses increased as the duration decreased. The second-syllable stressed response rate was 52 % when the duration step was at 1, and decreased to 41 %, 31 %, 22 %, and 17 % when the duration step was at 2, 3, 4, and 5, respectively.

Table 16. Summary of results of the logistic regression examining responses of older listeners at the level of the first syllable

Variable	Estimate (SE)	Z	P
(intercept)	2.81 (0.31)	8.94	< .01
Duration	-1.01 (0.06)	-17.81	< .01

For younger listeners, we also found a main effect of Duration ($p < .01$), indicating that the probability of the second-syllable stressed responses increased as the duration decreased (see Table 17). The second-syllable stressed response probability was 54 % when the duration step was at 1, and decreased to 48 %, 42 %, 36 %, and 35 % when the duration step was at 2, 3, 4, and 5, respectively.

Table 17. Summary of results of the logistic regression examining responses of younger listeners at the level of the first syllable

Variable	Estimate (SE)	Z	P
(intercept)	1.39 (0.22)	6.46	< .01
Duration	-0.42 (0.04)	-10.72	< .01

A separate linear mixed-effects model examining all participants' responses to the tokens for which the second syllable was manipulated, found no main effects or interactions, indicating that none of the listener groups were using the duration cue in perceiving Korean stress pairs. Table 18 presents the result of the logistic regression, and Figure 27 represents older and younger listeners' responses as a function of manipulated steps of three cues, showing the lack of effect of acoustic cues on the perception of the Korean stress pairs on the second syllable.

Table 18. Summary of results of the logistic regression examining responses of both listener groups at the second syllable level

Variable	Estimate (SE)	Z	P
(intercept)	-2.15 (0.59)	-3.65	< .01
Groupyoung	1.27 (0.77)	1.64	= .10
Duration	-0.03 (0.04)	-0.79	= .43

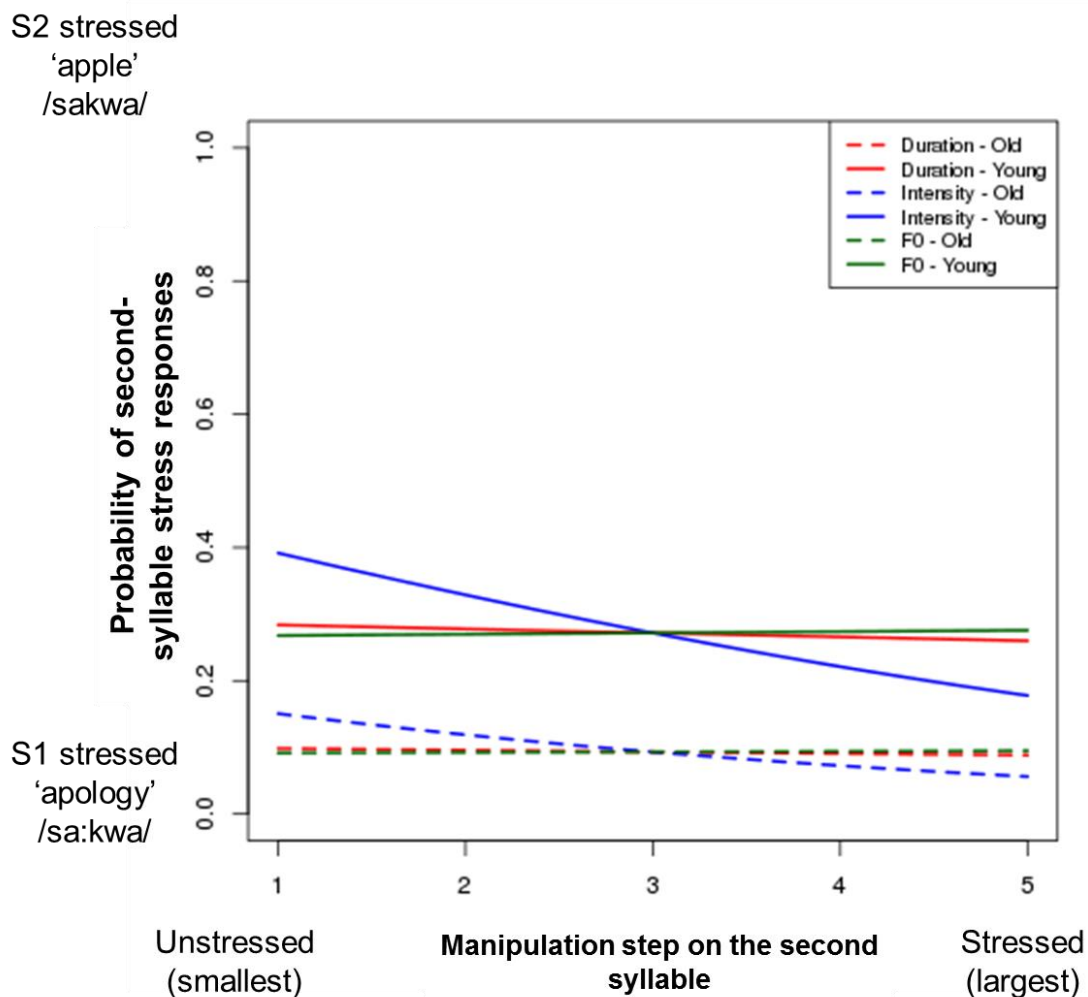


Figure 27. Probability of second-syllable stressed responses, /sakwa/, between the two listener groups. X-axis indicates the manipulated steps of each cue. 1 indicates that duration values were at the minimum endpoint, expressing first-syllable unstressed; and 5 indicates that duration values were at the maximum endpoint, expressing first-syllable stressed. Dotted lines indicate older Korean listeners' responses, and solid lines indicate younger Korean listeners' responses. Listeners' responses for each cue are illustrated with different colors: red, blue, green lines indicate listeners' responses for duration, intensity, and F0, respectively.

3.6. Summary of results

The current chapter examined whether Korean listeners' perception of stress changed as acoustic cues vary. The main finding of this chapter is that neither older nor younger Korean listeners use multiple cues to perceive prominence in Korean. When examining the cue weighting of the Korean listeners, we also found different patterns as a function of syllable manipulation. For the first syllable, we found a group effect on the perception of Korean stress pairs, indicating that older Korean listeners' cue weighting is different from that of younger

listeners, as supported by the two-way interaction between Duration and Group. We also found main effects of Duration on listeners' perception of /sakwa/ tokens, indicating that as duration varied in the tokens, listeners' perception changed from first- to second-syllable stressed words. This was interesting in the sense that younger listeners still use duration despite the fact that Korean is losing the duration due in the production. When examining the interactions between cues and among cues and Group, we found no interaction between Duration and Intensity, Intensity and F0, or F0 and Duration, indicating that listeners do not use multiple cues when perceiving Korean stress pairs.

In addition, when examining the cue weighting on the second syllable, we found that manipulation of the cue does not elicit perceptual changes, as supported by the lack of main effects as well as interactions. This result adds stronger evidence to suggest that Korean does not have lexical stress, since listeners' perception of prominence is not changed as a function of cue variation.

In sum, the current chapter found a generational difference between Korean listeners in their perceptual cue weighting. However, changes in cues in the second syllable do not affect perception of the prominence for Korean listeners.

3.7. Discussion

In this chapter, we conducted a perception study investigating whether Korean has lexical stress, and if so, which cue(s) Korean listeners use in perceiving word-level prominence in Korean. We hypothesized that if Korean listeners use one or more cues in addition to duration in perceiving word-level prominence, Korean has lexical stress; if Korean listeners only use duration, Korean has a phonemic vowel length distinction; if Korean listeners use duration in the first syllable and intensity and F0 in the second syllable, independently from duration, then Korean has both a phonemic vowel length distinction and lexical stress. We also investigated

whether Koreans use the same cues in their perception and production. Considering that the vowel length distinction has disappeared in contemporary Seoul Korean, younger listeners might not be sensitive to duration as much as older listeners. We also examined whether Korean listeners use intensity in their perception, as they do in their production.

The results revealed several interesting facts. First, we found that neither older nor younger Korean listeners use intensity and F0 independently from duration in identifying prominence in Korean. Both older and younger Korean listeners used only the duration cue in identifying Korean stress pairs. In addition, we also found that regardless of the fact that contemporary Seoul Korean has lost the vowel length distinction, younger Korean listeners still weight duration. This is surprising, given that younger Korean speakers do not have a vowel length distinction in their production. According to exemplar theory (Goldinger, 1996; K. Johnson, 1997), listeners mentally store variant details of speech sounds in their episodic memory, while mapping similar tokens into a single abstract category as a large cloud of exemplars. Highly similar tokens are tightly clustered and organized within a category, while dissimilar tokens are far apart and mapped onto two different categories. However, an exemplar-based model predicts that the production of categories may be deviant from perception, since the lexical entries that each listener stores are gathered from different speakers (Bybee, 2001; Johnson, 1997; Pierrehumbert, 2000, 2001). In the present case, this suggests that younger Korean speakers may have stored both long and short vowels as bad exemplars of a single category, reflecting the loss of the vowel length distinction in their production. However, the variations in the categorized percept (e.g., older speakers' contrastive production of the vowel length distinction) may have influenced younger listeners' perceptual sensitivity in identifying the vowel length contrasts. In other words, although younger listeners have not developed two

distinct vowel length categories, since younger listeners have collected both long vowels as in some of exemplars of /sa:kwa/ ‘apology’ and short vowels for /sakwa/ ‘apple’, the younger listeners may recognize this pair based on the duration of the vowel. This view, then, is compatible with our finding that younger Korean listeners still are sensitive to phonemic vowel length although the vowel length distinction no longer appears in their production. If the exemplars that each listener gathers affect category shift in language change (Bybee, 2000; Pierrehumbert, 2001), it will be interesting to investigate as a future study whether the loss of the vowel length distinction occurs earlier in high-frequency tokens than in low-frequency tokens, or vice versa. Also, it will be interesting to examine if it is the case that the earlier speakers are exposed to older speakers’ productions, the more resistant to the loss of the vowel length distinction they will be.

Another interesting finding is that only cue manipulation in the first syllable influenced listeners’ responses; a perceptual shift from the first-syllable stressed word to the second-syllable stressed word was not found when the second syllable was manipulated in terms of duration, intensity, and F0. Given that stress is defined as the relative difference in prominence between two syllables (Pierrehumbert, 1979; Beckman & Pierrehumbert, 1986), the fact that the cue manipulation in the second syllable did not trigger perceptual change of the stress location indicates that Korean listeners only put perceptual weight on the first syllable. If Korean had stress, the changes in prominence in the second syllable should also induce the perceptual shift; however, the current study did not find such a pattern. Therefore, taking into account these two pieces of evidence provided by the current perception study, in addition to the acoustic evidence from Chapter 2, we can conclude that Korean does not employ lexical stress, and that what has been claimed as stress pairs are actually vowel length contrasts. This finding is important, since

based on the status of word-level prominence in Korean, we may be able to predict how Korean learners of English can acquire lexical stress in their second language (L2), which will be investigated in the following two chapters.

Overall, the findings of the current chapter revealed that Korean does not employ word-level prominence, but that only vowel length contrasts on the first syllable differentiate (so-called) Korean lexical stress pairs. Based on these findings about production and perception of word-level prominence in Korean in Experiments 1 and 2, we will now investigate how Korean learners of English acquire lexical stress in a second language (L2) in two domains—production and perception. More specifically, we will examine whether L2 learners can acquire a new phonological feature (i.e., English lexical stress) if and only if learners' L1 has the same phonological feature, or whether L2 learners can transfer cues to higher-level prosodic domains from their native language and use them in learning a new phonological feature. More detailed research questions and hypotheses regarding the L2 production and L2 perception studies will be provided in the following two chapters.

CHAPTER IV.
INTRODUCTION TO PRODUCTION AND PERCEPTION OF ENGLISH
LEXICAL STRESS BY KOREANS

4.1. Introduction

If the feature of word-level prominence in the first language (i.e., Korean) is typologically distinct from that in the second language (i.e., English), can Korean learners learn to weight acoustic cues to English prominence as English native speakers do? The Stress Parameter Model (SPM; Peperkamp, 2004; Peperkamp & Dupoux, 2002) posits that the ability to encode stress patterns in the phonological representation is determined at an early stage of life. Therefore, according to the SPM, typological similarity between L1 and L2 will determine whether the stress patterns in the second language can be acquired by the learners. However, it might be the case that the age of acquisition does not matter as much as originally predicted, since simultaneous French-English bilinguals did not behave like English monolinguals in their sequence-recall tasks (Dupoux, Peperkamp, & Sebastián-Gallés, 2010).

The Cue Weighting Model of L2 speech perception posits that speakers with different native languages put different degrees of perceptual weight on phonetic cues because the importance of the cues varies across languages (e.g., Francis & Nusbaum, 2002; Holt & Lotto, 2006; Ingvalson, McClelland, & Holt, 2011; Zhang & Francis, 2010). The Cue Weighting Model bases its claim on empirical research regarding L2 learners' perceptual difficulty in learning L2 categories and explains that L2 learners' perceptual difficulty is caused by their different cue weighting based on the importance of the cue in their L1. In other words, while multiple cues are available on the surface form, the cues that are attuned to by L2 listeners depend on how these cues are weighted in their L1. When a cue is heavily weighted by an L2 listener, other cues are weighted less, showing a trade-off relation between the cues. Thus, the Cue Weighting Model

emphasizes that phonetic properties of the surface form are as important as abstract phonological features, suggesting that L2 listeners can use the correct acoustic cues in distinguishing L2 categories as long as the same cue is used in L1.

Thus, in the case of Korean learners' acquisition of English stress, the prediction made by the Cue Weighting Model is contrary to that of the Stress Parameter Model, since all suprasegmental cues (e.g., duration, F0, and intensity) indicating lexical stress in English are also available at higher-prosodic levels in Korean. However, considering that the status of word-level prominence in modern Korean is not yet clearly defined, it is difficult to predict whether Korean learners will be able to produce and perceive English lexical stress based on the typological relation between Korean and English, as SPM predicts, or will transfer cues from Korean, as the Cue Weighting Model predicts. Additionally, since no previous studies have directly investigated the acoustic correlates of Korean word-level prominence for younger Korean speakers, we do not know yet which phonetic cue(s) Korean speakers would use in producing and perceiving English lexical stress. This point will be the second main research question of the current dissertation.

First, we will review several second language acquisition studies that investigated the production and perception of English lexical stress by Koreans as well as the perceptual cue weighting of Chinese learners of English. Although this literature does not give us direct evidence of how Korean learners may use acoustic parameters in producing and perceiving Korean lexical stress, we can at least infer from the L2 data whether the English prosodic features (i.e., stress) can be acquired. Then, the main research questions and hypotheses of the current study will be proposed.

4.2. Production of English lexical stress by Korean early and late bilinguals

Lee, Guion, and Harada (2006) investigated whether the prosodic features of Korean influenced the acquisition of L2 English stress patterns, and whether any differences emerged as

a function of age of acquisition. The study compared productions of unstressed reduced English vowels by two groups of speakers – early bilinguals vs. late bilinguals. Ten English speakers, 10 Korean early bilinguals (Age of Acquisition: mean = 3.9, range = 1.7), and 10 Korean late bilinguals (Age of Acquisition: mean = 21.4, range = 6.3) recorded 19 English words embedded in a carrier sentence. The target words were chosen based on the orthographical representation and location of unstressed syllables within words (initial, medial, or final). Table 19 represents the stimuli used by Lee et al., (2006). The primary stress is marked with accent marks, secondary stress is marked with a grave accent and unstressed syllables under examination are bolded.

Table 19. English words examined in Lee et al., (2006). Unstressed syllables are marked in bold, syllables with primary stress are marked with acute accent, and syllables with secondary stress are marked with a grave accent

Orthographic representation	Unstressed vowel in initial position	Unstressed vowel in medial position	Unstressed vowel in final position
/a/	agénda banána machíne spaghétti	kàngaróo mánage	agénda banána
/e/	descént eléven	básket cáendar cómpensate ágent	médiúm
/i/	giráffe	índicate órigín	
/o/	posséss potáto	íntrodúce	

The early bilingual group was exposed to English before the age of 6, and the late bilingual group after the age of 15. Five acoustic parameters – F0, intensity, duration, F1, and F2 – were measured in both the unstressed and primary stressed syllables. F0 and intensity were measured at the peak of the vowels. The mean ratio of the duration, F0, and intensity was calculated based on the difference between unstressed and stressed vowels in a given word.

The results indicated that Korean speakers were not able to use duration and intensity in an English-like manner, but were able to use F0 in an English-like manner in their production of unstressed syllables. Both early and late Korean bilinguals produced stressed syllables with longer duration than unstressed syllables, but the duration ratio was significantly bigger than for the native English speakers (See Figure 28). The Korean speakers also produced stressed syllables with a higher F0 than unstressed syllables, in the same way that the English speakers did. Regarding intensity, both Korean bilingual groups produced unstressed syllables with smaller intensity values than the stressed syllables (2.4 dB for the early bilinguals; 3.2 dB for the late bilinguals). These differences were significantly smaller than the differences produced by native speakers (5.1 dB). Figure 28 represents the mean ratio of the duration, F0, and intensity of unstressed to stressed vowels, adopted from Lee et al. (2006).

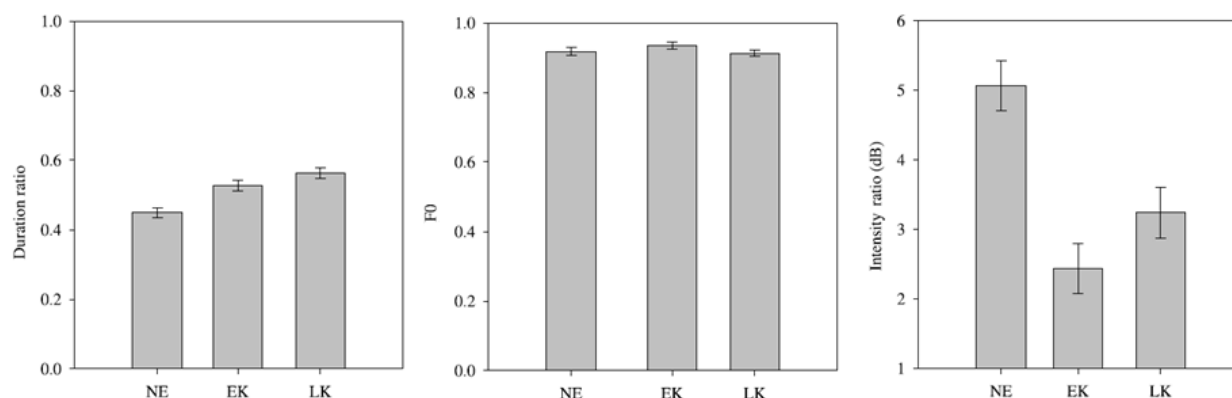


Figure 28. The mean ratio and standard error of the unstressed-to-stressed duration ratio (left), unstressed-to-stressed F0 ratio (middle), and stressed-to-unstressed intensity ratio (right). Adopted from Lee et al. (2006, p 500 - 503) (NE = Native English, EK = Early Korean bilinguals, LK = Late Korean bilinguals)

The results related to vowel quality, however, suggested that the Korean learners of English substituted the Korean high central vowel [ɨ] instead of using schwa when producing a reduced vowel. The normalized F1 values (in mel) from the early Korean bilingual speakers were higher than those of the native speakers, and late Korean bilinguals' productions were dispersed in the vowel chart. Figure 29 represents normalized F1 and F2 values of the three

groups. Each underlying vowel is represented with the corresponding Roman alphabet letter. While native English speakers produced unstressed vowels with formant frequencies similar to those of their underlying representations, Korean early bilinguals produced unstressed vowels in a similar way regardless of the underlying vowel. The unstressed syllables produced by late Korean bilinguals, on the other hand, showed greater dispersion than either of the two other groups, indicating that late Korean bilinguals reduced vowel quality of the unstressed syllables the least.

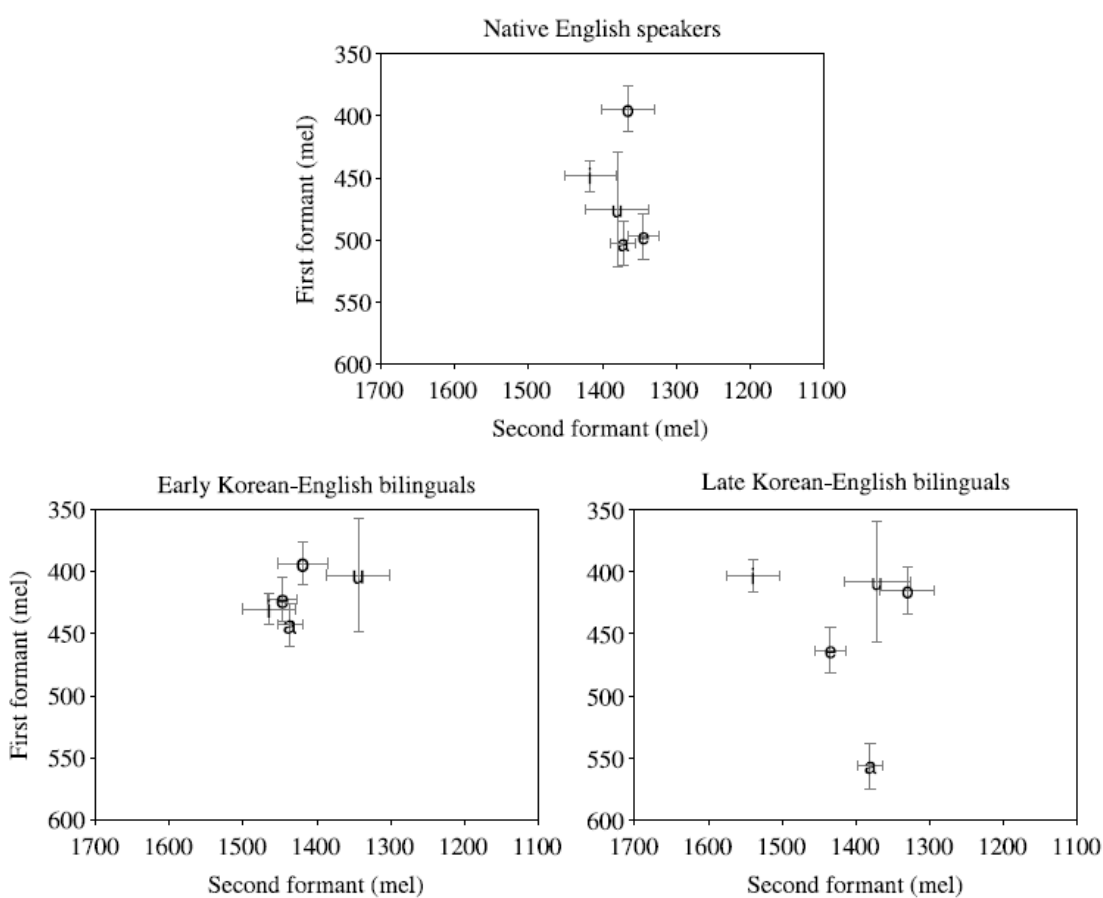


Figure 29. Normalized F1 and F2 mean values of unstressed vowels by orthographical representation. Adopted from Lee et al. (2006, p 504)

In addition, the Euclidean distance (in mel) between stressed and unstressed vowels showed a similar result: late Korean bilinguals' productions showed the greatest Euclidean

distance (117.7 mel), followed by native English listeners (70.2 mel) and early bilinguals (59.0 mel). Since English unstressed syllables do not have a target vowel, the reduced vowel quality is more subject to coarticulation with neighboring sounds (Browman & Goldstein, 1992). The smallest Euclidean distance of the early bilinguals' productions, therefore, indicates that early bilinguals consistently produced unstressed syllables with the Korean mid high vowel [ɪ], because if they had reduced vowel quality in a native-like way, then the perceptual distance would be comparable to that of native English speakers' productions. On the other hand, late bilinguals neither reduced vowel quality nor showed vowel substitution consistently: they only showed vowel substitution sporadically for the [u] and [o] vowel contexts.

Taken together, Korean learners of English could use F0 in a native-like manner in producing English lexical stress regardless of the age of acquisition, but intensity, duration, and vowel reduction were not acquired at a native-like level even if the speakers were exposed to English at a young age. However, early bilinguals were still able to use these three cues more than late bilinguals. Although neither bilingual group showed exactly the same vowel reduction as the native speakers, we can speculate at least that early bilinguals' over-substitution and late bilinguals' partial substitution reflect their learning process of new spectral cues to implement English stress.

Following Lee et al. (2006), Han, Hwang, and Choi (2011) also examined the production of vowel reduction of English unstressed syllables by Korean learners of English, and whether the length of residence (LOR) influenced their production of English stress. Taking the position of Flemming and Johnson (2007), Han et al. (2011) argued that English reduced vowels have different phonetic variants as a function of phonological positions, and examined whether Korean learners could acquire these phonetic details in L2 as a function of residency in an

English-speaking country. Previous studies (Choi, 2008; Flemming & Johnson, 2007) have argued that English unstressed syllables turn into schwa in stem-final position (e.g., *Rosa*) and into [ɪ] elsewhere (word-initially: *today*; word-internally: *roses*). Based on this claim, Han et al. (2011) also examined whether the unstressed vowels are acoustically different in different phonological positions: word-initially, internally, and finally.

To examine the production of unstressed syllables, Han et al. (2011) examined the unstressed-to-stressed syllable duration ratio as well as the F1 and F2 values from the three phonological positions in order to measure degree of vowel reduction. With respect to duration, surprisingly, the duration ratio from the productions of native English speakers was smaller than those of Korean speakers. Specifically, L2 learners without immersion (0.72) showed a greater ratio difference than native speakers' productions (0.65) and than L2 learners with immersion (0.61). The phonological position also showed an effect on the duration ratio, resulting in the greatest duration ratio for stem-final position (e.g., *Rosa*) (0.88), followed by word-internal position (e.g., *roses*) (0.66), and word-initial position (e.g., *assist*) (0.45)

In order to examine vowel reduction, the perceptual distance between the stressed and unstressed syllables was calculated, following Nordström & Lindblom (1975). Han et al. (2011) found that the F1 and F2 values of the Korean L2 learners with immersion were closer to those of native English speakers than those of Korean L2 learners without immersion. With respect to the phonological position of the reduced vowel, English speakers showed a significant difference in F1 values between word-initial position (e.g., *assist*) and word-internal position consisting of a mono-morphemic stem word and suffix (e.g., *roses*), whereas both groups of Korean learners showed a significant difference in all three phonological positions (e.g., word-initial (*assist*) vs. stem-final (*Rosa*); word-internal (*roses*) vs stem-final (*Rosa*); word-initial (*assist*) vs. word-

internal (*roses*). With respect to the F2 values, there was no significant difference between word types for native speakers, but there was a significant difference for the Korean learners. Korean learners without immersion produced each word pair differently, while Korean learners with immersion showed a difference only between stem-final position (e.g., *Rosa*) and word-internal position (e.g., *roses*) and between word-initial position (*assist*) and word-internal position (e.g., *roses*). With these results in hand, Han et al. (2011) concluded that English speakers have two allophones in terms of vowel height in producing unstressed English syllables (e.g., [ə] for *assist*, *Rosa*, [ɪ] for *roses*), while Korean learners had a three-way distinction. There was no difference in terms of vowel frontness in English speakers' productions, since both [ə] and [ɪ] are central vowels. However, Korean learners without immersion had a three-way distinction, while Korean learners with immersion showed a two-way distinction, like native speakers. These results indicate that with immersion, Korean L2 learners of English can acquire a new feature to express English stress.

Taken together, both Lee et al. (2006) and Han et al. (2011) found that Korean learners of English were not able to acquire vowel reduction at a native-like level. However, interestingly, both studies have suggested that some degree of vowel reduction, albeit non-native like, was acquired by Korean learners of English. In the following two sections, we will review studies that examined the perception of English lexical stress by Korean and Mandarin Chinese (hereafter: Mandarin) learners of English. Previous studies have not clearly examined whether Korean has word-level stress. However, claims have been made that Beijing Mandarin Chinese has lexical stress (Chen & Xu, 2006; Duanmu, 2007). In Mandarin, the stressed syllables are produced with a full vowel, longer duration, and greater amplitude while carrying a lexical tone (Duanmu, 2007). The unstressed syllables are produced with reduced vowel quality and smaller

articulatory movements while carrying a neutral tone. The following section reviews how different L1 prosodic systems affect the acquisition of an L2 prosodic system, and which perceptual cues are utilized in perceiving L2 lexical stress.

4.3. Perception of English lexical stress by Korean learners of English

Lin, Wang, Idsardi, and Xu, (2013) examined how the typological difference between first languages (Mandarin Chinese vs. Korean) affects the acquisition of lexical stress in L2 (i.e., English). Considering that Mandarin Chinese has lexical stress that is realized with similar acoustic correlates to English, Lin et al. (2013) predicted that Korean learners of English would have more difficulty perceiving English stress patterns as compared to Mandarin learners of English. The English proficiency of the two non-native groups was controlled so that the learners' performance in perceiving stress patterns was not confounded with participants' L2 proficiency. Two experiments – a sequence recalling task (Experiment 1) and a lexical decision task (Experiment 2) – were conducted to examine how the two different learner groups perceived English lexical stress patterns.

In a sequence recall test, a total of 60 listeners (19 Korean, 20 Mandarin, 21 English) were instructed to associate nonwords with the numbers [1] or [2] on a keyboard and hit the corresponding key after hearing a nonword. The nonwords were minimal pairs that were distinguished either segmentally (e.g., ['kupi] vs. ['kuti]) or suprasegmentally (e.g., ['mipa] vs. [mi'pa]). After 7 consecutive correct answers, the participants proceeded to the test phase. The test phase consisted of five blocks in an ascending order of number of word sequences (e.g., 1st block: 2 sequences, 2nd block: 3 sequences, etc.) in which the listeners had to indicate the sequence of the segmental or suprasegmental nonword minimal pairs. A visual representation (e.g., “two sequences”) indicating the number of sequences was provided at the beginning of each block. The participants answered right after the visual presentation of an “OK” sign on the

screen. The participants had to hit the correct and right number of keys for each sequence in order to proceed to the next trial within 5000 ms. No feedback was given during the test phase.

Both learner-groups' accuracy rates were significantly different from that of native English listeners for the stress-minimal pairs ($p < .001$). Interestingly, Mandarin listeners outperformed both English and Korean listeners in recalling sequences. Both Korean and English listeners performed worse when recalling the sequence of stress-minimal pairs than the segmental minimal pairs, while Mandarin listeners performed equally well on stress minimal pairs and segmental minimal pairs. The authors claimed that the lack of reduced vowel quality in the stimuli might have made the detection of stress more difficult for native listeners since native English listeners rely more on the segmental cue (i.e., vowel quality) in perceiving unstressed syllables than the suprasegmental cues (i.e., duration, intensity, and F0) (Cutler & van Donselaar, 2001; Cutler, 1986).

A second experiment was conducted with a lexical decision task to examine whether the three groups of listeners would benefit from reduced vowel quality, and also whether word frequency affects stress perception for non-native listeners. Since there is no vowel reduction in Korean, it was expected that vowel reduction in the unstressed syllable would not be facilitative for Korean listeners to process lexical stress. On the other hand, since Mandarin employs vowel reduction as a cue to implement stress (Duanmu, 2007; Shen, 1993), Mandarin speakers may benefit from spectral cues in perceiving English lexical stress.

A total of 54 participants (18 Korean, 17 Mandarin, and 19 English) took a lexical decision test. They heard a total of 180 word-to-nonword minimal pairs that either varied by stress location (60 disyllabic pairs, and 60 trisyllabic pairs) or segmental contrast (60 pairs; e.g., “*away*” [ə'wei] vs. [ə'mei]). Half of the stress-contrastive minimal pairs contained schwa in the

unstressed syllable (e.g., “human” /'hjumən/ vs. nonword /hju'mæn/), and the other half did not (e.g., “between” [br'twin] vs. ['bitwin]).

Generalized mixed-effects logistic regressions showed a significant interaction between language group and vowel change ($p < .003$ between Korean and English listeners; $p < .014$ between Mandarin and English listeners). This result indicates that while English listeners benefited from the vowel reduction cue in accurately rejecting nonwords, neither Korean nor Mandarin listeners showed a significant difference in rejecting nonwords as a function of vowel change. However, when comparing the performance between Mandarin and Korean listeners, Mandarin listeners were more accurate in performing the lexical decision task in general ($p < .02$). Moreover, a significant interaction between language group and learners' proficiency levels was found ($p < .001$), suggesting that Mandarin listeners with higher L2 proficiency benefited from the vowel quality change in performing the lexical decision task, while Korean listeners did not. In other words, Mandarin listeners learned to use the vowel change cue in identifying nonword-to-word stress minimal pairs as their proficiency increased; however, such an effect was not found in the results from Korean listeners. Although more proficient Korean learners performed better on the lexical decision task, they were not affected by the vowel change. Additionally, only Korean listeners were less accurate in correctly rejecting high-frequency nonwords (e.g., [hju'mæn] from “human”) as compared to low-frequency nonwords (e.g., [pou'ʃen] from “potion”) ($p < .002$). Neither Mandarin nor English listeners showed such a frequency effect on lexical judgment. These results seem to suggest that segmental cues did not help non-native listeners as much as native listeners, but the effect of vowel change on word recognition varied by the learners' first language.

In conclusion, this study found that the learnability of L2 lexical stress is dependent on the typological similarity of lexical stress between L1 and L2; however, the absence of lexical stress in L1 does not necessarily mean that learners cannot develop stress contrast processing abilities in the L2.

4.3.1. The role of vowel quality in native and nonnative listeners' perception of English lexical stress

Zhang and Francis (2010) compared the contribution of vowel quality to that of other cues (i.e., duration, intensity, and F0) in perceiving English lexical stress; they also examined whether the contribution differs as a function of the listeners' native language. Although previous research has found that Mandarin Chinese uses vowel reduction as a cue to lexical stress, Mandarin learners of Chinese often show difficulties in producing English unstressed syllables with reduced vowel quality (Lai, 2008; Zhang, Nissen, & Francis, 2008). Two groups of listeners – 24 Mandarin learners of English and 24 English native listeners – participated in three experiments. The Mandarin listeners completed a self-reported English proficiency questionnaire on a scale of 1 (poor) to 10 (excellent) before the main experiment. The average self-reported score was 7 (ranging from 6 to 8). The first experiment tested cue weighting of vowel quality and F0 with one minimal stress pair (i.e., *DE*sert vs. *de*SERT). The original token was produced by a female native English speaker and then the two dimensions (vowel quality and F0) were manipulated in 7 steps from stressed to unstressed. First, a stress-ambiguous token of “*desert*” was created by manipulating the first and second syllables to have the average values of stressed and unstressed syllables. This token and 12 other filler words were judged by 5 native English listeners in terms of the stress location. Results showed that the ambiguous token was judged as a noun in 47% of cases and as a verb in 53% of cases. Because listeners might be slightly biased to verb judgments because of the longer duration of the second syllable, the

second syllable was shortened by 10 ms for the main experiment. Then, the first syllable of the ambiguous token, ‘*de-*’, was manipulated in two dimensions so that two cues (vowel quality and one of the suprasegmental cues) would signal stress. The second syllable ‘*-sert*’ was also controlled to be ambiguous by taking the baseline token. Thus, a total of 49 tokens were created for each experiment.

For the first experiment, the vowel quality and F0 of the first syllable ‘*de-*’ was orthogonally manipulated in 7 steps signaling stressed (vowel quality for [ɛ]: F1 = 597 Hz, F2 = 1854 Hz, F3 = 2786 Hz; F0 for [ɛ] = 213 Hz) to unstressed (vowel quality for [ɪ]: F1 = 462 Hz, F2 = 1964 Hz, F3 = 2975 Hz; F0 for [ɪ] = 204 Hz). Duration and intensity were controlled to be constant by taking the mean value across the stressed and unstressed syllables. For the second experiment, vowel quality and duration were orthogonally manipulated signaling stressed (duration: 155 ms) to unstressed syllables (duration: 104 ms) in 7 steps while controlling intensity and F0 to be ambiguous. For experiment 3, vowel quality and intensity were orthogonally manipulated in 7 steps signaling stressed (intensity: 74 dB) to unstressed syllables (64 dB) while controlling F0 and vowel duration to be constant. The second syllable ‘*-sert*’ was controlled to be ambiguous throughout the three experiments. Thus, a total of 49 tokens were created for each experiment. The manipulated tokens were then played in randomized order with 10 repetitions for a total of 490 tokens. On each trial, the listeners were asked to identify the word category of the token presented with a visual representation of the possible choices (e.g., DEsert (noun) vs. deSERT (verb)). The responses of the first block were eliminated from the analysis, as those responses were considered as the familiarization period.

Three separate logistic regressions were conducted to compare the difference in cue weighting between vowel quality and one of the other parameters (F0, duration, intensity)

between two groups (Mandarin vs. English). The results of the three experiments showed that both English and Mandarin listeners were able to use all four cues in perceiving lexical stress. Additionally, both groups weighted vowel quality more heavily than suprasegmental cues ($p < .001$), indicating that Mandarin listeners were able to use spectral cues in a native-like way although their English production did not show appropriately reduced vowel quality (Zhang et al., 2008).

In terms of the suprasegmental cues, while English listeners were able to use all three cues, Chinese listeners were able to only use duration and F0 in perceiving lexical stress. The two listener groups treated spectral cues and suprasegmental cues differently. Mandarin listeners showed an interaction between vowel quality and F0 ($p < .001$), indicating that they identified the first syllable as stressed when both F0 and vowel quality cued stress, while English listeners identified the first syllable as stressed when it either had a higher F0 or full vowel quality. Regarding the use of duration, both groups showed a significant interaction between vowel quality and duration ($p < .001$), indicating that both groups identified the first syllable as stressed when it had a full vowel quality and longer duration. For intensity, while Mandarin listeners did not use intensity in identifying stress, English listeners treated spectral cues and intensity independently: English listeners identified the first syllable as stressed when it either had a greater intensity or full vowel quality.

In sum, this study found that vowel quality is the most salient cue for both Mandarin and English listeners. The native English listeners' cue weighting of the spectral cue was consistent with previous findings (Cutler, 1986; Sluijter & van Heuven, 1996). However, it was surprising that Chinese listeners were able to use spectral cues in perceiving lexical stress while not being able to use them in their production. The use of spectral cues by Mandarin listeners was also

reported by Lin et al. (2013), who found that vowel reduction facilitated the more proficient Mandarin listeners' performance on the lexical decision task. Mandarin listeners also showed that they used spectral cues and F0 in a combined manner, while English listeners used them in an independent manner. Since the phonemic role of F0 in Chinese is as important as segmental cues, it might be the case that Mandarin listeners have learned to treat spectral cues and F0 in an integral manner (Lee & Nusbaum, 1993).

4.4. Statement of problem

The four studies that we reviewed so far found that the dissimilar word-level prominence between the first language and second language of L2 learners might have contributed to the disadvantage in producing and perceiving L2 stress contrasts. As the Stress Parameter Model (SPM) postulates, Korean listeners were not able to develop a perceptual strategy to efficiently store stress cues in their short-term memory because they were not exposed to lexical stress from infancy. However, contrary to the SPM, both Lee et al. (2006) and Lin et al. (2013) found evidence that the L2 learners still could acquire L2 prosodic features to some degree even if they do not exist in their L1. This is a crucial finding from both papers: Even late learners of English can produce L2 stress contrasts very proficiently although not at a native-like level (Lee et al., 2006; Han et al., 2011), and non-advanced learners can also perceive the acoustic differences of stress contrasts above chance level (Lin et al., 2013). Both studies predicted that Korean listeners would not be able to employ duration in implementing stress contrasts because Korean no longer has phonemic vowel length. However, English, a very well-established stress language, uses duration to indicate stress while it does not have a phonemic vowel length distinction. Also, late bilinguals were found to be able to use duration in implementing lexical stress in English (Lee et al., 2006).

Thus, it is too soon to conclude that Korean speakers cannot use acoustic correlates in implementing lexical stress in English that do not exist in their L1 as cues to word-level prominence. If L1 word-level prosody is the only factor that determines whether Korean learners can acquire lexical stress, Korean learners of English should not be able to use any cue in producing English stress since Korean does not employ word-level prominence (See Experiments 1 & 2). However, as Lee et al. (2006) demonstrated, both early and late bilinguals were able to use F0 in a native-like manner, but not any other cues. This might suggest that learners' experience with cues in L1 (i.e., how frequent a given cue is realized to express prominence in L1) will predict which cue L2 learners will use in L2 prosody. Recall that F0 is the most frequently used in expressing phrasal-level prominence in Korean compared to duration and intensity. Therefore, one explanation for why Korean learners of English were unable to use duration and intensity cues to express L2 word-level prominence, on par with native speakers of English (Lee et al., 2006), is because they are relatively less experienced in using these cues, as compared to F0. Based on this, the current dissertation hypothesizes that experience with cues existing in L1 (i.e., how often a given cue is realized to express prominence in L1) will be the most important factor in determining the learnability of L2 prosodic features.

We also hypothesize that those cues that do not exist in either L1 word-level prominence or in phrasal-level prominence will be more difficult to be acquired by L2 learners. Since Korean does not employ vowel reduction, we expect that spectral cues (i.e., vowel reduction) will be the more difficult cue for Korean learners of English to acquire compared to suprasegmental cues (i.e., duration, intensity, F0). Recall that the vowel change in the nonword stimuli did not facilitate Korean learners of English in a lexical decision task (Lin et al., 2013), whereas

Mandarin learners of English were able to use vowel reduction in their perception of English lexical stress (Lin et al., 2013; Zhang & Francis, 2010).

Hence, the second part of the current dissertation aims to examine if and how L1 acoustic features are transferred into L2 production and perception. This will be investigated in two experiments (Experiments 3 & 4). Experiment 3 will examine if Korean speakers can produce acoustic cues to indicate stress location. Experiment 4 will examine the relative contribution (weight) of the acoustic cues to Korean learners' perception of English lexical stress. The next section provides more detailed research questions and hypotheses.

4.5. Goals of the study (Experiments 3 & 4)

The primary goal of Experiment 3 is to examine which acoustic cues Korean learners of English (i.e., younger Seoul Korean speakers) use in implementing lexical stress in Korean. According to the SPM, it is predicted that Korean learners would not be able to acquire English stress at all, if Korean does not have stress (or if Korean had lost word-level prominence). However, if Korean learners can transfer cues from higher-level prosody in their native language, as the Cue Weighting Model suggests, Korean learners would be able to use F0, intensity, and duration. Thus, Experiment 3 will examine five acoustic parameters (duration, F0, intensity, F1, and F2) from the productions of Korean learners of English and compare them with those from native English speakers. More detailed research goals and hypotheses are discussed in Chapter 4.

The primary goal of Experiment 4 is to investigate which cue(s) Korean learners use in perceiving English lexical stress. We examine which cues will be weighted most heavily in perceiving English stress, and compare the perceptual weighting between Korean learners and native English listeners. We hypothesize that Korean learners will be able to use cues to stress in perceiving English stress, but their perceptual weighting will follow the frequency with which

these cues signal higher-level prosodic structure in Korean. Thus, it is predicted that Korean learners will weight the F0 cue the most, followed by intensity and duration, because F0 is used on each syllable at every AP domain, while intensity is used only at the initial- and final-boundary of AP and duration is only used at the IP-final boundary. In addition, we also examine whether Korean learners will weight the vowel reduction cue like native English listeners. Given the fact that Korean does not have any vowel reduction (Ko, 2002), it is predicted that Korean learners would not weight the spectral cue at all. However, a previous study on Chinese learners showed that L2 learners still can acquire reduced vowel quality even though their native language does not employ it (Zhang & Francis, 2010). Thus, Korean learners may show a perceptual sensitivity to reduced vowel quality as a cue to stress. The detailed research questions and hypotheses are discussed in Chapter 5.

CHAPTER V.
PRODUCTION OF ENGLISH WORD-LEVEL PROMINENCE BY KOREAN
LEARNERS OF ENGLISH

5.1. Introduction

If the feature of word-level prominence in the first language (i.e., Korean) is typologically distinct from that in the second language (i.e., English), can second language (L2) learners of English learn to use the same acoustic cues to prominence as English native speakers? The current and following chapters try to answer this question in two dimensions: in L2 learners' production and perception. More specifically, we try to examine whether the similarity of the L1 phonological feature to the L2 (e.g., lexical stress) determines L2 learners' ability to acquire L2 word-level prominence. In addition, we also examine whether L2 learners' access to phonetic features in their L1 has an influence on the acquisition of L2 word-level prominence. In the current chapter, we will focus on the production of English lexical stress by Korean learners of English.

In chapter 2, we examined the status of word-level prominence in contemporary Seoul Korean and concluded that Korean does not have word-level prominence. According to the Stress Parameter Model (SPM; Peperkamp & Dupoux, 2002; Peperkamp, 2004), Korean learners of English will not be able to use any phonetic cues indicating lexical stress in producing English stress pairs due to the typological dissimilarity between Korean and English. On the other hand, according to the Cue-Weighting Model (e.g., Francis & Nusbaum, 2002; Holt & Lotto, 2006; Zhang & Francis, 2010; Ingvalson, Holt, & McClelland, 2011).), Korean learners of English will be able to use three suprasegmental cues (F0, intensity, and duration) in producing English lexical stress because Korean speakers can access the acoustic cues to higher-level prosody in

their native language. In the next sections, we will explore these two models in depth, and provide the research questions and goals of the current chapter.

5.2. Background

The Stress Parameter Model (SPM: Peperkamp & Dupoux, 2002; Peperkamp, 2004) posits that the ability to encode stress patterns in the phonological representation is determined at an early stage of development. According to the SPM, typological similarity between L1 and L2 will determine whether the stress patterns in the second language can be acquired by L2 learners. Therefore, the SPM predicts that Korean learners will not be able to acquire English lexical stress, because Korean speakers do not have abstract representations of lexical stress in their L1.

On the other hand, the Cue-Weighting Model of L2 speech perception predicts that phonetic properties of specific contrasts in L1 influence L2 learners' perceptual cue weighting (e.g., Francis & Nusbaum, 2002; Holt & Lotto, 2006; Ingvalson et al., 2011; Zhang & Francis, 2010). While multiple cues are accessible to L2 learners, not all cues will be weighted equally since some cues will be traded off with other cues, resulting in increasing or decreasing the perceptual sensitivity to one cue, depending on the significance of the cue in the L1. Hence, according to the Cue-Weighting Model, Korean learners of English will be able to use all suprasegmental cues (e.g., F0, duration, and intensity) to indicate English lexical stress, as all these cues are available at the higher level prosody in Korean. However, the use of a cue in Korean learners' English production and perception will vary depending on the frequency of occurrence of each cue at the AP boundary. Since F0 is used on every syllable to mark the domain of the accentual phrase with different pitch patterns (e.g., LHLH/HHLH for the four-syllable phrase), Korean learners will use F0 the most in their production of English stress. Intensity will be the second most heavily used, since intensity affects the AP-initial and final boundary. Duration will be the least used, since duration only affects the sentence-final

boundary. Unlike the suprasegmental cues, the segmental cue to stress (e.g., vowel reduction) will not be acquired by Korean learners of English, since Korean does not employ vowel reduction. Thus, it is predicted that Korean learners' production will not exhibit the centralized vowel quality on the unstressed English syllables.

Lee, Guion, and Harada (2006) provided evidence that Korean late bilinguals were able to use duration, F0, and intensity cues to implement stress in English, but were not able to reduce vowel quality on unstressed syllables in a native-like way. Lee et al. (2006) argued that instead of reducing the vowel quality to indicate stress location in English, Korean learners replaced English unstressed syllables with the Korean high central vowel [ɨ]. However, considering that there was no direct acoustic comparison between productions of the English unstressed syllables and productions of Korean vowels, it is not clear whether the unstressed English syllable was replaced with a Korean vowel or whether it was incompletely neutralized to schwa. Even if the productions of English unstressed syllables were equivalent to those of Korean vowels, it would still mean that Korean learners acquired some degree of vowel reduction. Thus, if their findings indicated an incomplete neutralization of unstressed English syllables, it would mean that L2 learners can acquire a new feature that does not exist in the L1.

Following Lee et al. (2006), Han, Hwang, and Choi (2011) also examined the production of vowel reduction of English unstressed syllables by Korean learners of English, and whether the length of residence (LOR) influenced their production of English stress. Based on the claims that English reduced vowels have different phonetic variants as a function of phonological positions (Flemming & Johnson, 2007), Han et al. (2011) examined whether Korean learners could acquire these phonetic details in L2 as a function of their LOR in an English-speaking country. The findings from Han et al. (2011) revealed that Korean learners of English with

residency in an English-speaking country patterned more like English native speakers than Korean learners without residency in an English-speaking country. With respect to vowel height, neither L2 group showed a native-like distinction: native English speakers showed two phonetic variants (word-initial position ‘*assist*’ vs. word-internal position ‘*roses*’), while both L2 groups showed a three-way distinction (word-initial position ‘*assist*’ vs. word-internal position ‘*roses*’ vs. stem-final ‘*Rosa*’). With respect to vowel frontness, native English speakers did not show any differences; however, L2 learners showed a different pattern as a function of L2 immersion: L2 learners without residency in an English-speaking country showed a three-way distinction, while L2 learners with residency in an English-speaking country showed a two-way distinction. Based on these results, Han et al. (2011) concluded that L2 learners can acquire L2 phonetic variants of unstressed syllables based on the experience of living in an English-speaking country.

Both Lee et al. (2006) and Han et al. (2011) found that Korean learners of English were able to use duration, albeit non-native-like, in producing English unstressed syllables, contrary to their prediction. Their prediction that Korean learners would not be able to use duration was based on the claim that Korean has lost its vowel length distinction. However, our findings from Chapter 2 revealed that younger Korean speakers still retain the phonemic vowel length distinction, and therefore, might still be sensitive to duration. If this is the case, then Korean learners might use duration cues more than F0 or intensity, although F0 and intensity are more frequently used in higher-level prosody in Korean. Also, although the degree of vowel reduction was non-native-like, both Lee et al. (2006) and Han et al. (2011) demonstrated that L2 learners (e.g., late bilingual and L2 learners without immersion) were able to acquire some degree of a new phonetic feature in L2 lexical stress. Thus, in this chapter, we focus on the acoustic correlates of the production of English word-level prominence by Korean learners of English,

and investigate whether L2 learners without any immersion are able to acquire L2 features of lexical stress.

5.3. Goal

The primary goal of the current chapter is to examine which acoustic correlates Korean learners of English (i.e., younger Korean speakers) use in producing L2 word-level prominence (i.e., English stress). The research questions that we are trying to explore in this chapter are as follows:

- 1) Will Korean learners of English be able to produce English lexical stress or not?
- 2) Will the abstract phonological representation in L1 determine the acquisition of L2 lexical stress or will the cues in L1 facilitate/inhibit the acquisition of L2 lexical stress?
- 3) Which cue(s) will Korean learners of English use in producing English lexical stress?
Will they transfer all suprasegmental cues existing in their L1 prosody to L2, or will the Korean learners only be able to use duration, considering that contemporary Seoul Korean still retains phonemic vowel length distinction?
- 4) Will Korean learners of English be able to acquire a new L2 segmental cue (e.g., vowel reduction) in producing English lexical stress?

5.4. Methodology

5.4.1. Participants

The 11 young Korean speakers who participated in the production and perception experiments on Korean word-level prominence (See Chapters 2 and 3) also completed an English production task. One participant's data was eliminated from the analysis because of recording problems. The data presented in this chapter are thus based on 10 participants. All subjects were born and raised in the Seoul or Kyunggi area where standard Korean dialect is spoken, and none of the subjects reported any hearing or speech disorders. The mean age of

Korean learners' of English was 23.4 years ($sd = 2.6$) and their age of acquisition (AOA) was 8.3 years ($sd = 1.5$). None of the Korean speakers had lived in a country where English is dominantly spoken. For the control group, 5 male English native speakers (mean age = 30.4, $sd = 5.0$) were recruited from the University of Kansas. The average score for the Michigan test (See 1.3.3) taken by all Korean participants was 39.3 out of 45 ($sd = 2.5$).

5.4.2. Stimuli

Fourteen disyllabic minimal word pairs that share identical segmental content adopted from Lai (2005) were used as target stimuli. These are classified either as nouns (trochaic stress) or verbs (iambic stress) depending on the rhythmic class. The words that were read by the speakers were “conflict, digest, import, insult, object, permit, present, progress, project, rebel, contract, desert, record, and subject.” Table 20 and Table 21 represent IPA symbols for each stressed vowels for the 14 target word pairs as a function of vowel height and frontness, respectively.

Table 20. IPA symbols for each stressed vowel of the 14 target word pairs used in the production as a function of vowel height of the first syllable. The numbers in parenthesis next to the IPA symbols indicate the number of words corresponding to the symbol. Syllables with uppercase indicate stressed syllables.

	Vowel Height	IPA when stressed	Words
First-syllable stressed	High vowels	[ɪ] (2)	IMport, Insult
	Mid vowels	[ɚ] (1)	PERmit,
		[ɛ] (4)	PREsent, REbel, DESert, REcord
		[ʌ] (1)	SUBject
	Low vowels	[ɑ] (5)	CONflict, OBject, PROgress, PROject, CONtract
Diphthong	[aɪ] (1)	Digest	
Second-syllable stressed	High vowels	[ɪ] (2)	conFLICT, perMIT
	Mid vowels	[ɚ] (1)	deSERT
		[ɛ] (7)	diGEST, obJECT, preSENT, proGRESS, proJECT, reBEL, subJECT
		[ɔ] (2)	imPORT, reCORD
		[ʌ] (1)	inSULT
	Low vowels	[æ] (1)	conTRACT

Table 21. IPA symbols for each stressed vowel of the 14 target word pairs used in the production as a function of vowel frontness of the first syllable. The numbers in parenthesis next to the IPA symbols indicate the number of words corresponding to the symbol. Syllables with uppercase indicate stressed syllables.

	Vowel Frontness	IPA when stressed	Words
First-syllable stressed	Front vowels	[ɪ] (2)	IMport, INSult
		[ɛ] (4)	PREsent, REbel, DESert, REcord
	Central vowels	[ɚ] (1)	PERmit,
	Back vowels	[ʌ] (1)	SUBject
		[ɑ] (5)	CONflict, OBject, PROgress, PROject, CONtract
Diphthong	[aɪ] (1)	DIgest	
Second-syllable stressed	Front vowels	[ɪ] (2)	conFLICT, perMIT
		[ɛ] (7)	diGEST, obJECT, preSENT, proGRESS, proJECT, reBEL, subJECT
		[æ] (1)	conTRACK
	Central vowels	[ɚ] (1)	deSERT
	Back vowels	[ɔ] (2)	imPORT, reCORD
		[ʌ] (1)	inSULT

The participants read the target words in a contextually related carrier sentence in order to prompt the speakers to produce the words with the intended syntactic category. For example, the noun ‘contract’ was embedded in “The new **contract** needs to be signed,” (8 syllables) and the verb ‘contract’ was embedded in “Steel will **contract** when it is cooled” (8 syllables). After reading the whole sentence, the critical word (e.g., ‘contract’) was embedded in a contextually-neutral sentence (“Please say **contract** again”). The contextually related sentence was always followed by the contextually neutral sentence. The related carrier sentences that were used for recording are listed in Appendix B. The order of each sentence pair of the 14 lexical stress pairs was randomized. Only the productions from the contextually neutral sentences were analyzed and reported below.

5.4.3. Procedure

First, Korean learners of English took the University of Michigan Listening Comprehension Test (1972) (Michigan Test; See Appendix C) in order to assess their English proficiency before the recording. The Michigan Test is an off-line computer-based auditory test that consists of 45 questions about English grammar. Although the Michigan Test does not examine learners’ oral proficiency, learners’ verbal proficiency can be indirectly estimated based on their listening comprehension. After completing the Michigan Test, 10 Korean learners of English who also participated in Experiment 1 (see chapter 2) produced 14 English word pairs in contextually related sentences and contextually neutral carrier sentences with two repetitions. Only the words produced in the neutral sentences were examined for the analysis. Thus, a total of 560 tokens (14 word pairs × 2 repetitions × 10 speakers) were collected. The recording was conducted in a seminar room at Sungkyunkwan University in Seoul, Korea. A Marantz Digital Recorder (PMD 671) and a SHURE head-mounted microphone were used for the recording.

A control group of 5 native speakers of English also participated in the recording. Their recordings were made in the anechoic chamber at the University of Kansas, Lawrence. An Electro-Voice N/D 767 cardioid microphone and a Marantz Portable Solid State Recorder (PMD 671) were used. A total of 280 tokens (14 word pairs \times 2 repetitions \times 5 speakers) were collected. The sampling rate of the recording for both speaker groups was 22050 Hz.

5.4.4. Measurements

Duration, intensity, F0, F1, and F2 values were measured for the first syllable and second syllable of the target words using Praat (Ver 5.4.03). F0 values of each vowel were measured at every 10 % of the vowel using a script (Xu, 2006) and then averaged from 20% to 80% to avoid any perturbation effect. The intensity of each vowel was also averaged across the total duration of the vowel by a script (Xu, 2006). F1 and F2 values were averaged over a 25ms window at the midpoint of each vowel by a script (Lee, 2015). Vowel duration was determined from the onset of the first formant to the offset of the second formant. When a sonorant followed the vowel and could not be reliably separated from the preceding vowel on the spectrogram, the duration of the sonorant was also included for both members of the minimal pair for the native English speakers' production. For Korean speakers' production, since we do not know whether the sonorant was correctly produced as the intended phoneme, we excluded these tokens from the analysis. A total of 138 tokens (25 %) from Korean learners' productions were discarded for the analysis. When a nasal stop followed the vowel, an abrupt change in the high frequencies resulted from the oral closure. This point was taken as the offset of the vowel. In addition to the raw values of each measurement (i.e., F0, duration, intensity, F1, and F2), second-to-first syllable ratios for the three suprasegmental measurements (i.e., F0, duration, and intensity) are also analyzed, by using Beckman (1986)'s formulas as below:

$$F0 \text{ ratios (in semitone)} = 17.31 \ln[\text{Hz}(S2)/\text{Hz}(S1)]$$

$$\text{Average intensity ratio} = \text{dB}(S2) - \text{dB}(S1)$$

$$\text{Log duration ratio} = \ln[\text{ms}(S2)/\text{ms}(S1)].$$

First-syllable stressed words will give us a negative value of each ratio, and second-syllable stressed words will result in a positive value.

5.4.5. Data analysis

In order to examine the raw values of each measurement, repeated measures three-way ANOVAs were conducted with Stress (first, second), Syllable (first, second), and Group (Korean, English) as independent variables and intensity, duration, and F0 values as dependent variables. When examining second-to-first syllable ratios of each measurement, we conducted repeated measures two-way ANOVAs with Stress (first, second) and Group (Korean, English) as independent variables and ratios of duration, intensity, and F0 as dependent variables. For F1 and F2 values, repeated measures ANOVAs on F1 and F2 values of the first and second syllable were separately conducted with Stress (first vs. second) and Group (i.e., Korean vs. English) as dependent variables. Results of raw values and ratio of each measurement will be reported below.

5.5. Results

5.5.1. Duration

A repeated measures three-way ANOVA found a main effect of Stress [$F(1, 13) = 19.54$, $p < .001$], indicating that the first-syllable stressed words were produced with a significantly longer syllable duration (81 ms) than the second-syllable stressed words (77 ms). There was also a significant interaction between Stress and Syllable [$F(1, 13) = 69.99$, $p < .01$], and between Stress and Group [$F(1, 13) = 8.36$, $p < .01$]. The durational difference between the first and second syllable was greater for the second-syllable stressed words ($S2 - S1 = 20$ ms) than the

first-syllable stressed words ($S2 - S1 = -9$ ms). Also, English speakers produced English stress pairs with a greater duration difference between first-syllable stressed words and second-syllable stressed words ($S1$ stressed words – $S2$ stressed words = 8 ms) than Korean speakers ($S1$ stressed words – $S2$ stressed words = 2 ms). We also found a statistically significant three-way interaction among Stress, Syllable, and Group [$F(1, 13) = 24.61, p < .01$]. This result indicates that Korean learners produced second-syllable stressed words with a greater duration difference than the first-syllable stressed words, and also the difference between the stress pairs was greater for the English speakers than the Korean learners.

In order to further examine the three-way interaction, we ran two-way ANOVAs independently for each group with Stress and Syllable as independent variables. The analysis for English speakers' productions found a main effect of Stress [$F(1, 4) = 17.04, p = .01$], indicating that first-syllable stressed words were produced with a significantly longer syllable duration (83 ms) than second-syllable stressed words (76 ms). A two-way interaction between Stress and Syllable [$F(1, 4) = 68.53, p < .01$] was also found, indicating that the duration difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = -21$ ms) than second-syllable stressed words ($S2 - S1 = 31$ ms). The analysis for the Korean learners' productions found a two-way interaction between Stress and Syllable [$F(1, 9) = 8.59, p = .02$], indicating that the duration difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = -2$ ms) than second-syllable stressed words ($S2 - S1 = 12$ ms). Figure 30 illustrates the duration values of first and second syllable of English stress pairs between English speakers and Korean learners of English.

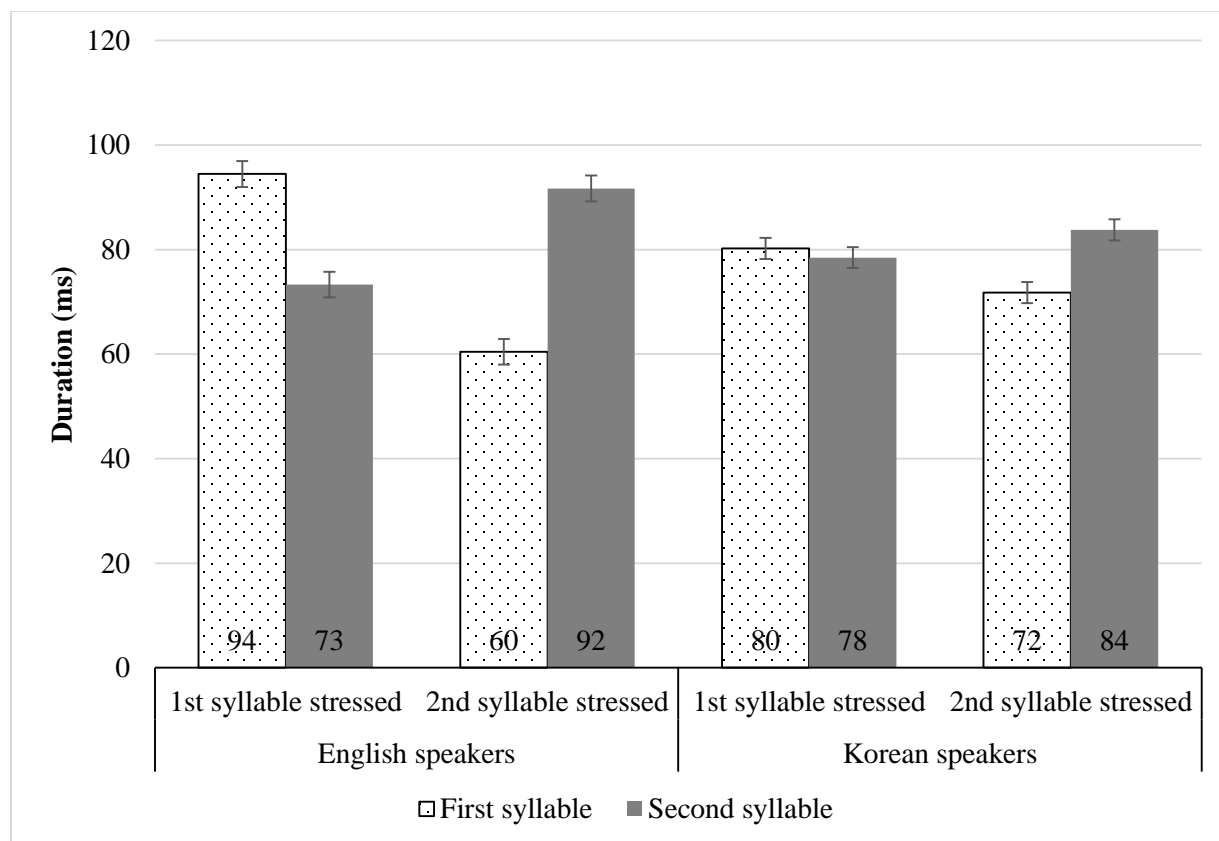


Figure 30. Duration of first and second syllable of English stress pairs between Korean and English speakers.

With respect to the second-to-first syllable duration ratio, repeated measures 2 x 2 ANOVAs found a significant main effect of Stress [$F(1, 13) = 70.91, p < .01$]. The first-syllable stressed words were produced with a smaller second-to-first syllable duration ratio (-0.11) than the second-syllable stressed words (0.27). We also found a significant interaction between Stress and Group [$F(1, 13) = 28.51, p < .001$], indicating that the duration ratio difference between the stress pairs was greater for English speakers (S1 stressed words – S2 stressed words = -0.72) than Korean speakers (S1 stressed words – S2 stressed words = -0.17).

In order to further examine the two-way interaction, we ran one-way ANOVAs independently for each group with Stress as independent variable. A main effect of Stress was found for both English speakers [$F(1, 4) = 289.53, p < .01$] and Korean learners [$F(1, 9) = 5.33, p$

= .046]. Figure 31 illustrates second-to-first syllable duration ratios of the English stress pairs produced by two speaker groups.

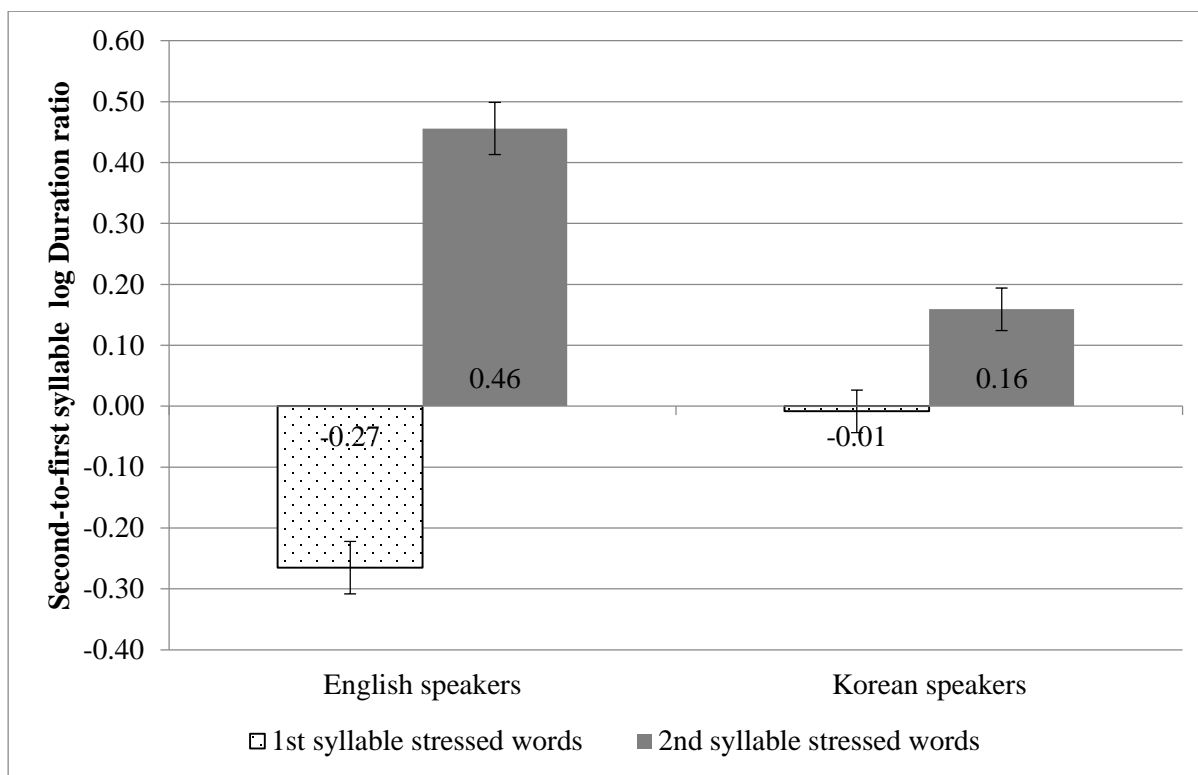


Figure 31. Second-to-first syllable log duration ratio English stress pairs between English and Korean speakers.

5.5.2. Intensity

Regarding Intensity, we found a significant interaction between Stress and Syllable [$F(1, 13) = 41.60, p < .001$], indicating that the intensity difference between the stressed and unstressed syllables was greater for first-syllable stressed words ($S2 - S1 = -1.75$ dB) than second-syllable stressed words ($S2 - S1 = 1.68$ dB). We also found a significant three-way interaction among Stress, Syllable, and Group, [$F(1, 13) = 9.80, p < .01$], indicating that the intensity difference between the first and second syllable of the stress pairs was greater for the English speakers than the Korean speakers.

In order to further examine the three-way interaction, we ran two-way ANOVAs independently for each group with Syllable and Stress as independent variables. The analysis of

the English speakers' productions found a two-way interaction between Stress and Syllable [$F(1, 4) = 36.07, p < .01$], indicating that the intensity difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = -3.64$ dB) than second-syllable stressed words ($S2 - S1 = 1.93$ dB). The analysis of the Korean learners' productions also found a two-way interaction between Stress and Syllable [$F(1, 9) = 8.10, p = .02$], indicating that the duration difference between the first and second syllable was smaller for first-syllable stressed words ($S2 - S1 = -0.50$ dB) than second-syllable stressed words ($S2 - S1 = 1.51$ dB). Figure 32 illustrates the intensity values of first and second syllable of English stress pairs between English speakers and Korean learners of English.

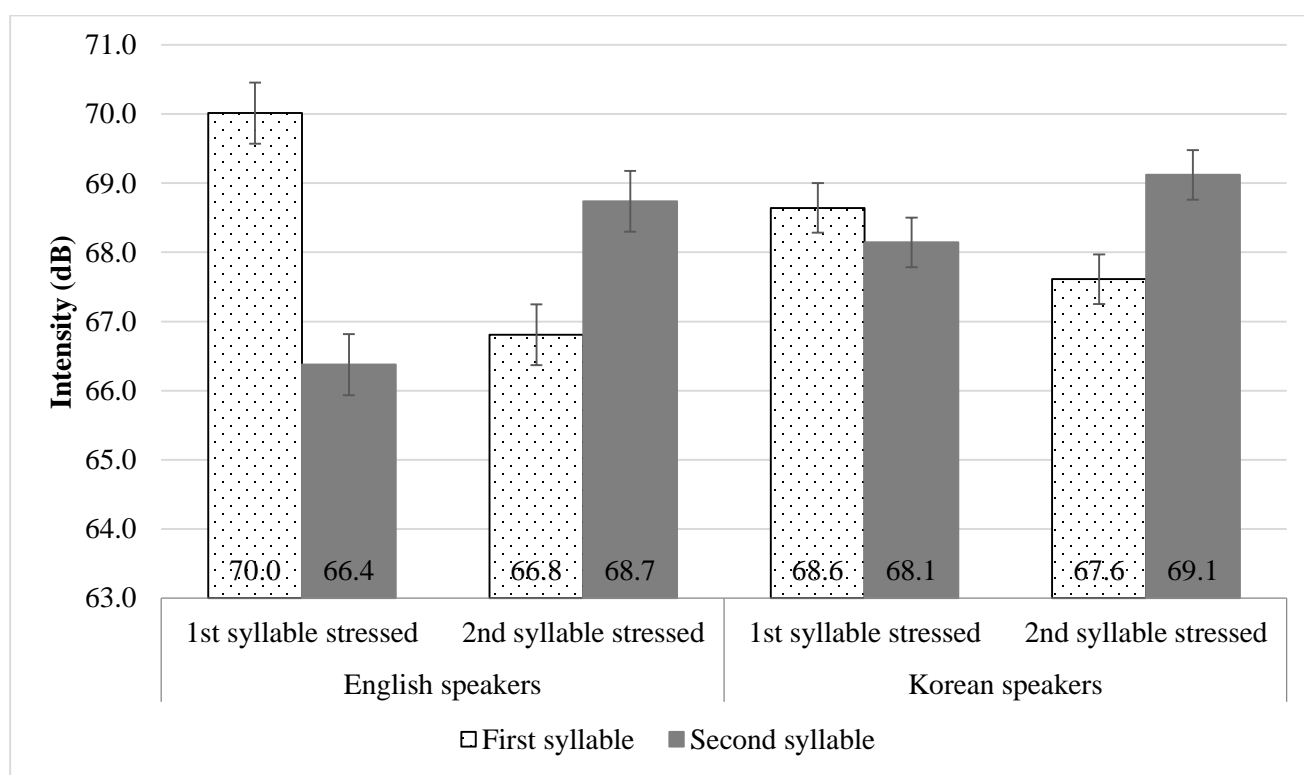


Figure 32. Intensity of first and second syllable of Korean stress pairs between older and younger speakers.

With respect to the second-to-first syllable intensity ratio, a repeated measures 2 x 2 ANOVA found a significant main effect of Stress [$F(1, 13) = 41.60, p < .01$], indicating that first-syllable stressed words were produced with a smaller second-to-first intensity ratio (-1.75)

than the second-syllable stressed words (1.68). We also found a significant interaction between Stress and Group [$F(1, 13) = 9.80, p < .001$], indicating that the intensity ratio difference between first-syllable stressed words and second-syllable stressed words was greater for the English speakers (S1 stressed words – S2 stressed words = -5.57) than the Korean speakers (S1 stressed words – S2 stressed words = -2.01).

In order to further examine the three-way interaction, we ran two-way ANOVAs independently for each group with Syllable and Stress as independent variables. A main effects on Stress was found from the productions of English speakers [$F(1, 4) = 36.07, p = .003$] as well as Korean learners [$F(1, 9) = 8.09, p = .019$]. Figure 33 illustrates the second-to-first syllable intensity ratio of English stress pairs by two speaker groups.

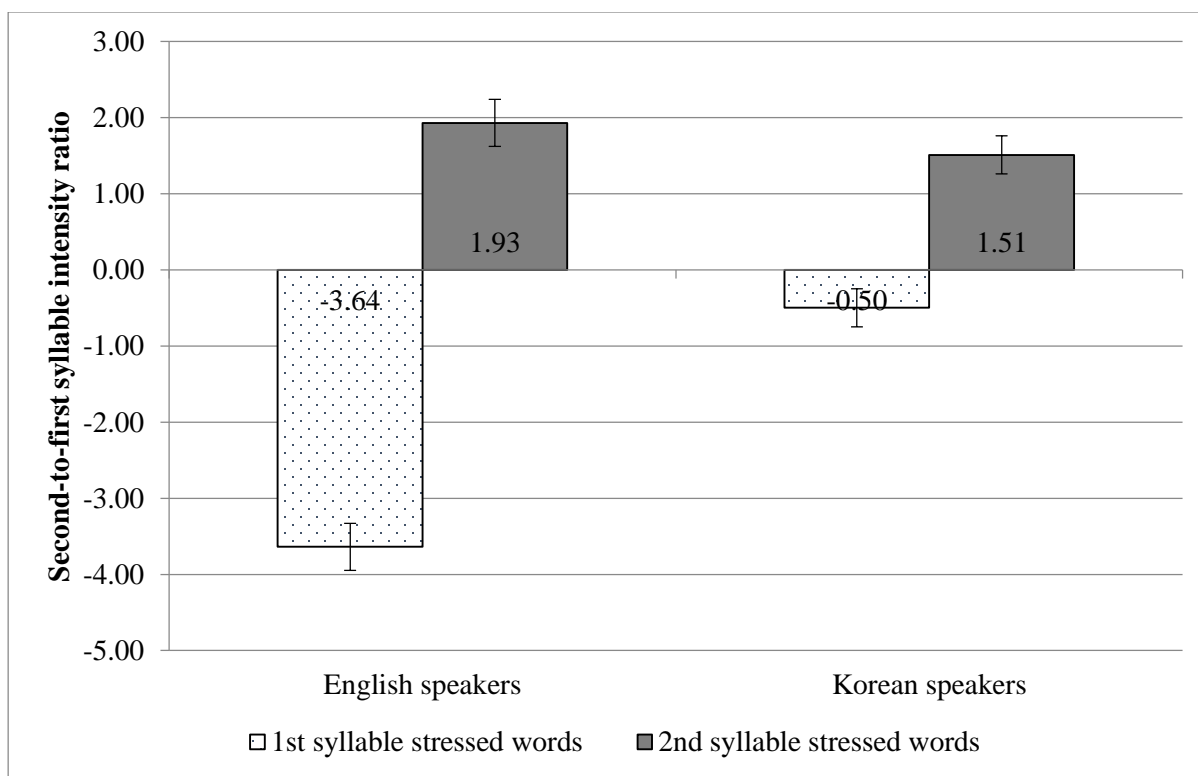


Figure 33. Second-to-first syllable intensity ratio of Korean stress pairs produced in sentence between older and younger speakers.

5.5.3. F0 values

With respect to F0, repeated measures ANOVAs found a significant interaction between Stress and Syllable $F(1, 13) = 8.92, p < .01$], indicating that first-syllable stressed words had higher F0 values on the first syllable (123 Hz) than the second syllable (117 Hz), whereas second-syllable stressed words had higher F0 values on the second syllable (119 Hz) than the first syllable (123 Hz). Figure 34 illustrates the F0 values of first and second syllable of English stress pairs between English and Korean speakers.

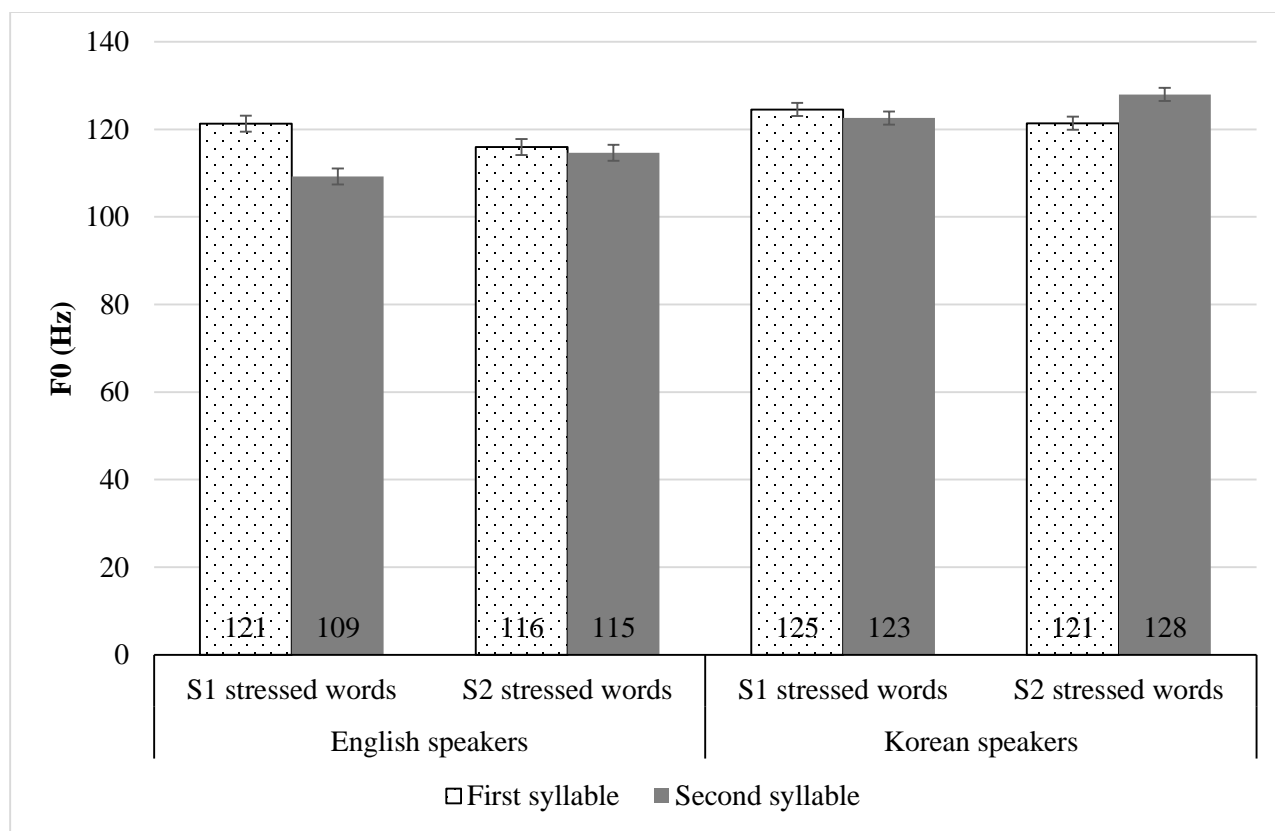


Figure 34. F0 values of first and second syllable of English stress pairs between English and Korean speakers.

With respect to the second-to-first syllable F0 ratio, repeated measures 2×2 ANOVAs found significant main effects of Stress [$F(1, 13) = 11.95, p = .004$], only. The first-syllable stressed words were produced with a smaller second-to-first syllable F0 ratio (-0.84) than the

second-syllable stressed words (0.54). Figure 35 represents F0 ratio differences between the two groups.

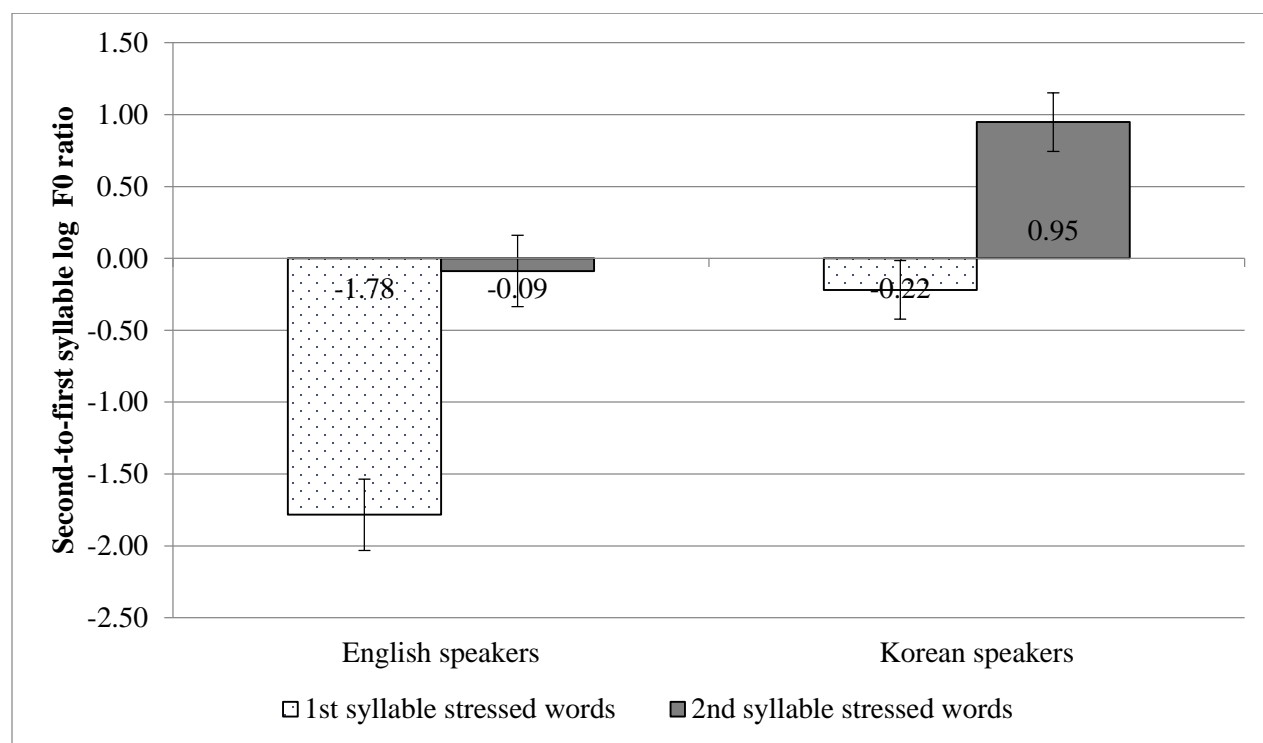


Figure 35. Second-to-first syllable log F0 ratio of English stress pairs between English and Korean speakers.

5.5.4. F1 values

5.5.4.1. F1 values in the first syllable

In order to examine vowel reduction by stress location, repeated measures ANOVAs were conducted separately for F1 values and F2 values of the first and second syllable. For F1 values, a repeated measures three-way ANOVA was conducted with Stress (first, second), Vowel Height (high vs. mid vs. low), and Group (English, Korean) as independent variables. Tokens with a diphthong in the first syllable (e.g., digest) were excluded from the F1 and F2 analysis of the first syllable.

For the F1 values of the first syllable, we found statistically significant main effects of Stress [$F(1, 13) = 16.90, p = .001$], Vowel Height [$F(2, 12) = 28.59, p < .001$], and Group [$F(1,$

13) = 7.51, $p = .017$]. These results indicate that the F1 values for the first-syllable stressed words were higher (598 Hz) than the second-syllable stressed words (510Hz), and the F1 values decreased as vowel height increases (high: 446 Hz, mid: 524 Hz, low: 630 Hz). Tukey post hoc comparisons reported that F1 values of high vowels on the first syllable were significantly different from those of mid ($p < .01$) and low vowels ($p < .01$), and also F1 values of mid vowels were significantly different from low vowels at $p = .001$. Also, the F1 values from the productions of English speakers were higher (615 Hz) than those of the Korean speakers (512 Hz). We also found a two-way interaction between Stress and Group [$F(1, 13) = 9.39, p = .009$], indicating that the difference in F1 values as a function of stress location was greater for the English speakers' production (S1 stressed words – S2 stressed words = 171 Hz) than Korean speakers (S1 stressed words – S2 stressed words = 32 Hz). Table 22 represents the F1 values of the stressed- and unstressed- syllables on the first syllable between the two speaker groups.

Table 22. F1 values of the first-syllable stressed and unstressed vowels as a function of vowel height between the two speaker groups. Values in parentheses indicate standard errors.

		First-syllable stressed	First-syllable unstressed
English	High	542 Hz (81)	443 Hz (30)
	Mid	656 Hz (26)	513 Hz (23)
	Low	818 Hz (42)	584 Hz (44)
Korean	High	406 Hz (57)	407 Hz (21)
	Mid	506 Hz (18)	467 Hz (16)
	Low	597 Hz (30)	565 Hz (31)

5.5.4.2. F1 values of the second syllable

For the F1 values of the second syllable, we found statistically significant main effects of Vowel Height [$F(2, 12) = 49.28, p < .001$] and Group [$F(1, 13) = 6.04, p = .029$]. These results

indicate the F1 values were different as a function of Vowel Height (high: 497 Hz, mid: 563 Hz, low: 654 Hz), and that F1 values were greater for English speakers (634 Hz) than for Korean speakers (512 Hz). Tukey post hoc comparisons reported that F1 values of high vowels on the second syllable were significantly different from those low vowels, but were not significantly different from mid vowels at $p < .05$. F1 values of mid vowels were significantly different from low vowels ($p = .05$). A significant interaction between Stress and Height [$F(2, 12) = 4.18, p = .04$] was also found, indicating that the difference in the F2 values between the stressed and unstressed syllables was significantly different as a function of vowel height (S1 stressed F1 – S2 stressed F1 for high vowels: 18 Hz, mid vowels: -56 Hz, back vowels: -21 Hz). Table 23 represents the F1 values of the stressed and unstressed second syllables between the two speaker groups.

Table 23. F1 values of the second-syllable stressed and unstressed vowels as a function of vowel height between the two speaker groups. Values in parentheses indicate standard errors.

		Second-syllable unstressed	Second-syllable stressed
English	High	629 Hz (88)	570 Hz (50)
	Mid	631 Hz (43)	624 Hz (31)
	Low	741 Hz (61)	803 Hz (59)
Korean	High	423 Hz (62)	433 Hz (36)
	Mid	500 Hz (30)	539 Hz (22)
	Low	558 Hz (43)	610 Hz (42)

5.5.5. F2 values

5.5.5.1. F2 values of the first syllable

For F2 values, we conducted repeated measures three-way ANOVAs with Stress (first, second), Vowel Frontness (front vs. central vs. back), and Group (younger, older) as independent

variables. For the F2 values of the first syllable, we found significant main effects of Stress [$F(1, 13) = 41.71, p < .001$] and Frontness [$F(2, 12) = 92.26, p < .001$]. These results indicate that the F2 values were lower for first-syllable stressed words (1520 Hz) than second-syllable stressed words (1629 Hz), and the F2 values decreased as a function of vowel frontness (front: 1805 Hz, central: 1435 Hz, back: 1372 Hz). Tukey post hoc comparisons reported that F2 values of front vowels in the first syllable were significantly different from those of central ($p < .01$) and back vowels ($p < .01$), but F2 values of central vowels were not significantly different from back vowels ($p < .01$). We also found significant two-way interactions between Stress and Frontness [$F(2, 12) = 13.24, p = .001$], between Stress and Group [$F(2, 13) = 6.87, p = .02$], and between Frontness and Group [$F(2, 12) = 14.51, p = .001$]. These results indicate that the F2 difference between the stressed and unstressed syllables was significantly different as a function of vowel frontness (S1 stressed F2 – S2 stressed F2 for front vowels: -38 Hz, central vowels: -30 Hz, back vowels: -196 Hz). Also, the difference in the F2 values between stressed and unstressed syllables was significantly greater for English speakers (S1 stressed words – S2 stressed words = -164 Hz) than Korean learners (S1 stressed words – S2 stressed words = -72 Hz). In addition, F2 values as a function of Vowel Frontness were significantly different between the two groups. For English speakers, F2 values were 1734 Hz for front vowels, 1445 Hz for central vowels, and 1500 Hz for back vowels, whereas F2 values for Korean speakers were 1855 Hz, 1428 Hz, and 1289 Hz, for front, central and back vowels, respectively. We also found a three-way interaction among Stress, Frontness, and Group [$F(2, 12) = 6.02, p = .015$], indicating that the difference in F2 values between stressed- and unstressed-syllables was greater for the English speakers than the Korean learners.

In order to further examine the three-way interaction, we ran two-way ANOVAs independently for each group with Syllable and Stress as independent variables. The analysis of the English speakers' productions found main effects of Stress [$F(1, 4) = 16.28, p = .016$] and Frontness [$F(2, 3) = 32.24, p = .009$]. These results indicate that first-syllable stressed words were produced with significantly lower F2 values (1519 Hz) than second-syllable stressed words (1689 Hz). Also, F2 values decreased as a function of Vowel Frontness (front: 1734 Hz, central: 1445 Hz, back: 1500 Hz). We also found a two-way interaction between Stress and Frontness [$F(2, 3) = 75.60, p = .003$]. This result indicates that F2 values between stressed and unstressed first syllables were significantly different as a function of Vowel Frontness (S1 stressed words – S2 stressed words for front vowels: -10 Hz, for central vowels: -43 Hz, for back vowels: -351 Hz).

The analysis of the Korean learners' productions found main effects of Stress [$F(1, 9) = 18.38, p = .02$] and Frontness [$F(2, 8) = 102.73, p < .01$]. These results indicate that Korean learners produced stressed syllables with lower F2 values than unstressed syllables, and F2 values decreased as a function of Vowel Frontness (front: 1855 Hz, central: 1428 Hz, back: 1289 Hz). Table 24 represents the F2 values of the first syllable as a function of stress location between the two speaker groups.

Table 24. F2 values of the first-syllable stressed and unstressed vowels as a function of vowel frontness between the two speaker groups. Standard errors are indicated in parentheses.

		First-syllable stressed	First-syllable unstressed
English	Front	1729 Hz (60)	1739 Hz (59)
	Central	1424 Hz (76)	1467 Hz (79)
	Back	1301 Hz (43)	1675 Hz (49)
Korean	Front	1826 Hz (42)	1885 Hz (42)
	Central	1417 Hz (54)	1439 Hz (56)
	Back	1242 Hz (30)	1337 Hz (35)

5.5.5.2. F2 values of the second syllable

For the F2 values of the second syllable, we found significant main effects of Stress [$F(1, 13) = 7.59, p = .016$], Frontness [$F(2, 12) = 40.70, p < .001$], and Group [$F(1, 13) = 5.09, p = .042$]. These results indicate that the F2 values of the unstressed second syllable (1646 Hz) were higher than the F2 values of the stressed second syllable (1597 Hz). Also, the F2 values increased as a function of Vowel Frontness (front: 1713 Hz; central: 1585 Hz; back: 1262 Hz). Tukey post hoc comparisons reported that F2 values of front vowels in the second syllable were significantly different from those of central and back vowels at $p < .01$, and also F2 values of central vowels were significantly different from back vowels ($p = .035$). Table 25 represents the F2 values of the second syllable as a function of stress location between the two speaker groups.

Table 25. F2 values of the second-syllable stressed and unstressed vowels as a function of vowel frontness between the two speaker groups. Standard errors are indicated in parentheses.

		Second-syllable unstressed	Second-syllable stressed
English	Front	1772 Hz (51)	1673 Hz (52)
	Central	1812 Hz (84)	1630 Hz (65)
	Back	1508 Hz (123)	1300 Hz (118)
Korean	Front	1700 Hz (36)	1716 Hz (37)
	Central	1502 Hz (60)	1507 Hz (46)
	Back	1166 Hz (87)	1109 Hz (83)

Figure 36 represents the vowel distribution of the first syllable from the two different stress conditions (e.g., first-syllable stressed vs. second-syllable stressed) by two speaker groups.

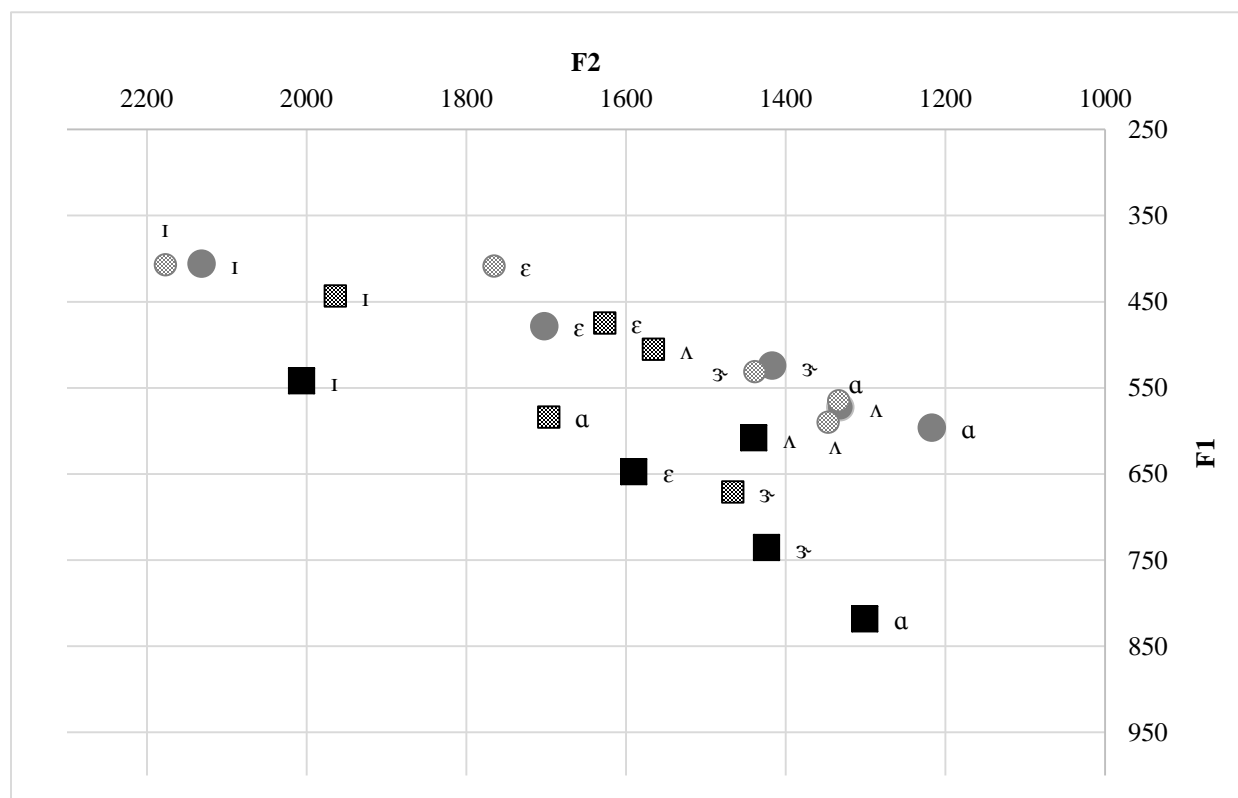


Figure 36. Scatterplot of vowel productions of the first syllable. Black squares represent productions by the native English speakers, and gray dots represent productions by the Korean speakers. Solid colors represent productions of the stressed syllables (e.g., noun production) and the patterned colors represent productions of the unstressed syllables (e.g., verb production).

Figure 37 represents the vowel distribution of the second syllable from the two different stressed conditions (e.g., first-syllable stressed vs. second-syllable stressed) by two speaker groups.

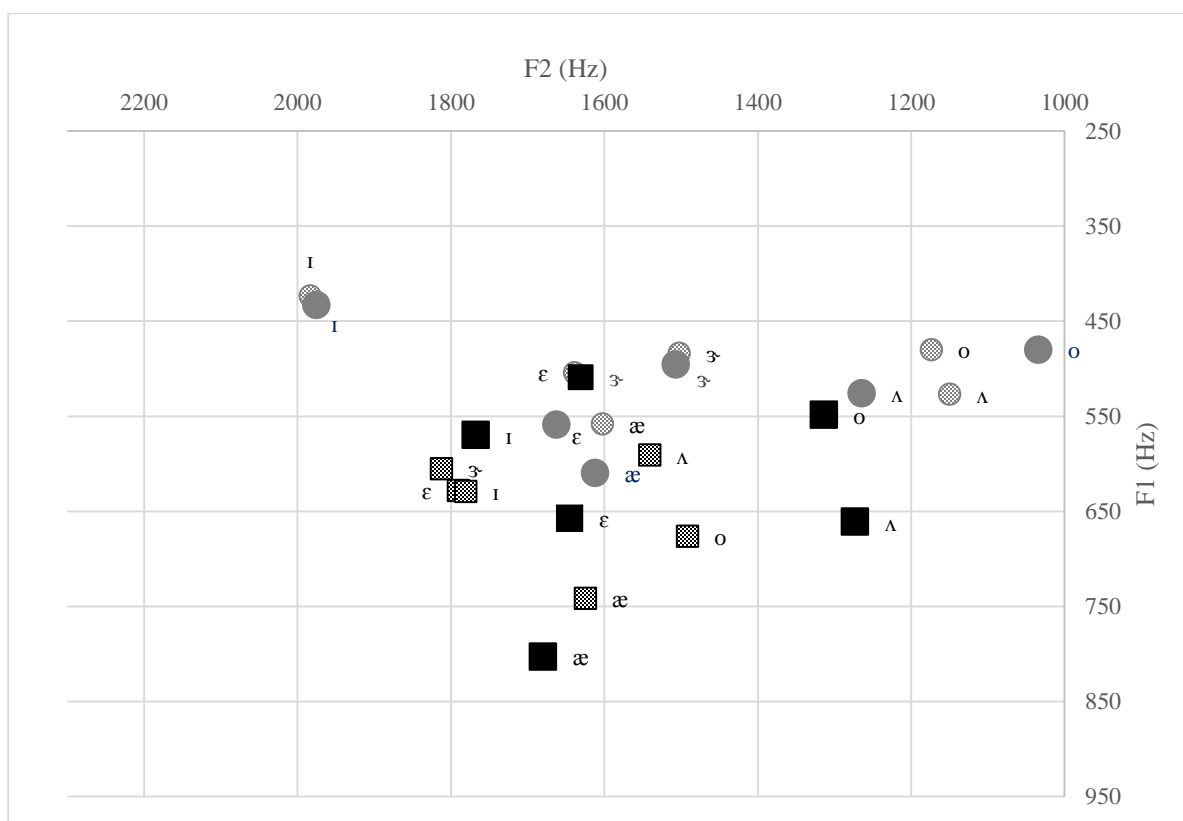


Figure 37. Scatterplot of vowel productions of the second syllable. Black squares represent productions by the native English speakers, and gray dots represent productions by the Korean speakers. Solid colors represent productions of stressed syllables (e.g., verb production) and the patterned colors represent productions of unstressed syllables (e.g., noun production).

5.6. Summary of results

This chapter examined the acoustic characteristics of English stress minimal pairs produced by Korean learners of English and native English speakers. We found that Korean learners of English use the three suprasegmental cues to indicate lexical stress in English, but were not able to implement vowel reduction in producing English unstressed syllables. First, we will discuss the results of the suprasegmental cues.

Regarding duration, the main effect of Stress on raw duration values indicates that both groups use duration to indicate lexical stress in English. However, contrary to the Han et al.

(2011) findings, Korean learners use duration to a lesser extent than native English speakers, as supported by a three-way interaction between Group, Stress, and Syllable: the duration difference between the stressed and unstressed syllables was greater in the productions of English speakers than in the Korean speakers' productions. The same result was also found for the second-to-first syllable duration ratio, as indicated by a two-way interaction between Stress and Group.

With respect to intensity, we found a similar result to duration. A three-way interaction among Stress, Group, and Syllable for the raw intensity values indicates that Korean learners of English employ intensity cues in implementing English stress, but not in a native-like way. Korean learners produced second-syllable stressed words with a greater intensity difference between the first and second syllable than the first-syllable stressed words, whereas English speakers produced first-syllable stressed words with a greater intensity difference than the second-syllable stressed words. This suggests that although Korean learners are able to acquire lexical stress in L2, they are more affected by the phrasal boundary in their native language, resulting in a higher intensity value on the second syllable (See Chapter 2) because the target words were always located in sentence-medial position. The same result was also supported by the intensity ratio results, as indicated by a significant two-way interaction between Stress and Group.

With respect to the F0 values, the absence of a significant two-way interaction between Stress and Group indicates that both Korean and English speakers employed F0 in indicating stress. This is also supported by a main effect of Stress for the second-to-first F0 ratio values but a lack of Stress by Group interaction. These results indicate that Korean learners of English were

able to acquire to use of three suprasegmental cues in implementing lexical stress in English, their performance was not at the native-like level, as predicted by the Cue weighting Model.

Lastly, regarding vowel reduction, Korean learners of English were not able to acquire the vowel reduction cue in expressing lexical stress in English. The significant interaction between Stress and Frontness for F2 in the first syllable of English speakers' productions suggests that English speakers reduce the vowel quality as a function of stress. However, Korean speakers did not show such an effect, as supported by the lack of a two-way interaction between Stress and Frontness from Korean speakers' productions⁴. Table 26 and Table 27 present a summary of main effects and interactions found in this chapter for three suprasegmental measurements as well as F1 and F2 from the production by two speaker groups.

⁴ An analysis of a subset of 8 words which overtly change vowel quality as a function of stress (rebel, desert, record, conflict, object, progress, project, contract) showed the same results as the analysis of the 14 pairs.

Table 26. Summary of statistical results of three suprasegmental and segmental raw values.

Acoustic cues	Main analysis	Post-hoc analysis	
		English speakers	Korean learners
Duration	Main effect of Stress Stress * Syllable Stress * Group Stress * Syllable * Group	Main effect of Stress Stress * Syllable	Stress * Syllable
Intensity	Stress * Syllable Stress * Syllable * Group	Stress * Syllable	Stress * Syllable
F0	Stress * Syllable	n/a	n/a
F1 on the first syllable	Main effect of Stress Main effect of Vowel Height Main effect of Group Stress * Group	n/a	n/a
F1 on the second syllable	Main effect of Vowel Height Main effect of Group Stress * Height	n/a	n/a
F2 on the first syllable	Main effect of Stress Main effect of Frontness Stress * Frontness Stress * Group Frontness * Group Stress * Frontness * Group	Main effect of Stress Main effect of Frontness Stress * Frontness	Main effect of Stress Main effect of Frontness
F2 on the second syllable	Main effect of Stress Main effect of Frontness Main effect of Group	n/a	n/a

Table 27. Summary of statistical results of three suprasegmental second-to-first ratio values.

Acoustic cues	Statistical results	Post-hoc analysis	
		English speakers	Korean learners
Duration Ratio	Main effect of Stress Stress * Group	Main effect of Stress	Main effect of Stress
Intensity ratio	Main effect of Stress Stress * Group	Main effect of Stress	Main effect of Stress
F0 ratio	Main effect of Stress	n/a	n/a

Taken together, the current chapter found that Korean learners of English were able to use all three suprasegmental cues to indicate lexical stress in English, and were not able to acquire a new cue (e.g., vowel reduction) in expressing word-level prominence in L2.

5.7. Discussion

In this chapter, we investigated how Korean learners of English implement acoustic correlates of English lexical stress. We compared the productions of Korean learners to those of English native speakers to examine how suprasegmental cues are acquired in L2 speakers' production. The secondary purpose of this chapter was to investigate to which extent L2 learners can acquire non-contrastive L2 phonetic properties in expressing lexical stress. To answer this question, we examined whether Korean learners of English can acquire a new cue (e.g., vowel reduction) that does not exist in their L1 when producing L2 lexical stress. Given the findings that Korean does not employ vowel reduction and does not have lexical stress (see Chapter 2), we predicted that Korean learners would not be able to produce English unstressed syllables with reduced vowel quality. However, we predicted that Korean learners would be able to use suprasegmental cues – duration, intensity, and F0 – in expressing English stress because not only is the duration contrast still retained in contemporary Seoul Korean, but higher-level prosody in Korean also employs duration, in addition to F0 and intensity.

The results revealed that Korean learners of English were indeed able to use duration, intensity, and F0 in producing English stress pairs. This result is consistent with the previous claim that L2 learners' linguistic experience will attune their perceptual attention to specific acoustic cues, and therefore, will affect their acquisition of L2 stress, which will lead to underattending or allocation of certain acoustic cues in L2 (Evans & Iverson, 2004; Francis & Nusbaum, 2002; Guion & Pederson, 2007; Iverson et al., 2003; Lee et al., 2006). According to this claim, then, only the acoustic cues that are used in the L1 will be attended to, but the cues

that are used in the L2 will be underattended and are not likely to be acquired (Schmidt, 2001; Tomlin & Villa, 1994). Our findings regarding the new L2 cue (e.g. vowel reduction) were also consistent with this claim.

Our results suggested that Korean learners are not able to reduce vowel quality of unstressed syllables. This result is consistent with what Han et al. (2011) found, that the Korean learners who were not immersed in L2 environments were not able to reduce vowel quality. Han et al. (2011) claimed that L2 learners without immersion were producing English unstressed syllables with corresponding Korean vowels, suggesting that immersion in the target language will make L2 learners capable of acquiring an abstract phonological category and its phonetic variants.

Overall, this chapter found that L2 learners are not able to acquire a new cue that does not exist in their L1 phonological category, but the L1 phonological feature will facilitate the perceptual system of the L2 learners, and help L2 learners' acquisition of L2 phonetic features. However, we do not yet know which cue the Korean learners are most attuned to, since we have not tested their perceptual weighting of each cue in identifying the stress pattern. Will the Korean listeners be most sensitive to perceptual cues based on the presence of each cue in their L1? Or will their perceptual weight be based on the phonetic saliency of each cue? These questions will be investigated in more detail in the following chapter.

CHAPTER VI.
PERCEPTION OF ENGLISH WORD-LEVEL PROMINENCE BY KOREAN
LEARNERS OF ENGLISH

6.1. Introduction

In Experiment 3, we found that Korean learners were able to use suprasegmental cues but not segmental cues in producing lexical stress in English. These results suggest that L2 learners of English can acquire an abstract phonological feature (i.e., lexical stress) even though their native language does not employ it. When learners' first language uses the suprasegmental cues expressing lexical stress (i.e., duration, intensity, and F0) at different levels of prominence, learners were able to extract and transfer those cues to express word-level prominence in L2. Recall that Korean is a language with phrasal-level prominence expressed by F0, intensity, and duration: F0 is used to express specific pitch patterns within an accentual phrase (AP), intensity is used at the AP initial- and final- boundaries, and duration is used at the intonational phrase (IP) boundary. Given the fact that suprasegmental cues that are used in expressing lexical stress in English are also utilized in expressing higher-level prosody in Korean, Korean learners were able to access the acoustic cues expressing phrasal-level prominence from their L1 and transfer them to express lexical stress in L2. Also, we found that Korean learners were not able to acquire a new cue that does not exist in their native language. Given that Korean does not have vowel reduction (See Chapter 2), Korean learners of English were not able to reduce vowel quality when producing English unstressed syllables.

Based on the findings of the acoustic study (Experiment 3), in this chapter, we aim to examine which perceptual cue(s) Korean learners rely on in processing English stress contrasts. We investigate this question by manipulating acoustic cues that signal lexical stress in English.

We examine which cue Korean learners weight the most heavily in perceiving stress, and whether Korean learners' cue weighting is different from that of the English listeners. We hypothesize that the frequency of occurrence of a cue in the higher-level prosody in L1 may influence the use of a cue in L2, and that L2 learners will weight cues accordingly. In other words, the acoustic cue that is used most frequently in L1 prosody (i.e., F0) will be the one that facilitates processing of L2 lexical stress the most, as compared to the less frequently used cues (i.e., intensity and duration). However, given the fact that younger Korean speakers does not retain a phonemic vowel length distinction in Korean (see Experiment 1), Korean learners might not weight duration cue at all in perceiving English stress.

If acoustic cues to higher-level prosody help Korean learners to acquire L2 phonological features, then, a cue that does not exist in the native language (i.e., vowel reduction) will not be acquired. Given that previous literature suggested that Korean learners do not use vowel reduction as a cue in perception (Lin et al., 2013), Korean learners might not be able to use spectral cues at all, but instead only weight suprasegmental cues in perceiving English stress. Thus, the main focus of this chapter is to revisit whether Korean L2 learners of English perceive word-level prominence (i.e., lexical stress), and which cue Korean learners weight the most heavily in processing lexical stress in English .

6.2. Background

Acquisition of an L2 speech contrast is strongly influenced by the phonological characteristics of the learners' native language. For example, previous literature has suggested that the presence of a phonological feature (i.e., stress contrasts) in the native language determines whether the L2 learners are able to acquire L2 lexical stress (Dupoux, Peperkamp, & Sebastián-Gallés, 2001; Dupoux, Sebastián-Gallés, Navarrete, & Peperkamp, 2008). However, numerous studies have also found that if the learners' native language has a phonological

prosodic contrast expressed by a parameter that serves as a cue to stress in the L2, such as lexical tone, those learners are less constrained to use those cues in L2. For example, Vietnamese learners of English were also able to use F0 more than duration or vowel reduction, perhaps since Vietnamese employs lexical tone (Nguyễn, Ingram, & Pensalfini, 2008; Nguyen & Ingram, 2005). Also, in producing English stress contrasts, Chinese learners of English were able to use F0 more than duration, intensity (Lai, 2008) and vowel reduction (Zhang et al., 2008). Moreover, both Mandarin Chinese and Taiwanese Chinese learners were able to use F0 in detecting stress location in a sequence recall task, although the employment of lexical stress differs between the two dialects of Chinese (Qin & Tremblay, 2014). Mandarin Chinese has been suggested to have lexical stress realized primarily with duration (Shen, 1993), while Taiwanese Chinese does not employ lexical stress (Chao, 1968). When both duration and F0 were provided as a cue to stress, Mandarin Chinese learners showed a more accurate performance than Taiwanese Chinese learners, perhaps because Chinese uses duration as the strongest cue to stress. However, when only F0 was used as a cue to stress, Taiwanese Chinese learners showed an equally accurate performance as Mandarin Chinese learners. Thus, it seems that in addition to whether L2 learners' native language employs lexical stress the way in which prosodic cues to stress are utilized in L1 may also play an important role in acquiring lexical stress in L2. If this is the case, Korean learners of English may be able to use duration more than F0 or intensity in perceiving L2 English lexical stress, since younger Korean listeners still perceptually retain a phonemic vowel length distinction (see Experiment 2). However, given the finding that L2 learners do not only use the cues to a phonological feature in their L1 in implementing L2 lexical stress (e.g., Chinese learners also use intensity and duration in addition to F0 for English stress), it is possible that L2 learners can also attune to other acoustic cues used at different levels of prosodic

structure in their L1 and use them in perceiving L2 lexical stress. If that is the case, learners' experience with cues in L1 might predict the degree of acquisition of lexical stress in L2.

For example, Korean does not employ cues to stress at the lexical level, however, the same cues are also utilized at the higher-level prosody. Korean has phrasal-level prominence that is mainly realized with F0, but intensity and duration also mark the phrasal and sentence boundaries (Jun, 1993; 1995). Previous studies have found that Korean late bilinguals were able to use F0 in implementing English stress in a native-like manner, but were not able to use intensity and duration in a native-like way (Lee et al., 2006). If the native-like acquisition of F0 is due to the fact that Korean uses F0 most frequently, we might be able to predict that Korean learners of English will use F0 most heavily in their perception as well.

Regarding the acquisition of spectral cues, it is predicted that Korean learners of English will not be able to acquire vowel reduction in expressing English stress, since Korean does not have vowel reduction (see Experiment 1). This was supported by Lin et al. (2013)'s findings that Korean learners of English were not helped by reduced vowel quality when performing a lexical decision task (e.g., 'human' [hju.mən] vs. nonword [hju'mæ n]). This seems to suggest that experience with a cue will predict the L2 learners' ability to use vowel quality. However, Lin et al. also found that with increased proficiency, Chinese learners of English, who also participated in the same lexical decision task, benefited from vowel reduction. Lin et al. concluded that the fact that Chinese has lexical stress might have helped Chinese learners to acquire the vowel reduction cue. However, their interpretation is not convincing, since Chinese does not employ vowel reduction in expressing Chinese lexical stress.

The use of the vowel reduction cue by Chinese learners of English was also found in Zhang & Francis (2010): when Chinese learners were asked to identify the stress location of

‘desert’, in which vowel quality and one of the suprasegmental cues were manipulated, Chinese listeners, like English native listeners, weighted vowel quality more heavily than other cues. Zhang and Francis concluded that this could be because Chinese learners stored separately as two non-native categories the full vowel [ɛ] from the first-syllable stressed word ‘DEsert’ and the reduced vowel [ɪ] from the second-syllable stressed word ‘deSERT’. Therefore, Chinese listeners could easily detect the difference between stressed and unstressed vowels. A similar pattern was found among L2 learners of Russian, although the primary cue to stress in Russian is duration rather than vowel reduction: Russian learners weight vowel quality more heavily than other cues in identifying the stress location of an English nonword (Chrabaszcz, Winn, Lin, & Idsardi, 2014).

The ability to use vowel reduction by L2 learners in their perception of L2 stress is interesting, given the fact that L2 learners were unable to produce reduced vowel quality in a native-like manner. Zhang et al. (2008) reported incomplete vowel reduction from the productions of English unstressed syllables by Mandarin learners of English. However, the perception study by Zhang & Francis (2010) suggests that Mandarin listeners showed a native-like weighting of vowel reduction. Previous studies have found that Korean learners of English with advanced proficiency also showed an imperfect vowel reduction in their production, suggesting that Korean learners of English were replacing English unstressed syllables with the corresponding Korean vowel [i] (Lee et al., 2006; Han et al., 2011). However, the current study found Korean learners were not able to produce reduced vowel quality in English unstressed syllables (Experiment 3). These findings might suggest that sufficient exposure to the target language is required in order to acquire vowel reduction. Recall that Lee et al. (2006) tested the productions of Korean-English late-bilinguals and Han et al. (2011) reported non-native like

vowel reduction in the productions of Korean learners who had lived in English-speaking countries, while none of the Korean learners from the present study have such residential experience. Thus, these findings seem to suggest that Korean learners might be able to acquire some degree of vowel reduction, albeit non-native like, only with increased exposure to L2. However, even if Korean learners cannot produce vowel reduction, they might still be able to perceive vowel reduction as a cue to stress, like Chinese learners.

Taken together, results from production (Lee et al., 2006; Han et al., 2011) and perception studies (Lin et al., 2013) on the acquisition of English lexical stress by Korean learners seem to be inconsistent in indicating whether Korean learners are able to acquire the reduction cue or not. If the cue weighting of vowel reduction by Chinese and Russian learners of English is due to the fact that both Chinese and Russian has lexical stress, Korean learners would not weight vowel quality in identifying lexical stress in English, as Lin et al. (2013) suggests. If L2 learners weight vowel quality equally regardless of the phonological feature in their L1, then, saliency of a cue might be a stronger indicator of whether L2 learners can acquire cue(s) to stress in L2.

Thus, the primary goal of this chapter is to examine which cue(s) Korean learners of English weight most heavily in their perception of English lexical stress. If learners' experience of a cue can only predict the acquisition of L2 stress, Korean learners would weight F0, intensity, and duration according to their frequency of occurrence as a cue to higher-level prominence in Korean: however, vowel quality will not be weighted at all. That being said, Korean learners of English might be able to acquire vowel quality as a cue to stress in their perception, as previous studies have found for Russian and Chinese learners' perception of English stress. We hypothesize that if the saliency of the vowel quality is stronger than that of suprasegmental cues,

Korean learners would also be able to acquire this spectral cue as well. The specific goal and hypotheses of this chapter are listed below:

6.3. Goals

Experiment 4 examines which acoustic cues Korean learners of English use when perceiving English stress. If typological similarity is the main factor in determining the learnability of a different L2 prosody, then the Korean learners of English will not be able to use duration, F0, intensity, and vowel reduction in perceiving English stress. If Korean learners can use acoustic cues to higher-level prosody in their native language, the Korean learners will be able to use only suprasegmental cues (i.e., F0, intensity, and duration), but will not be able to use vowel quality. Therefore, the main purpose of Experiment 4 is to investigate whether Korean learners weight acoustic cues in processing L2 lexical stress as a function of frequency of occurrence in Korean. The secondary purpose of Experiment 4 is to examine whether Korean learners can acquire a new cue to stress in L2. Given the fact that Korean does not employ vowel reduction, Korean learners may not weight vowel reduction at all. However, if the reduced vowel quality of the unstressed vowel is perceptually easy to discriminate from the quality of the stressed vowel, Korean learners may be able to acquire vowel reduction in their perception like Russian and Chinese learners of English. If whether learners' native language employs lexical stress is the most important factor in acquiring vowel reduction, regardless of whether vowel reduction is used in L1, then, unlike Chinese or Russian learners of English, Korean learners of English will not be able to weight the vowel reduction cue. This chapter aims to investigate the following research questions:

- 1) Are Korean learners of English able to perceive English lexical stress contrasts?
- 2) Will Korean learners of English not be able to perceive L2 lexical stress, given that Korean does not employ lexical stress?

- 3) Which cue(s) will Korean learners of English use in perceiving English lexical stress?
- 4) Does the frequency with which cues signal higher-level prosodic structure predict the use of acoustic cues in perceiving lexical stress in L2?
- 5) Will Korean learners of English be able to acquire a new L2 segmental cue (i.e., vowel reduction) in perceiving English lexical stress?

6.4. Methodology

6.4.1. Participants

Thirteen Korean learners of English completed an English stress identification task. All Korean learners were speakers of Seoul dialect, so that we can assume the use of prosodic cues to be identical across the subjects, since some of the Korean dialects (e.g., the Kyungsang dialect) display tonal contrasts, which can affect the use of F0. The mean age of Korean learners' of English was 23.4 years (sd = 2.5) and their age of acquisition (AOA) was 9 years (sd = 2.5). None of the Korean speakers had lived in a country where English is dominantly spoken. The mean score of the Michigan proficiency test (1972) was 37.9 out of 45 points (sd = 2.5). None of the subjects reported any hearing or speech disorders.

For the control group, 14 English native speakers (mean age = 21.4, sd = 2.4) recruited from the University of Kansas completed the same English stress identification task.

6.4.2. Stimuli

6.4.2.1. Original base token

The English stress pair OBject-obJECT produced by a male native speaker was chosen as the baseline token. The frequency of occurrence of the noun OBject (uppercase letters indicate stressed syllable) was 104 per million, and that of the verb obJECT was 24 per million (Kucera & Francis, 1967). At first, we recorded 5 native speakers producing the target word pairs with three repetitions. The speakers read the target words embedded in a contextually-related sentence

to prompt the intended word category (e.g., The **object** of this game is to win.), and then read the same token embedded in a contextually-neutral sentence (e.g., Please say **object** again). This procedure was repeated three times. From 15 productions of the ‘object’ pair, we chose a production of Speaker B (age 39) as the baseline token, since Speaker B’s productions showed the greatest difference in duration and F0 between the noun and the verb productions among the recordings of the 5 native speakers. Then, as the baseline segment, we chose the first syllable from the noun production (‘OB’) and the second syllable from the verb production (‘JECT’) to manipulate acoustic parameters, in order to preserve possible acoustic information in the long vowel and also to minimize any possibility of losing acoustic information by lengthening the short vowel to a long vowel. The vowel quality of the first syllable was manipulated, and three acoustic parameters – duration, F0, and intensity – were manipulated in both syllables.

6.4.2.2. Stimulus manipulation

The stress minimal pair ‘OBject’ and ‘obJECT’ was produced in a carrier sentence ‘Please say *object* again’ and used for the manipulation. For the vowel quality, we took the F1, F2, and F3 values of the first syllable of the noun and verb productions respectively, and created 5-step continua from /a/ to /ə/. For the suprasegmental cues, we took the maximum and minimum values of the duration, F0, and intensity values across the 5 native speakers’ productions as the two endpoints of the manipulation.

For each condition, vowel quality and one of the suprasegmental cues were orthogonally manipulated (e.g., vowel quality x duration) to signal the stress patterns while the other two suprasegmental cues (e.g., F0 and intensity) were controlled to be neutral. The vowel quality of the second syllable was always identical across all manipulation conditions. When the first syllable was manipulated, the suprasegmental cues of the second syllable were controlled to be neutral (at step 3) between a stressed and an unstressed syllable; when the second syllable was

manipulated, the vowel quality of the first syllable was controlled to be neutral (at step 3), while having one of the suprasegmental cues signal stress. Since having a neutral vowel quality in the first syllable is already manipulating a cue, we only manipulated one suprasegmental cue in the second syllable, so that all conditions have two cues that are manipulated at a time. After completing constructing vocalic portions of the first and the second syllable, these manipulated vocalic segments were then concatenated with the consonantal portions. The durations of the consonantal portions ([b], [dʒ], [k], and [t]) were also constructed to be at the midpoint of the noun and the verb productions. These manipulated words were then embedded in a semantically neutral carrier sentence (e.g., ‘Please say ____ again’) produced by Speaker B, and presented as the auditory stimuli in the perception experiment. Table 28 represents the duration of the consonantal portions from the noun and verb productions.

Table 28. Duration of the consonantal portions of the baseline ‘object’ pairs by Speaker B.

	Noun productions	Verb productions	Midpoint
[b]	88 ms	112 ms	100 ms
[dʒ]	51 ms	57 ms	54 ms
[k]	99 ms	118 ms	108.5 ms
[tʰ]	1 ms	1 ms	1 ms

Thus, we created 75 manipulated tokens by independently manipulating vowel quality (VQ) and duration (5 by 5), vowel quality and F0 (5 by 5), and vowel quality and intensity (5 by 5) for the first-syllable condition. When we manipulated the first syllable, since all suprasegmental cues in the second syllable were controlled to be neutral (at step 3), this procedure resulted in 8 repeated tokens with three cues at step 3 three times for the first-syllable condition (e.g., a token with VQ at step 1, duration at step 3, intensity at step 3, and F0 at step 3 was created three times), and four cues at step 3 three times (e.g., a token with VQ at step 3,

duration at step 3, intensity at step 3, and F0 at step 3 was created three times), generating a total of 10 repeated tokens. Therefore, a total of 65 tokens were created for the first-syllable condition. For the second-syllable condition, we created 15 tokens with the vowel quality of the first syllable at step 3 while varying one of the suprasegmental cues vary (5 steps of duration + 5 steps of intensity + 5 steps of F0). This procedure also created three repeated tokens with four cues at step 3 (e.g., a token with VQ at step 3, duration on the second syllable at step 3, intensity in the second syllable at step 3, and F0 on the second syllable at step 3). Thus, a total of 13 tokens were created at the second-syllable condition. These 78 tokens were repeated 3 times in 3 blocks in a randomized order, which resulted in a total of 234 trials (78 tokens x 3 repetitions) for each subject.

6.4.2.3. Vowel Quality manipulation

Five-step continua from [a] to [ə] were created by using line spectral frequencies (LSF) interpolation in Matlab (Ver. R2014a). Like the Linear Predictive Coding (LPC) spectrum, LSF is another representation of the linear prediction (LP) spectrum, proposed by Itakura (1975). LSF interpolation is often used in speech spectrum compression. By having a continuous trajectory of parameter vectors, LSF makes interpolation much easier than the LPC spectrum, since speech resynthesis by Fourier-spectrum modification from LPC may introduce audible artifacts (Pfitzinger, 2004).

6.4.2.4. Vowel duration manipulation

Five steps of the first and second syllable were created based on the maximum (when the syllable is stressed) and minimum (when the syllable is unstressed) values of the vowel duration from our acoustic data for the ‘object’ pair from Experiment 3. For the first syllable, 5 steps were created in 27.18 ms increments from the minimum duration (63.81 ms) to the maximum duration (172.52 ms). And 5 steps of the second syllable were created with a 14.35 ms increment from the

minimum (81.06 ms) to the maximum value (138.47 ms). When the first syllable was varied, the second syllable was kept constant at the midpoint (step 3) throughout the 5 steps of the first syllable continuum, so that listeners would identify the syllable prominence based on the acoustic cues contained in the first syllable. The same was done for the second syllable: after creating a 5-step continuum for the second syllable, each step was concatenated with the midpoint of the first syllable (step 3). The duration manipulation was conducted by setting the onset and offset of periodicity of the vowels in the *Duration manipulation tier* of Praat to extract the *Duration Tier*. Then, the vowel duration was multiplied with a manipulation factor for each step. For example, a manipulation factor of 0.685 was used when shortening the vowel duration of the original token (172.52 ms) to the duration of 118.16 ms (for step 3). Then, a new token with manipulated vowel duration was synthesized by replacing the original duration tier with the new tier.

6.4.2.5. F0 manipulation

F0 had 5 steps from the maximum to the minimum value both for the first and the second syllables. Five steps of the first syllable were created with a 5.85 Hz decrease from the maximum F0 value (step 5: 123.88 Hz) to the minimum F0 value (step 1: 100.49 Hz). The second syllable also had 5 steps with a 7.25 Hz decrease from the maximum F0 value (step 5: 129.58 Hz) to the minimum F0 value (step 1: 100.58 Hz) from stressed to unstressed syllables. This F0 manipulation was done after manipulating the vowel duration of each step. F0 values for each step were manipulated by using the *Pitch Manipulation Tier* of Praat by either lowering or raising the F0 point of each tier. For example, to decrease the F0 of the baseline token (129.58 Hz) to the F0 of the neutral token (115.08 Hz), we first removed all the pitch points shown on the *Pitch Tier*, and then recreated an initial and a final pitch point at 115.08 Hz. The remaining

points between the initial and final points were interpolated in Praat after resynthesizing the token.

6.4.2.6. Intensity manipulation

After both duration and F0 manipulation were conducted, intensity was also manipulated, using a script (Vicenik). Intensity had 5 steps in increments of 2.12 dB for the first syllable from the minimum (62.25 dB) to the maximum intensity values (71.14 dB). For the second syllable, the intensity value incrementally increased from the minimum value (64.27 dB) to the maximum value (72.17 dB) in 1.97 dB steps. Table 29 represents the manipulation values of the five steps for first and second syllables for duration, F0, and intensity.

Table 29. Five steps of manipulation values of first and second syllable for duration, F0, intensity, F1 and F2 values.

	First syllable					Second syllable				
	Unstressed		Stressed			Unstressed		Stressed		
Step	1	2	3	4	5	1	2	3	4	5
Duration (ms)	63.81	90.98	118.16	145.34	172.52	81.06	95.42	109.77	124.12	138.47
Intensity (dB)	62.65	64.77	66.90	69.02	71.14	64.27	66.25	68.22	70.20	72.17
F0 (Hz)	100.49	106.34	112.19	118.03	123.88	100.58	107.83	115.08	122.33	129.58
F1 (Hz)	441	521	675	933	945	597				
F2 (Hz)	1775	1775	1737	1543	1121	1656				
F3 (Hz)	2743	2598	2440	2317	2325	2744				

6.5. Procedure

A stress identification task was employed to examine which acoustic cue(s) Korean learners of English weight in identifying English stress contrasts as compared to native English

listeners. First, Korean learners of English took the University of Michigan Listening Comprehension Test (1972) (Michigan Test) in order to assess their English proficiency before participating in the perception test. Next, the participants participated in a stress-identification test, in which they were asked to identify which syllable of the target word was stressed after hearing the sentence ‘*please say object again*’ by pushing either [q] (first-syllable stressed word, OBject) or [p] (second-syllable stressed word, obJECT) on the keyboard. The response buttons associated with the stress location were counterbalanced. The production task for English stress (Experiment 3) was conducted 6 months before the perception experiment.

The experiment was conducted with three different blocks, each with 78 trials in a randomized order. Thus, the experiment consisted of a total of 234 tokens (78 stimuli x 3 repetitions). The intertrial interval (ITI) was 1500 ms from the offset of the response to the onset of the presentation of the following trial. A practice session with 12 trials was conducted before the main experiment to ensure that the participants were familiar with the task. The subjects were allowed to take a short break between the blocks.

6.5.1. Data analysis

We conducted a series of binomial logistic regressions to examine the effect of four acoustic parameters (duration, intensity, F0, and vowel quality) on the perception of stress between the two listener groups, using the lme4 package (Bates, 2005; Bates & Maechler, 2010) in the R statistical environment (R development Core Team, 2012, Version 3.1.2). Choice (first syllable vs. second syllable) was entered as a dependent variable, and Syllable (first vs. second), Vowel Quality (VQ) manipulation (steps 1-5), Duration manipulation (steps 1-5), Intensity manipulation (steps 1-5), F0 manipulation (steps 1-5), and Group (younger vs. older) were entered as fixed effects. Participant was entered as random effect. The word with first-syllable stressed word, noun ‘OBject’, was coded as ‘1’ because of its higher frequency of occurrence

(‘OBject’: 104 per million vs. ‘obJECT’: 24 per million, based on the CELEX database; Baayen, Piepenbrock, & van Rijn, 1993). The model tested the main effect of the independent variables, two-way interactions between the segmental and suprasegmental cues (VQ by Duration; VQ by Intensity; VQ by F0), a two-way interaction between Group and Syllable, three-way interactions among Group and two of the cues (e.g., Group by VQ by Duration), and four-way interactions among Syllable, Group, and two of the cues (e.g., Syllable by Group by VQ by Duration). When there was an interaction between the independent variables, we stratified the data by the factors that showed the interaction. The English native listener group was used as a baseline against the performance of Korean learners of English for the comparison, since using the performance of English listeners would allow us to see which cue Korean learners use and to which extent, in perceiving English stress, as compared to English listeners. Thus, the baseline in the model was the English native listeners’ performance on the first-syllable stressed word ‘OBject’ with intensity 1, duration 1, F0 1, and vowel quality 1.

6.6. Results

A linear mixed-effects model was conducted on all participants’ responses in identifying English stress pairs. A series of fitted mixed-effects regression models were tested in a stepwise analysis to find the most parsimonious model. Table 30 represents the result of the logistic regression on both syllables.

Table 30. Summary of results of the optimal model from the logistic regression examining responses to both syllables.

Variable	Estimate (SE)	Z	P
(intercept)	-2.93 (1.11)	-2.63	< .01
GroupKorean	-3.61 (1.62)	-2.23	< .01
Syllable	-0.69 (0.64)	-1.07	= .28
Vowel Quality	1.00 (p.23)	4.36	< .01
Intensity	0.05 (0.21)	0.22	= .84
Duration	0.04 (0.21)	0.20	= .84
F0	0.07 (0.21)	0.33	= .74
GroupKorean:Syllable	3.41 (0.99)	3.43	< .01
VowelQuality:Intensity	-0.05 (0.03)	-1.05	= .30
VowelQuality:Duration	0.07 (0.04)	1.58	= .11
VowelQuality:F0	-0.05 (0.04)	-1.10	= .27
GroupKorean:VowelQuality	-0.66 (0.31)	-2.10	= .04
GroupKorean:Intensity	1.03 (0.30)	3.43	< .01
GroupKorean:Duration	0.06 (0.30)	0.19	= .85
GroupKorean:F0	0.50 (0.30)	1.66	= .10
Syllable:Intensity	0.13 (0.12)	1.08	= .28

Syllable:Duration	-0.15)-/12_	-1.26	= .21
Syllable:F0	0.09 (0.12)	0.74	= .46
GroupKorean:VowelQuality:Intensity	-0.02 (0.06)	-0.31	= .76
GroupKorean:VowelQuality:Duration	-0.01 (0.06)	-0.20	= .84
GroupKorean:VowelQuality:F0	0.09 (0.06)	1.46	= .14
GroupKorean:Syllable:Intensity	-0.68 (0.19)	-3.57	< .01
GroupKorean:Syllable:Duration	-0.02 (0.19)	-0.09	= .93
GroupKorean:Syllable:F0	-0.53 (0.19)	-2.8	< .01

The analysis found significant main effects of Group ($p < .01$) and Vowel Quality ($p < .01$). These results indicate that native English listeners were less biased toward the second-syllable stressed word ‘obJECT’ (54 %) than Korean learners (66 %), and the listeners’ response changed as a function of the vowel quality. When the vowel quality of the first syllable was at step 1 (unstressed on the first syllable), listeners’ first-syllable stressed response rate was 21%, and this response rate increased to 27%, 29%, 60%, and 72% at step 2, 3, 4, and 5 (stressed on the first syllable), respectively. We also found significant two-way interactions between Group and Syllable ($p < .01$), Group and VowelQuality ($p = .04$), Group and Intensity ($p < .01$), and three-way interactions among Group, Syllable, Intensity ($p < .01$) and among Group, Syllable, F0 ($p < .01$). In order to have a better understanding of these interactions, we stratified the data as a function of Syllable, and ran a model that include Group, Vowel Quality, Intensity, Duration, F0

as main effects, and two-way interactions between Group and each of the acoustic cues, with Subject as random effect.

When the cues on the first syllable were manipulated, we found a main effect of Vowel Quality ($p < .01$), and two-way interactions between Group and Vowel Quality ($p < .01$), between Group and Intensity ($p < .01$), and between Group and F0 ($p < .01$). The main effect of Vowel Quality again indicates that both groups weighted vowel quality of the first syllable in identifying stress location of the stimuli. Table 31 presents the summary of results of the model with the listeners' responses to the tokens for which the first syllable was manipulated while controlling the second syllable (first syllable level).

Table 31. Summary of results of the logistic regression examining responses on the tokens at the level of first syllable.

Variable	Estimate (SE)	Z	P
(intercept)	-3.32 (0.34)	-9.75	< .01
GroupKorean	-0.70 (0.49)	-1.44	= .15
Vowel Quality	0.91 (0.04)	23.75	< .01
Intensity	0.04 (0.05)	0.75	= .45
Duration	.10 (0.05)	1.82	= .07
F0	0.01 (0.05)	0.22	= .83
GroupKorean:VowelQuality	-0.48 (0.05)	-9.36	< .01
GroupKorean:Intensity	0.29 (0.08)	3.80	< .01
GroupKorean:Duration	0.01 (0.08)	0.14	= .90
GroupKorean:F0	0.23 (0.08)	3.07	< .01

Figure 38 presents the probability of first-syllable stressed responses ('OBject') between the two listener groups for the tokens in which four acoustic parameters varied in the first syllable while controlling the cues in the second syllable. Each cue is represented with a different color, and two listener groups are represented by different lines (Korean learners: dashed lines; Native English listeners: solid lines). This figure shows that native English listeners weight vowel quality more heavily than the Korean learners, and English listeners do not weight other

suprasegmental cues in perceiving English stress pairs. On the other hand, Korean learners weight Vowel Quality the most, and also weight intensity, duration, and F0.

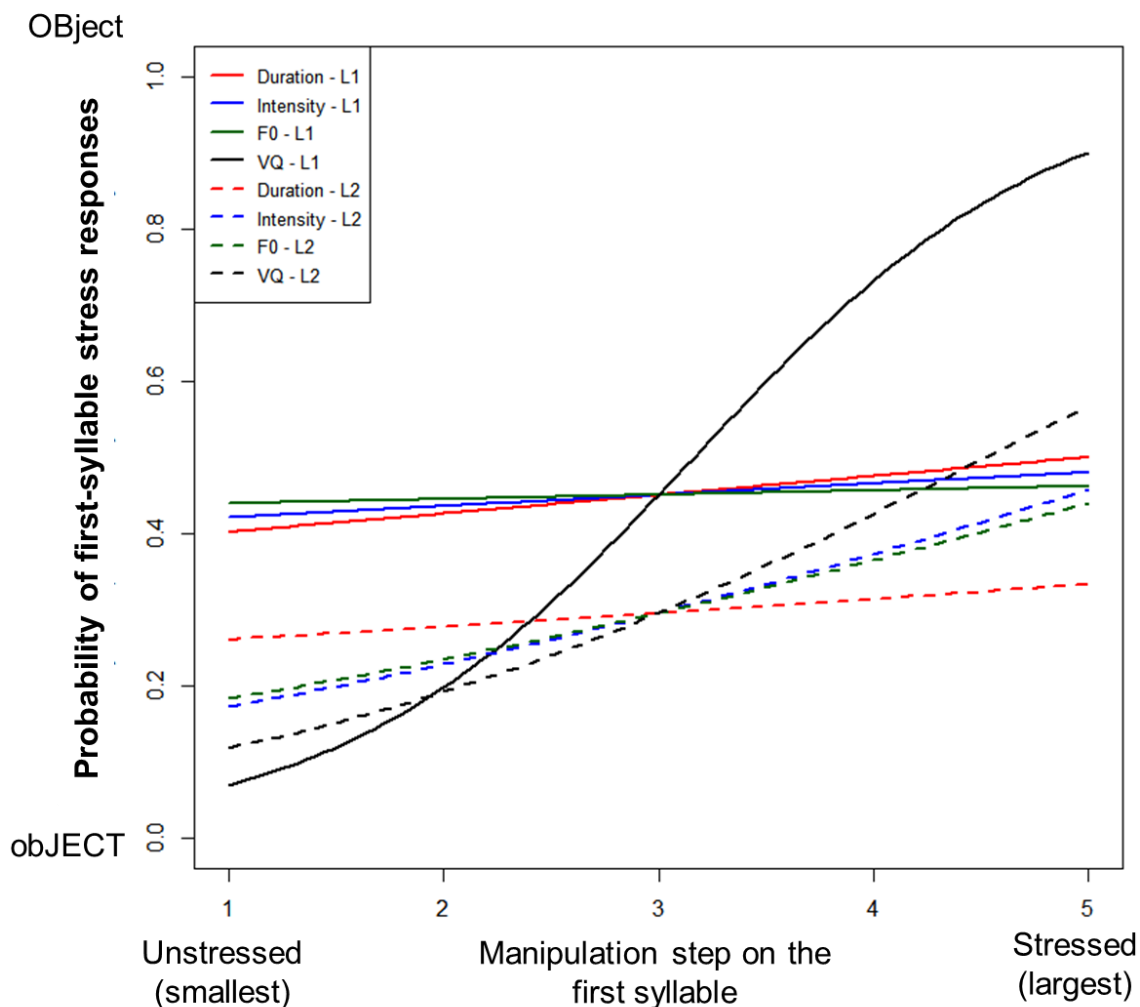


Figure 38. Probability of the first-syllable stressed response, 'Object' between the two listener groups when the cues on the first syllable were manipulated, while controlling cues on the second syllable to be neutral. X-axis indicates the manipulated steps of each cue. 1 indicates that duration values were at the minimum endpoint, expressing first-syllable unstressed; and 5 indicates that duration values were at the maximum endpoint, expressing first-syllable stressed. Dotted lines indicate Korean learners' responses, and solid lines indicate native English listeners' responses. Listeners' responses for each cue are illustrated with different colors: red, blue, green, and black lines indicate listeners' responses for duration, intensity, F0, and Vowel Quality respectively.

In order to examine the interactions between Group and Vowel Quality, Group and Intensity, and Group and F0, we further conducted two separate linear mixed-effects models examining participants' responses to the tokens for which the first syllable was manipulated with

each listener group. For Native English listeners, we found a main effect of only Vowel Quality only ($p < .01$), indicating that English listeners only weight Vowel Quality of the first syllable in identifying stress pattern. Table 32 represents a summary of results of the model at the level of the first syllable by the native English listeners.

Table 32. Summary of results of the logistic regression examining responses to the tokens at the level of the first syllable by the native English listeners.

Variable	Estimate (SE)	Z	p
(intercept)	-3.30 (0.32)	-10.30	< .01
Vowel Quality	0.90 (0.04)	23.65	< .01
Intensity	0.04 (0.05)	0.75	= .45
Duration	0.10 (0.05)	1.82	= .07
F0	0.01 (0.05)	0.21	= .83

For Korean learners, we also found a main effect of Vowel Quality ($p < .01$), indicating that the probability of the first-syllable stressed responses decreased as the vowel quality was reduced. The smaller estimate score for Korean learners (0.43) than English listeners (0.90) indicates that English listeners weight vowel quality more heavily than the Korean listeners. We also found main effects of Intensity ($p < .01$) and F0 ($p < .01$). These results indicate that when the intensity value on the first syllable increases, the probability of responding first-syllable stressed word also increased. The first-syllable stressed response rate when the intensity was at step 1 (first syllable unstressed) was 24 %, and this rate increased to 27%, 37%, 39%, and 51% at step 2, 3, 4, and 5 (first syllable stressed), respectively. Similarly, when the F0 values on the first syllable were increased, the first-syllable stressed response rate also increased. The response rate to the

first-syllable stressed word when F0 was at step 1 (first syllable unstressed) was 29 %, and this rate increased to 34%, 35%, 41%, and 49% at step 2, 3, 4, and 5 (first syllable stressed), respectively. Table 33 presents a summary of results of the model at the level of the first syllable by Korean learners.

Table 33. Summary of results of the logistic regression examining responses to the tokens at the level of the first syllable by Korean learners.

Variable	Estimate (SE)	Z	p
(intercept)	-4.06 (0.37)	-10.90	< .01
Vowel Quality	0.43 (0.04)	12.48	< .01
Intensity	0.33 (0.06)	6.11	< .01
Duration	0.11 (0.05)	2.01	= .04
F0	0.25 (0.05)	4.57	< .01

When we conducted a linear mixed-effects model on the tokens for which the suprasegmental cues in the second syllable were manipulated while controlling the acoustic cues in the first syllable to be neutral, we found no main effects or interactions, indicating that neither listener group was using cues in the second syllable in perceiving English stress pairs. Table 34 presents the result of the logistic regression, and Figure 39 presents native and L2 listeners' responses as a function of manipulated steps of three cues, showing the lack of effect of acoustic cues in the second syllable on the perception of the English stress pairs.

Table 34. Summary of results of the logistic regression examining responses on the tokens at the level of the second syllable.

Variable	Estimate (SE)	Z	p
(intercept)	-0.55 (0.58)	-0.94	= .04
GroupKorean	-0.98 (0.52)	-1.90	= .06
Intensity	0.03 (0.09)	0.37	= .71
Duration	-0.07 (0.09)	-0.82	= .41
F0	-0.02 (0.09)	-0.2	= .86

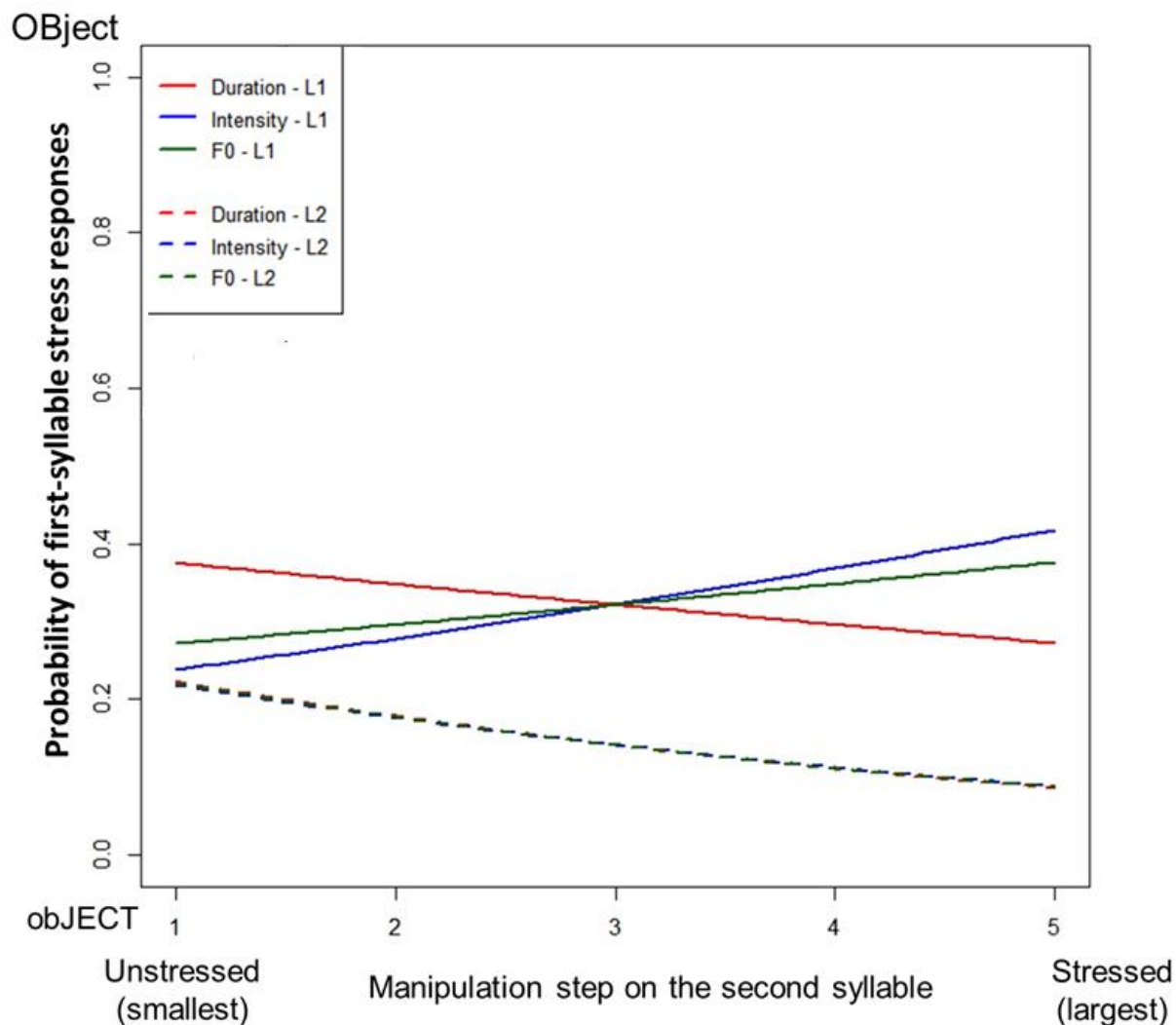


Figure 39. Probability of first-syllable stressed response, 'Object' between the two listener groups when the cues on the second syllable were manipulated, while controlling cues in the first syllable to be neutral. X-axis indicates the manipulated steps of each cue. 1 indicates that duration values were at the minimum endpoint, expressing first-syllable unstressed; and 5 indicates that duration values were at the maximum endpoint, expressing first-syllable stressed. Dotted lines indicate Korean learners' responses, and solid lines indicate native English listeners' responses. Listeners' responses for each cue are illustrated with different colors: red, blue, green, and black lines indicate listeners' responses for duration, intensity, F0, and Vowel Quality respectively.

6.7. Discussion

In this chapter, we examined which acoustic cue(s) Korean learners of English use in perceiving English lexical stress. We manipulated segmental and suprasegmental cues in order to investigate whether Korean L2 learners would also show a perceptual sensitivity to vowel reduction, as native English listeners do. We predicted that Korean listeners would be able to use

F0, duration, and intensity, given the fact that the three suprasegmental cues in English lexical stress also cue Korean higher-level prosody. Our hypothesis was that L2 learners' perceptual sensitivity to a word-level prominence cue in English will follow the frequency of occurrence in the native language. Thus, it is predicted that Korean learners show the strongest sensitivity to F0, followed by intensity, and duration. However, duration might be a stronger cue than F0 or intensity for Korean learners, given that younger Korean speakers still retain a phonemic vowel length distinction in their production of Korean. The secondary goal of this chapter was to examine whether Korean learners can acquire a new cue to stress – vowel reduction. Although Korean learners' production of unstressed syllables was non-native-like (*see* Chapter 4), it is predicted that Korean learners might be able to show a perceptual sensitivity to the segmental cue, since L2 learners of other languages (e.g., Chinese) showed an incomplete acquisition in production, and native-like sensitivity in the perception of vowel reduction.

The results showed that Korean learners of English weighted vowel quality most strongly, as did the native English listeners. This is very interesting, given that a previous study (Lin et al., 2013) showed that Korean learners of English were unable to use the vowel reduction cue in performing a lexical decision task. One reason for these discrepant results can be the difference in tasks between the current study and Lin et al.'s. We introduced a stress identification task, so that the listeners pay more attention to differences in the acoustic cues in judging lexical stress, while Lin et al. used a lexical decision task ('between' [bi.'twin.] vs. [bi.twin.]). Since the nonwords used in Lin et al.'s experiment were very similar to the real words, Korean learners may have used top-down processing rather than paying attention to the small acoustic differences, resulting in incorrectly judging nonword counterparts (e.g., [bi.twin.]) as real words. This is also indirectly supported by their findings on Korean learners'

accuracy as a function of word frequency in Lin et al.: Korean subjects were less accurate in correctly rejecting nonwords of higher frequency counterpart real-words (e.g., ‘human’ [hju'mæn]) than nonwords with lower frequency counterpart real-words (e.g., ‘potion’ [pəʊ'ʃɛn]).

The other interesting finding of the current study is that Korean learners did not use duration, even though their native language still retains the phonemic distinction at the lexical level. This is very intriguing, given the fact that for speakers whose native language employ a cue at the lexical level to express a phonological feature (e.g., lexical tone), it was easier to transfer the same cue (F0) to L2 and acquire a new L2 phonological feature. However, Korean learners of English did not transfer the cue used in L1 at the lexical level (i.e., phonemic vowel length) to acquire L2 lexical stress. This might be because Korean learners are aware of the ongoing loss of the vowel length distinction in Korean, and therefore, do not use the duration cue in L2. The other possibility is that the frequency of occurrence of duration at higher-prosodic levels in Korean is lower compared to F0 or intensity. Therefore, duration was less attended to by Korean learners. Then, the attendance to cues by Korean listeners, at least for the suprasegmental cues, would seem to follow the prediction made by the frequency of occurrence in L1.

This result is also in line with previous research that L2 learners’ linguistic experience will attune their perceptual attention to specific acoustic cues, and therefore, will affect their acquisition of L2 stress (Francis & Nusbaum, 2002; Guion & Pederson, 2007; Iverson et al., 2003; Lee et al., 2006). We found that Korean learners used F0 and intensity in identifying English stress, since their experience with these cues in L1 led them to attend to these cues in their L2 perception. With respect to the weighting of the suprasegmental cues, at least, our

findings seem to support the Cue-Weighting Model (e.g., Francis & Nusbaum, 2002; Holt & Lotto, 2006; Zhang & Francis, 2010; Ingvalson et. al., 2011).

The remaining question is, then, how are Korean learners able to attune to spectral cues to vowel reduction in identifying lexical stress in English, even though their native language does not have vowel reduction? According to the Cue Weighting Model, the cues that are not used in the L1 will be underattended and are not likely to be acquired in L2 (Tomlin & Villa, 1994; Schmidt, 2001). However, our findings, regarding the new L2 cue (e.g. vowel reduction) in L2 perception, are not consistent with this claim. Consistent with the findings of the current study, Chrabaszc et al. (2014) found that both Mandarin learners and Russian learners showed the most stable perceptual sensitivity to the reduced vowel quality in identifying the stress pattern of the English nonword, “maba”, regardless of the degree of the vowel reduction in their native languages. In Russian, duration serves as a primary cue and vowel reduction as a secondary cue to stress, which only appears in non-high vowels (Jones & Ward, 2011; Kijak, 2009). On the other hand, Chinese primarily uses duration as a cue to stress and also employs some degree of vowel reduction only in light syllables with neutral tones (Chao, 1969); however, vowel reduction in Chinese is not associated with stress. Based on this cross-linguistic difference in the use of cues in the native language, Chrabaszc et al. (2014) predicted that both Russian and Chinese listeners would use duration as the primary cue to stress followed by vowel reduction, but Russians will weight vowel reduction more strongly than Chinese listeners, given the claim that vowel reduction in Chinese is qualitatively weaker and more restricted than in Russian. However, the results showed that both listener groups weighted vowel reduction the most heavily: Chinese listeners used vowel reduction and F0 as the strongest cues to stress, while Russian listeners weighted vowel reduction most heavily.

Based on these findings, Chrabaszc et al. (2014) argued that the fact that L2 listeners show a similar pattern in their perception of a spectral cue may be due to the fact that vowel reduction is a more stable cue than suprasegmental cues. Suprasegmental cues to stress are detected as relative differences between syllables and are affected by indexical characteristics of the speakers. For example, a low pitch tone of a speaker can be perceived as a higher pitch tone in a different context, where the overall pitch of the total sentence is much lower. Also, depending on the loudness of the speaker's voice and the speech rate, the same thing can happen to intensity or duration. In contrast, vowel reduction is a relatively more stable cue, since speaker variability or coarticulation as a function of speech rate does not affect the characteristics of the reduced vowel quality as much as suprasegmental cues. Therefore, Chrabaszc et al. (2014) argued that the vowel reduction cue may be the most stable cue so that L2 learners were able to use it in a native-like fashion. However, previous research has also found that vowels are perceived in relation to the formant frequencies of other vowels occurring in the same sentence (e.g., Ladefoged & Broadbent, 1957). When four different target words, /bVt/ (i.e., *bit*, *bet*, *bat*, *but*) followed a carrier sentence, '*please say what this word _____*', listeners' identification of the target word was influenced by the decreased or increased F1 and F2 values of the carrier sentence. This change in the perception of the target word suggests that the relative formant structure of the vowels in the context also affects speech perception. This finding questions the claim by Chrabaszc et al. (2014) that spectral cues may be more stable than suprasegmental cues, and therefore easier to acquire than suprasegmental cues. One alternative explanation might be that the perception of vowel reduction is not as relative as that of stress: a reduced vowel may be recognized more or less by itself, but suprasegmental cues require some context in order to perceive the relative differences in prominence between the syllables. If this is the case, it might

be easier for all L2 learners, regardless of their native language, to weight spectral cues than suprasegmental cues in perceiving English stress.

Another alternative explanation may be that L2 learners might have assimilated English vowels into their corresponding L1 phones. For example, Zhang and Francis (2010) argued that Chinese listeners were able to weight a spectral cue probably because English [ɪ] and [ɛ] from the first syllable of 'desert' are perceived as the corresponding Chinese vowels, [i] and [ɛ]. The same explanation is also possible for Korean learners: English [ɑ] and [ɔ] from the first syllable of 'object' might have been perceived as the corresponding Korean vowels, [ɑ] and [ʌ], which may have facilitated the identification of stress location based on the spectral cue. The other possibility is that all L2 learners, regardless of their native language, apply the same perceptual strategy in identifying stress location. Bohn (1995) suggested that a particular cue might be easier for L2 learners to use than other acoustic cues regardless whether their native language employs it or not. If this is the case, then it might be possible to explain why all L2 learners, regardless of whether their native languages employ vowel reduction or not, were able to show a systematic similarity in how they weighted spectral cues in perceiving lexical stress in English. In order to elaborate this, further examination is needed to investigate cue weighting of L2 learners whose native language employs lexical stress but not vowel reduction, like Dutch.

Overall, this chapter found that L2 learners are able to acquire a new cue that does not exist in their L1 phonological system, and also revealed that L2 learners can extract cues from the L1 higher-level prosody, and transfer these cues to acquire L2 word-level prominence.

CHAPTER VII. CONCLUSIONS

The current dissertation investigated whether contemporary Seoul Korean has lexical stress, and which acoustic cues(s) younger Korean speakers use in expressing word-level prominence in Korean as compared to older speakers, given the claim that the main cue that expresses word-level prominence in Korean, duration, has disappeared. An acoustic study (Experiment 1) and a perception study (Experiment 2) explored these research questions, and reported that Korean does not have lexical stress, but only has a phonemic vowel length distinction. Interestingly, we found that although younger speakers have lost the phonemic vowel length distinction in their production, they were still sensitive to this distinction in their perception. . The secondary goal of this dissertation was to examine which acoustic correlates/cues Korean learners of English utilize in producing and perceiving English lexical stress. An acoustic study (Experiment 3) and a perception study (Experiment 4) examined the production and perception of English lexical stress by Seoul Korean speakers as compared to native English speakers. This research found that Korean learners were only able to transfer L1 higher-level prosody cues in implementing L2 lexical stress, but were not able to produce a new cue (i.e., vowel reduction) that does not exist in their L1. However, Korean L2 learners were able to use vowel reduction in their perception.

First, the production study on Korean word-level prominence (Experiment 1) examined the productions of (so-called) Korean stress pairs by older and younger Korean speakers. We examined the acoustic measurements in two different contexts – at the sentence level and in isolation – in order to examine how five acoustic correlates (i.e., duration, intensity, F0, F1, and F2) distinguished these Korean stress pairs and whether speakers of different generations expressed stress pairs differently. The acoustic evidence suggested that duration distinguished

stress patterns in both contexts only for older speakers, although the duration difference was reduced in isolation. Because of the final-lengthening effect, the second-to-first syllable duration ratio was greater in the production of words in isolation than at the sentence level. With respect to intensity, the relative difference between the first and second syllable varied not only by stress but also by context. That is, intensity of the second syllable was always greater than on the first syllable at the sentence level, while intensity values on the first syllable were always greater than on the second syllable in word-isolation. Regarding F0, no effect of stress was found for productions of either speaker group. However, we found a difference in the way different speaker groups expressed phrasal-level prominence in the two production contexts. Accentual Phrase theory suggests that F0 values of the first syllable of the target words will be affected by initial consonant type: when the first syllable begins with a lenis obstruent, the F0 values in the first syllable were produced with a lower F0 than when the first syllable began with an aspirated (or plain) obstruent. Consequently, the target words beginning with lenis obstruents exhibited an LH F0 pattern, whereas target words beginning with aspirated (or plain) obstruents exhibited an HH F0 pattern at the sentence level. In the word isolation condition, however, due to the IP-final boundary tone, the second syllable is lowered to the low tone, resulting in either a LL/HL F0 pattern. The initial consonant effect on F0 of the first syllable was found for both speaker groups in both contexts. However, the effect of F0 tone pattern was found for both speaker groups at the sentence level; but only for younger speakers in the word isolation condition. In other words, older speakers produced the target words with LL F0 patterns in word-isolation. Our finding of an inconsistent pattern for both intensity and F0 across the two contexts, combined with a consistent pattern for duration, leads us to conclude that Korean does not have lexical stress, but only has a vowel length distinction that appears in the first syllable.

In Experiment 2, the perception study on Korean word-level prominence examined whether the two Korean listener groups showed a perceptual difference in identifying a Korean (stress) pair (i.e., first-syllable stressed word [ˈsa:.kwa] ‘apology’ vs. second-syllable stressed word [sa.ˈkwa] ‘apple’). The main purpose of this chapter was to examine whether Korean has lexical stress at the level of perception, and whether younger Korean listeners substituted or augmented the duration cue with other acoustic cues, given that the duration distinction is disappearing in contemporary Seoul Korean. First, we found that both listener groups only paid attention to the duration cue in the first syllable, although the effect of the duration cue was weaker for the younger than for the older listeners. Second, we found that none of the listeners used multiple cues in identifying Korean pairs. Moreover, listeners did not shift their perception at all when the second syllable was manipulated. Given the fact that lexical stress was defined as a relative difference in prominence between the syllables, we concluded that the perceptual evidence, in addition to the acoustic evidence from Experiment 1, strongly suggests that Korean does not have lexical stress, and only has a vowel length distinction that is experiencing a change in progress.

To summarize, Experiments 1 and 2 explored whether Korean has lexical stress in two domains – acoustically and perceptually – and established that Korean does not have lexical stress, and only has a phonemic vowel length distinction. We hypothesized that if Korean had lexical stress, the acoustic correlates that express lexical stress at the sentence level should also indicate stress for words in isolation. Also, given the claims that Korean has lost its vowel length distinction, it is hypothesized that if Korean has lexical stress, younger Korean speakers would have replaced the duration cue with other acoustic cues, such as intensity or F0. Perceptually, we also hypothesized that if Korean has lexical stress, Korean listeners would weight multiple cues,

given the fact that word-level prominence is not realized with a single cue (Ladefoged et al., 1958; Lehiste & Peterson, 1959; Lieberman, 1960). If Korean has only a vowel length distinction, it is predicted that Korean listeners would only use the duration cue in their perception. The results of Experiment 1 and 2 reported that acoustically and perceptually, speakers of Korean only used the duration cue. This strongly suggests that Korean does not have lexical stress, and only has a vowel length distinction that is realized in the first syllable. These findings provide a clear picture of the status of word-level prominence in Korean.

Then, without having word-level prominence in Korean, how can we explain vowel shortening found in previous studies (Davis & Cho, 1994)? Ko (2013)'s claim that Korean has word-level prominence explains vowel shortening based on accent avoidance: when the long vowel is adjacent to the affix that bears an accent, it changes to a short vowel in order to avoid accent clash. Without word-level prominence in Korean, as found in the current study, how can we explain this vowel alternation? Although Ko (2013) argued that her claim about word-level prominence in Korean is a better explanation than affix-triggered vowel shortening, her analysis does still not falsify the original explanation. S. Lee (2013) also suggested that the type of morpheme determines whether a long vowel is shortened or not in Korean: when a vowel-initial inflectional morpheme is attached, a long vowel is shortened; when a derivational morpheme is attached, the vowel shortening is lexically motivated. Yet, regardless of whether the motivation of this vowel alternation is correct or not, we do not know whether this alternation actually happened, since none of the previous studies have provided acoustic evidence. For example, it is not known if there are any differences in duration between homophonous affixes that cause vowel shortening (e.g., nominalizing suffix /-i/ and passive/causative suffix /-ki/) and the ones that do not cause vowel shortening (e.g. adverbializing suffix, nominative case marker /-i/, and

nominalizing suffix /-ki/) (J.-K. Kim, 2000; Ko, 2013). Without phonetic evidence, it is unclear how the accented vowels in Ko (2013) are different from the unaccented vowels.

Additionally, what is the current realization of the vowel length alternation? In Ko (2013)'s analysis, stress is defined as the actual location at which physical correlates of word-level prominence are realized with acoustic features, whereas accent is defined as the potential location of stress. Ko (2013) analyzed Korean vowel alternation as stress assignment, explaining that stress falls on the initial syllable if it is accented, otherwise on the second syllable. That is to say, syllables with long vowels are stressed, and these stressed syllables become unstressed (become short vowels) when the adjacent syllable (e.g., affixes) has an accent. Thus, according to Ko (2013)'s analysis, it seems that accented vowels influence stress location because accented vowels cause the preceding syllables with long vowels to be destressed. However, considering that only long vowels undergo vowel-shortening but short vowels do not undergo vowel-lengthening (Davis & Cho, 1994), it is hard to interpret how accented vowels can be realized with stressed syllables. Thus, the notion of accent that Ko (2013) used – potential location of stress – is problematic to explain stress placement in Korean since accented vowels are never realized as stressed. Also, considering that Ko (2013) examined minimal pairs with vowel length contrasts (e.g., /sakwa/ vs /sa:kwa/) instead of examining the words with long vowels and their shortened counterparts, it is difficult to understand how Ko (2013)'s results reflect the acoustic realization of stress in contemporary Seoul Korean. Taken together, considering that none of the previous studies have acoustically examined the duration of long vowels and their shortened counterparts, it is still unclear whether vowel shortening (or accent avoidance) really occurred in traditional Seoul Korean. Thus, as a future study, it will be interesting to examine how the

duration of accented vowels alters in various suffixes in older and younger speakers' productions.

Based on the acoustic and perception data for Korean, we next investigated how Korean learners of English acquired lexical stress in English. The focus of Experiments 3 and 4 was to investigate which cue(s) Korean learners transfer from their L1 when acquiring a new phonological feature in their L2, and also whether they could acquire a new cue to L2 stress. Given the fact that all three suprasegmental cues (duration, intensity, and F0) are utilized in the higher-level prosody in Korean, we hypothesized that the frequency of occurrence of a cue in L1 may predict the extent to which Korean learners will use the cue in their L2. Accordingly, Experiment 3 examined Korean learners' productions of English stress pairs as compared to the productions of native English speakers. Measurements of duration, intensity, F0, F1, and F2 revealed that Korean learners were able to use duration, intensity, and F0, but not vowel reduction cues, to implement L2 stress. Among all cues, Korean learners used F0 in the most native-like way in their production; Korean learners also used duration and intensity in their production, but not in a native-like manner. Regarding F1 and F2, we also found that L2 learners did not reduce vowel quality when producing unstressed syllables. Given the fact that Korean does not have lexical stress or vowel reduction, it was predicted that Korean learners would not be able to use vowel reduction at all; the results also demonstrated that Korean learners were able to transfer the cues that exist in their L1 and use them in producing L2 stress pairs, but were not able to acquire a new cue that does not exist in their L1.

Experiment 4 further examined which cue Korean learners weighted the most when perceiving English lexical stress as compared to native English listeners. To examine which acoustic cue Korean learners weight the most in identifying the stress location of English stress

pairs (i.e., OBject vs. obJECT), we manipulated spectral cues (i.e., vowel reduction) and one of the suprasegmental cues (i.e., duration, intensity, and F0) orthogonally for each syllable. The responses to the manipulated tokens showed that 1) English listeners only weighted vowel quality in the first syllable, 2) Korean listeners weighted vowel quality the most, 3) Korean learners also weighted F0 and intensity, 4) Korean listeners did not use duration in their perception, despite the fact that Korean still retains a phonemic vowel length distinction, and 5) None of the listener groups weighted cues in the second syllable in identifying stress location. These findings suggested that Korean learners were able to acquire a new cue (i.e., vowel reduction) and their perceptual weighting was similar to that of native English listeners in the sense that the spectral cue was weighted most strongly. Also, the results indicated that the frequency of occurrence of a cue in L1 can predict the use of that cue in L2, given the fact that F0 was weighted more strongly than intensity or duration.

Overall, the findings in Experiments 3 and 4 on L2 production and perception of English stress showed that Korean learners can acquire a new phonological feature that does not exist in their native language. Interestingly, we found an asymmetrical pattern between production and perception in the acquisition of vowel quality. In production, Korean learners were able to use duration, intensity, and F0, but not vowel reduction. This was predicted given that Korean does not employ lexical stress nor vowel reduction. However, an interesting pattern was found in perception: Korean learners weighted vowel quality most strongly, as compared to other suprasegmental cues. Also, Korean learners did not use duration although Korean still retains a phonemic vowel length distinction. There are a number of implications of the different patterns observed between production and perception.

First, the asymmetric pattern of production and perception in the use of spectral cues may be explained by the Speech Learning Model (SLM) proposed by Flege (1995). According to SLM, accurate perception is considered a necessary prerequisite for accurate production; L2 learners can produce L2 phonetic categories accurately if and only if their perception of these categories is accurate. Although accurate perception must precede accurate production, accurate perception does not guarantee accurate production, because the primitives that underlie speech perception are acoustic in nature. In other words, L2 learners may be able to perceive L2 sounds in a native-like manner based on the acoustic properties of these sounds, yet they may fail to produce the necessary articulatory gestures in a native-like manner. Thus, according to the SLM, our findings about Korean learners' perceptual weighting of the spectral cue, but non-native-like production of reduced vowel quality, can be explained by an incomplete mastery of the gestural movements for reduced vowel quality.

Second, Korean learners' more native-like perception of the spectral cue than suprasegmental cues in identifying English stress might be because the English stressed and unstressed vowels of the target word 'object' may have been perceived as the corresponding Korean vowels, [ɑ] and [ʌ]. If this is the case, Korean learners could easily identify English stress based on the spectral information in the first syllable of the target word. Alternatively, there is also a possibility that L2 learners use the same perceptual strategy regardless of the features existing in their native language, since certain cues are easier to use for L2 learners than others (Bohn, 1995). If this is the case, it might be able to explain why all L2 learners from the current study as well as other studies with different L1 backgrounds (e.g., Zhang & Francis, 2010; Chrabaszcz et al., 2014) showed a systematic pattern by weighting vowel reduction most heavily in identifying lexical stress. More examination will be needed in order to investigate this,

with L2 learners whose native language does not employ lexical stress but has vowel reduction, and also L2 learners whose native language employs lexical stress but not vowel reduction.

Third, the saliency of the vowel reduction cue overrode not only suprasegmental cues in the first syllable but also cues in the second syllable. Recall that all listeners based their perception of English stress on the changes in vowel quality in the first syllable regardless of the changes in the suprasegmental cues in first or second syllables. Chrabaszcz et al. (2014) argued that vowel reduction is a relatively more stable cue than suprasegmental cues, since suprasegmental cues are context-dependent and can be affected by factors such as speech rate, speaker's emotion, or loudness. However, perception of segmental cues (e.g., identification of vowels) can also be influenced by changes in F2 of the context (Ladefoged & Broadbent, 1957), which leads us to conclude that segmental cues are not more stable than suprasegmental cues. However, in the absence of context, vowel reduction seems to be more interpretable and less relative to context than suprasegmental cues, since a reduced vowel by itself can be recognized as stressed or not without any context, while suprasegmental cues to stress require some context to determine whether a syllable is more prominent than the previous or next syllable. If this is the case, it might be able to explain how L2 learners were able to use the vowel reduction cue, regardless of whether their native languages employ vowel reduction.

The stronger impact of vowel reduction than suprasegmental cues on the perception of stress was also found for English listeners. Previous research has found that vowel reduction is the strongest cue to stress perception for native English listeners (e.g., Lehiste & Peterson, 1958, Zhang & Francis, 2010). Moreover, when vowel reduction is absent, the lack of vowel reduction impairs native English listeners' ability to perceive unstressed-stressed contrasts (Braun, Lemhöfer, & Mani, 2011). That is, even though unstressed syllables were implemented with

appropriate suprasegmental cues, English native listeners were not able to overcome the incorrect vowel quality, and consequently, failed to correctly perceive the stress patterns. The present research also showed consistent findings; native English listeners only weighted the vowel reduction cue, perhaps because the target word ‘object’ contains overt vowel reduction in the first syllable. Interestingly, we also found that the effect of vowel reduction overrode the suprasegmental cues in the second syllable. Recall that the manipulation of the cues in the second syllable did not influence listeners’ responses when the first syllable was kept neutral and suprasegmental cues in the second syllable were manipulated. This may be due to the fact that when the second syllable was manipulated, the first syllable was controlled to be at step 3 (to be neutral between the stressed and unstressed syllable), which already contains some degree of vowel reduction. Thus, it might be the case that English listeners in the current study perceived the neutral vowel quality in the first syllable as a reduced vowel.

Lastly, we found that Korean learners did not use all the cues available from their L1 higher-level prosody. According to the Cue-Weighting Model, (e.g., Francis & Nusbaum, 2002; Holt & Lotto, 2006; Zhang & Francis, 2010; Ingvalson et al., 2011), L2 learners’ perceptual cue weighting is influenced by the acoustic properties of L1 contrasts. In perceiving an L2 phonetic category, L2 learners put more weight on cues that are significant in L1, and less weight on less significant cues in L1. The current study also found a similar result: Korean learners primarily use F0, followed by intensity, in the absence of vowel reduction cues in identifying English stress pairs. Since Korean uses F0 more frequently at higher levels of prosody than intensity, it was predicted that F0 would be used more strongly than intensity in perceiving English stress. This prediction was borne out in the current research.

However, notably, we also found that duration was not weighted at all in perceiving L2 stress. This is surprising, and somewhat contrary to the prediction of the Cue-Weighting Model, considering that the vowel length distinction is still used in the native language in higher level prosody in Korean. Then, could it be the case that Korean learners do not rely on duration in perceiving English stress, since duration is a cue to segmental identity rather than to word-level prominence in Korean? If so, do Korean learners use duration just to recognize segmental contrasts, and not for perceiving stress? If this is the case, it might be able to explain why Korean learners did not use duration in their perceptual weighting. This explanation raises the issue whether or not a cue to segmental identity in L1 can be transferred to word-level prominence in L2. Previous literature has found that L2 learners can transfer cues that exist in their L1 at the lexical level to acquire a new phonological feature in L2. For example, both Vietnamese and Chinese learners of English were able to use F0 more than duration or intensity since both languages employ lexical tone (See Nguyễn et al., 2008; Nguyen & Ingram, 2005 for Vietnamese, see Lai, 2008; Zhang et al., 2008 for Chinese). Taiwanese Mandarin learners of English also were able to transfer F0 cues in perceiving lexical stress (Qin & Tremblay, 2014), although Taiwanese Mandarin does not employ lexical stress (Chao, 1968). Also, Lee et al. (2006) found that both Korean and Japanese late bilinguals were able to use F0 to implement stress patterns in a native-like way, perhaps because both languages employ F0 in their higher level prosody: Japanese is a mora-timed language (Ramus, Nespors, & Mehler, 1999) in which word-level pitch patterns are realized with F0 (Sugito, 1980), and Korean employs F0 in expressing Accentual Phrase (See section 1.5.1.). However, regarding the use of duration, only Japanese late bilinguals were able to use duration in a native-like manner. This might be because Japanese has a durational contrast both in consonants and vowels (e.g., *su* “vinegar” vs. *suu*

“number”; *ita* “existed” vs. *itta* “said”), while contemporary Seoul Korean has lost the vowel length distinction. Taken together, these findings seem to suggest that L2 learners might be able to pick and choose any cues that are available in their native language at any prosodic level, but it is much easier for L2 learners to transfer L1 cues to L2 if both L1 and L2 use the cues at the same prosodic level.

An alternative explanation is that it might be because Korean learners were aware of the on-going loss of the phonemic vowel length distinction in Korean, and therefore put the least perceptual weight on the duration cue in perceiving L2 lexical stress. Also, the duration cue is used the least frequently in Korean since final lengthening is only realized in IP-final position, whereas F0 and intensity are used at each AP domain. Both of these factors could affect the perception of Korean learners, and could explain the lack of perceptual weighting of the duration cue.

To conclude, this dissertation was able to define the status of lexical stress in Korean – Korean does not have lexical stress and only has a vowel length distinction. Also, the current research revealed that L2 Korean learners were able to not only acquire a new phonological L2 feature (i.e., lexical stress) by transferring the L1 higher-level prosody cues to L2, but also to acquire a new cue, vowel reduction, that does not exist in their native language.

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APPENDICES

Appendix A. Stimulus list of contextually-related sentences (16 syllables per sentence) for Experiment 1

1. 사과 /sakwa/ ‘apple’ vs. 사:과 /sa:kwa/ ‘apology’
 - a. 제사 과일로 사과와 배가 자주 사용된다.
[ce.sa. gwa.il.lo. **sa.gwa**.wa. be.ga. ca.cu. sa.joŋ. tʃen.da.]
‘apples and pears are often used for ancestor veneration ceremonies.’
 - b. 잘못을 하면 사과하고 먼저 용서를 빈다.
[cal.mo.sil. ha.mjɔn. **sa:gwa**.ha.go. mʌn.ɕʌ.joŋ.sa.ril. bin.da.]
‘If you do wrong, you apologize first and ask for forgiveness.’

2. 장사 /caŋsa/ ‘business’ vs. 장:사 /ca:ŋsa/ ‘strong man’
 - a. 상가에서 종일 장사하는 사람들을 봤다.
[saŋ.ga.ɛ.sa. coŋ.il. **caŋ.sa**.ha.nin. sa.ram.dil.il. bwatʰ.tʰa.]
‘I saw people running small businesses all the day at the shopping district.’
 - b. 힘이 센 사람을 장사라고 예부터 불렀다.
[him.i. sen. sa.ram.il. **ca:ŋ.sa**.ra.go. jɛ.bu.tʰə. bu:l.lətʰ.tʰa]
‘men with great strength have long been called ‘cangsa’’

3. 시장 /sicaŋ/ ‘hunger’ vs. 시:장 /si:caŋ/ ‘market’
 - a. 일을 하고 시장할 때 음식을 많이 먹는다.
[il.il.ha.go. **si.caŋ**.hal.tʰɛ. im.sikʰ.il. ma.ni. mʌkʰ.nin.da.]
‘You eat a lot when you feel hungry after working hard.’
 - b. 상인들이 시장에서 물건을 사고 팔았다.
[saŋ.in.dil.i. **si:caŋ**.ɛ.sa. mu:l.gʌn.il. sa.go. pʰal.atʰ.tʰa]
‘Merchants were selling or purchasing goods at the market’

4. 가정 /kacəŋ/ ‘family’ vs. 가:정 /ká:cəŋ/ ‘hypothesis’
 - a. 결혼 후 부부는 가정에 충실해야만 한다.
[gʲɛl.hon.hu. pu.bu.nin. **ka.caŋ**.ɛ. cʰuŋ.sil.he.ja.man.han.da.]
‘Married couples must be faithful to their family.’
 - b. 과학적 사실은 가정과 증명에 기반한다.
[kwa.hakʰ.caŋʰ. sa.sil.in. **ka.caŋ**.gwa. ciŋ.mjʌŋ.ɛ. ki.ban.han.da.]
‘Scientific truths are based on hypotheses and supporting evidence.’

5. 가장 /kacáŋ/ ‘most’ vs. 가:장 /ká:caŋ/ ‘head of family’
 - a. 된장국은 가장 서민적인 한국 음식이다.
[twen.caŋ.kʰu.gin. **ka.caŋ**. sa.min.ca.gin. han.guŋkʰ. im.sikʰ.i.da.]
‘Miso soup is one of the most common Korean food.’

- b. 아버지는 **가장**으로서 자녀를 책임진다.
[a.bʌ.ci.nin. **ka.caŋ.i.ro.s'**ʌ. ca.njə.ril. c^hɛ.gim.cim.da.]
'As the head of his family, a father takes care of his children.'
6. 어미 /əmi/ 'mother' vs. 어:미 /ɛ:mi/ 'suffix'
- a. 동물의 새끼는 **어미**의 보살핌을 받는다.
[doŋ.mu.lwi. sɛ.k'i.nin. **ə.mi.wi.** po.sal.p^hi.mil. ban.nin.da.]
'Young animals are taken care of by their mothers.'
- b. 한국어 문장의 **어미**에 종류가 매우 많다.
[han.gu.gʌ. mu.n.caŋ.wi. **ə.mi.ɛ.** coŋ.rju.ga. mɛ.wu. man.t^ha.]
'Korean has a lot of different types of suffixes.'
7. 저리 /cəli/ 'there' vs. 저:리 /cɛ:li/ 'low interest'
- a. 아버지는 바쁘니깐 **저리** 비키라고 했다.
[a.bʌ.ci.nin. pa.p'i.ni.k'an. **cə.li.** pi.k^hi.ra.go. hɛt^l.t'a.]
'My dad told me to move over there because he was busy.'
- b. 은행에서 요즘 돈을 **저리**로 빌릴 수 있다.
[in.hɛŋ.ɛ.sʌ. jo.cim. to.nil. **cə.li.ro.** pil.ril.s'wu. it^l.t'a.]
'You can take out a loan from the bank with low interest these days.'
8. 소금 /sokim/ 'salt' vs. /sókim/ 'short flute'
- a. 정량 보다 많은 **소금**을 넣어서 맛이 짜다.
[caŋ.rjaŋ.bo.da. man.in. **so.gi.mil.** nʌ.ə.sə. ma.si. c'a.da.]
'This food tastes too salty because you put more salt than in needed.'
- b. 전통관악기는 **소금**과 대금이 유명하다.
[caŋ.t^hoŋ. kwa.na.k'i.nin. **so.gim.gwa.** tɛ.gi.mi. ju.mjʌŋ.ha.da.]
'Among Korean traditional wind instruments, 'sogum (short flute)' and 'degum (long flute)' are the most famous.'
9. 수치 /sutʃi/ 'disgrace' vs. 수치 /su:tʃi/ 'number'
- a. 소박맞은 여자는 가문의 **수치**로 여겼다.
[so.bak^l.ma.cin. jə.ca.nin. ka.mu.nwi. **su.tʃi.ro.** jə.gjət^l.t'a]
'Historically, jilted women were considered to be a disgrace for the family.'
- b. 예부터 셈이 빠른 사람은 **수치**에 밝았다.
[jɛ.bu.t^hʌ. sɛ.mi. p'a.rin. sa.ra.min. **su.tʃi.ɛ.** bar.gat^l.t'a.]
'People who are good with numbers tend to be also good at arithmetics.'

10. 전기 /cənki/ ‘biography’ vs. 전:기/cə:nki/ ‘electricity’
- 역사적 인물의 전기를 위인전이라 한다.
[jʌkʰ.sʰa.cəkʰ. in.mu.lwi. **cən.gi**.ril. wi.in.cə.ni.ra. han.da.]
‘Records of the lives of historically famous figures are called biographies.’
 - 무더운 여름에 전기 소모량이 가장 높다.
[mu.də.uun. jə.ri.mə. **cən.gi**. so.mo.rjaŋ.i. ka.caŋ. nopʰ.tʰa.]
‘The consumption of electricity is the highest during the hot summer.’
11. 정도 /cəŋto/ ‘degree’ vs. /cə:ŋto/ ‘straight path’
- 녹차는 쓴맛이 발효 정도에 따라 다르다.
[nokʰ.cʰa.nin. sʰin.ma.si. pal.hjo. **cəŋ.do**.e. tʰa.ra. ta.ri.da.]
‘The bitterness of green tea varies by the degree of fermentation of the leaves.’
 - 불의와의 타협 없이 정도를 따라 걷는다.
[pu.lwi.wa.wi. tʰa.hjəpʰ. ʌpʰ.sʰi. **cəŋ.do**.ril. tʰa.ra. kʌn.nin.da.]
‘One should walk a straight path without compromising.’
12. 사기 /saki/ ‘china’ vs. 사:기 /sa:ki/ ‘morale’
- 점토가 좋아야 좋은 사기그릇을 얻는다.
[cəm.tʰo.ga. co.a.ja. co.in. **sa.gi**. kʰi.ri.sil. ʌn.nin.da.]
‘The quality of the clay is important in making high quality china.’
 - 국가 대표팀은 이미 사기가 충만 되었다.
[kukʰ.kʰa. tɛ.pʰjo.tʰi.min. i.mi. **sa.gi**.ga. cʰuŋ.man. twɛ.ʌtʰ.tʰa.]
‘The morale of the national team was already at its highest.’
13. 고대 /kote/ ‘Korea university’ vs. 고:대 /ko:te/ ‘ancient’
- 독수리, 호랑이는 연대, 고대를 상징한다.
[tokʰ.sʰu.ri. ho.raŋ.i.nin. jən.dɛ. **ko.dɛ**.ril. saŋ.ɕŋŋ.han.da.]
‘Yonsei University’s mascot is an eagle, and Korea University’s mascot is a tiger.’
 - 콜로세움은 로마 시대 고대 유적물이다.
[kol.ro.se.uum.in. ro.ma.si.dɛ. **ko.dɛ**.ju.ɕəkʰ.mu.li.da.]
‘The Colosseum is an ancient ruins of Rome.’
14. 부자 /puca/ ‘father and son’ vs. 부:자 /pu:ca/ ‘rich man’
- 아버지와 아들의 부자간 의견이 다르다.
[a.bə.ɕŋi.wa. a.dɛ.lwi. **pu.ca**.gan. wi.gjə.ni. ta.ri.da.]
‘The father and the son have different opinions.’
 - 가난한 사람보다 부자들이 더 인색하다.
[ka.nan.han. sa.ram.bo.da. **pu.ca**.dɛ.li. tɛ. in.səkʰ.ha.da.]
‘The rich are stingier than the poor.’

15. 고장 /kocaŋ/ ‘town’ vs. 고장 /ko:caŋ/ ‘malfunction’,
- 농산물 하나도 **고장** 특산물이 될 수 있다.
[noŋ.san.muul. ha.na.do. **ko.caŋ**. tʰɪkʷ.san.mu.li. twəl.s’w.itʷ.t’a.]
‘One single farm product can become the specialty of the town.’
 - 노화된 기계는 **고장**이 잦고 자주 멈춘다.
[no.hwa.dwen. ki.gjɛ.nin. **ko.caŋ**.i. catʷ.k’o. ca.ɕw. mʌm.cʰwun.da.]
‘Aged machines often break and stop working.’
16. 조리 /cori/ ‘cooking’ vs. 조:리 /co:ri/ ‘strainer’
- 삼계탕은 **조리**하는 시간이 오래 걸린다.
[sam.gjɛ.tʰaŋ.in. **co.ri**.ha.nin. si.ga.ni. o.rɛ. gal.rin.da.]
‘It takes a long time to cook Samgyetang.’
 - 찌꺼기는 **조리**를 사용하여 다 건져냈다.
[c’i.l’ʌ.gi.nin. **co.li**.ril. sa.joŋ.ha.jə. ta. kʌn.ɕjə.netʷ.t’a.]
‘I used the strainer to filter out the residue.’
17. 조기 /coki/ ‘yellow croaker’ vs. 조:기 /co:ki/ ‘flag’
- 할아버지 제사상에 **조기**찜이 올라왔다.
[ha.la.bʌ.ɕi. cɛ.sa.s’aŋ.ɛ. **co.gi**.c’i.mi. ol.ra.watʷ.t’a.]
‘A dish of steamed yellow croaker was prepared for grandfather’s memorial service.’
 - 한국에선 현충일에 **조기**게양을 꼭 한다.
[han.guokʷ.ɛ.sʌ. hʃɔn.cʰwŋ.i.lɛ. **co.gi**.gjɛ.jaŋ.il. k’okʷ. han.da.]
‘On Memorial Day, Koreans fly the national flag at half-mast.’

Appendix B. Stimulus list of contextually-related sentences used for Experiment 3

1. conflict
 - a. There is a conflict between them. (8 syllables)
 - b. This does not conflict with her plan. (8 syllables)
2. contract
 - a. The new contract is much better. (8 syllables)
 - b. Steel will contract when it is cooled. (8 syllables)
3. desert
 - a. This desert is very hot. (8 syllables)
 - b. It is bad to desert pets. (8 syllables)
4. digest
 - a. Reader's Digest is popular. (8 syllables)
 - b. It is hard to digest this book. (8 syllables)
5. import
 - a. Bananas are an import for Japan. (10 syllables)
 - b. We import apples from America. (10 syllables)
6. insult
 - a. That is the worst insult I know. (8 syllables)
 - b. It is mean to insult people. (8 syllables)
7. object
 - a. The object of this game is to win. (9 syllables)
 - b. I object this proposal strongly. (9 syllables)
8. permit
 - a. I got my learner's permit this year. (9 syllables)
 - b. I will not permit you to go there. (9 syllables)
9. present
 - a. Jack gave me a present for Christmas. (9 syllables)
 - b. We will present our project today. (9 syllables)
10. progress
 - a. I am making progress on my book. (9 syllables)
 - b. Children learn as they progress in school. (9 syllables)
11. project
 - a. Mary started her project yesterday. (10 syllables)
 - b. He likes to project photos on big screens. (10 syllables)

12. rebel

- a. He is a rebel in his own country. (10 syllables)
- b. It is unwise to rebel against him. (10 syllables)

13. record

- a. It is a record of your grades. (8 syllables)
- b. We record ten native speakers. (8 syllables)

14. subject

- a. It is an easy subject for him to learn. (11 syllables)
- b. It makes no sense to subject yourself to this. (11 syllables)

APPENDIX C. English Language Institute Listening Comprehension Test (Michigan Test)

(Instructions)

A recording should be playing now.
If you can't hear it, please inform the examiner.
If the sound is OK press the space bar to continue.

Please read the following instructions carefully!
This is a test of your ability to understand spoken English.
The computer will either ask a question or make a statement.

To show that you have understood what was said, you are to select **ONE** answer choice you think is correct by clicking on it with your mouse.

Press the space bar to listen to two examples

Practice 1. When are you going?

A. I am. B. Tomorrow. C. At home.

(The answer is B)

Practice 2. The camera on the desk was expensive.

A. The camera is expensive. B. The desk is expensive. C. The camera and the desk are expensive.

(The answer is A).

---This is the end of the practice---

(Instruction 2)

Please be quiet and listen carefully.
None of the questions or statements will be repeated.
When you are ready to begin, press the space bar.

(Main session)

1. Was that a good movie that you saw?

A. Yes, it is. B. Yes, it was. C. Yes, I have.

(The answer is B)

2. Does Mary know the assignment already?

A. No, she doesn't. B. Mary. C. No, she hasn't.

(The answer is A)

3. Gail did the dishes because father was too tired and mother had to go out.

A. Mother did the dishes. B. Father did the dishes. C. Gail did the dishes.

(The answer is C)

4. Laura won't sing, and Cathy won't either.

A. Neither of them will sing. B. One of them will sing. C. Both of them will sing.

(The answer is A)

5. Do you know if Gren's grandfather is coming for dinner on Thursday?

A. Yes, we are. B. Yes, he is. C. Yes, they are.

(The answer is B)

6. We planned to vacation in Europe, but went to Japan, too.
A. We went to Europe and Japan. B. We went only to Europe. C. We went only to Japan.
(The answer is A)
7. What do you want to see her for?
A. For about five minutes. B. To thank her. C. In five minutes.
(The answer is B)
8. Her job isn't very good, but her husband is.
A. Neither is good. B. Both are good. C. Only his is good.
(The answer is C)
9. Who's talking to Mr. Smith?
A. My brother is. B. My brother does. C. To my brother.
(The answer is A)
10. I've never seen snow here.
A. There has been no snow in the past. B. There has been less snow in the past. C. There has been more snow in the past.
(The answer is A)
11. I read Susie and Jane's story.
A. Susie and Jane listened to the story. B. Jane wrote the story. C. Susie and Jane wrote the story.
(The answer is C)
12. Has mother's letter arrived yet?
A. Yes, it is. B. Yes, it has. C. Yes, she has.
(The answer is B)
13. Sally told Jane who the new boy was.
A. Sally knew him. B. Sally thought Jenny knew him. C. Neither Sally nor Jane knows him.
(The answer is A)
14. Haven't you left the university yet?
A. No, I begin there next year. B. No, I've finished already. C. No, I finish there next year.
(The answer is C)
15. Charley will be surprised if Alice came to his party.
A. He didn't think Alice would come. B. He thought Alice would come. C. He doesn't think Alice will come.
(The answer is C)
16. Have you taken this train before?
A. Yes, I have. B. Yes, it is. C. Yes, it was.
(The answer is A)
17. Has your brother seen the movie?
A. No, he doesn't. B. My brother. C. No, he hasn't.
(The answer is C)
18. We went to California for our vacation because Florida's too hot and Canada's too cold.
A. We went to Florida. B. We went to California. C. We went to Canada.
(The answer is B)

19. Bill eats meat and so does his wife.
 A. Both of them eat it. B. Neither of them eats it. C. One of them eats it.
 (The answer is A)
20. Can you see if the people are in their seats?
 A. Yes, he is. B. Yes, they are. C. Yes, it is.
 (The answer is B)
21. We wanted to buy the motorcycle but got a car instead.
 A. We bought only the motorcycle. B. We bought only a car. C. We bought a car and a motorcycle.
 (The answer is B)
22. How soon are you going to New York?
 A. In a few days. B. For about a week. C. To see my parents.
 (The answer is A)
23. He doesn't like tea nor does he like coffee.
 A. He likes only one. B. He likes neither. C. He likes both.
 (The answer is B)
24. Who was Bill talking to just now?
 A. His sister is. B. His sister did. C. To his sister.
 (The answer is C)
25. We've seen more people in this park.
 A. Usually more people come. B. Usually no people come. C. Usually fewer people come.
 (The answer is A)
26. I played Mary Sam's composition?
 A. Sam and Mary heard it. B. Sam wrote it. C. Sam and Mary wrote it.
 (The answer is B)
27. Is Sally's dinner invitation here yet?
 A. Yes, it has. B. Yes, she has. C. Yes, it is.
 (The answer is C)
28. Mr. and Mrs. Jones wondered who their new neighbors were.
 A. Mrs. Jones thought Mr. Jones knew them. B. Neither Mr. nor Mrs. Jones knew them.
 C. Mrs. Jones knew them.
 (The answer is B)
29. Have you gotten rid of your bicycle yet?
 A. No, I sold it. B. No, I will get one. C. No, I want to sell it.
 (The answer is C)
30. John was happy that David didn't bring his friend.
 A. John didn't want the friend to come. B. John wants the friend to come. C. John wanted the friend to come.
 (The answer is A)
31. Is it snowing right now?
 A. Yes, it was. B. Yes, I have. C. Yes, it is.
 (The answer is C)
32. Who went to Europe this summer?
 A. No, he doesn't. B. Marc. C. No, he hasn't.

- (The answer is B)
33. Gary likes his English class the best because math is too hard and history is too dull.
A. His favorite class is English. B. His favorite class is History. C. His favorite class is Math.
(The answer is A)
34. Alan doesn't like girls but Jim does.
A. Both boys like them. B. Neither boy likes them. C. One boy likes them.
(The answer is C)
35. Do you know if the car his grandparents ordered arrived yet?
A. Yes, they did. B. Yes, it did. C. Yes, he did.
(The answer is B)
36. We intended to ski and skate but didn't have time to skate.
A. We went skiing and skating. B. We only went skiing. C. We only went skating.
(The answer is B)
37. How long will the party last?
A. Her birthday. B. In two hours. C. For about two hours.
(The answer is C)
38. Chicago is pretty windy but so is Detroit.
A. Only one is windy. B. Neither is windy. C. Both are windy.
(The answer is C)
39. Who brought these books to you today?
A. To Mike. B. Mike's. C. Mike did.
(The answer is C)
40. John's never seen his wife looking more angry.
A. She never looked as angry. B. She has looked more angry. C. She never looks angry.
(The answer is A)
41. I showed Dave and John my article.
A. Dave and John saw it. B. John wrote the article. C. Dave and John wrote the article.
(The answer is A)
42. Has father received his coat from the cleaners?
A. No, it hasn't. B. No, he hasn't. C. No, it isn't.
(The answer is B)
43. Bill asked Jack who their new teacher was.
A. Neither Bill nor Jack knows him. B. Bill knew him. C. Bill thought Jack knew him.
(The answer is C)
44. Are you still reading that book?
A. No, I finished it. B. No, I'm reading it now. C. No, I haven't seen it.
(The answer is A)
45. Bill was upset that his wife hired a cook.
A. Bill wanted her to hire one. B. Bill doesn't care if she hires one. C. Bill didn't want her to hire one.
(The answer is C)

---You have completed the test---

APPENDIX D. Language Background Questionnaire (for Korean speakers)

Participant #:	Age:	Sex: M F	Major:
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Have you ever had (check all that apply):

vision problems?
 hearing impairment?
 language disability?
 learning disability?

If yes to any, please explain (including any corrections) _____

How old are you? (identify the year that you were born)? _____ years old (born in _____)

What is **your** native language (and dialect)? _____

What is your **mother's** native language (and dialect)? _____

What is your **father's** native language (and dialect)? _____

What language(s) were used in your house from...

birth to 5 years of age?	6 to 11 years of age?	12 to 17 years of age?

Did you learn a **second language**? yes no

Which language was it? _____

How old were you when you started to learn English? _____ years old

Where did you start to learn English?

primary/elementary school high school college other

Have you ever lived in a English-speaking country? yes no

If yes, where? _____

And for how long? _____ years and _____ months

In what **country/countries** did you live...

...as a child?	...as a teenager?	...as an adult?

Excluding language classes, in what language were you taught (e.g., math, history, etc.) in...

... elementary school?	... middle school?	... high school?

Please list all languages you know **in order of dominance**.

1)	2)	3)	4)	5)
----	----	----	----	----

Please list your languages **in order of acquisition** (beginning with native language).

1)	2)	3)	4)	5)
----	----	----	----	----

Please estimate your **global proficiency** in all the languages you know (beginner, intermediate, advanced, near-native, native).

Language	Korean	English			
Proficiency					

Please give the **percentage of time** you currently **use** each language (your percentages should add to 100%).

Language	Korean	English			
Percent					

If a text were available in all your languages, what **percentage of the time** would you **choose to read it** in each language (assume the original language of the text was a language you do not know)?

Language	Korean	English			
Percent					

When speaking a language with someone who is equally fluent in all your languages, **what percent of the time** would you choose to **speak** each of your languages?

Language	Korean	English			
Percent					

APPENDIX E. Language Background Questionnaire (for English native speakers)

How many years of English instruction have you received? _____

What English dialects did your instructors speak (circle all that apply)?

American Australian British Canadian S. African

Were a majority of your instructors native English speakers? Yes No

At what **age** did you begin...

... learning English at school?	... listening to English?	...interacting with native English speakers?

Please provide information about your **experiences in a English speaking environment**.

Country	Age during visit	Length of visit (in months)	Context (study abroad, vacation, etc.)

How would you estimate your **proficiency in English** (beginner, intermediate, advanced, near-native) for...

...reading?	... writing?	... listening?	...speaking?

Please describe the **circumstances** in which you **currently use English** (e.g., English class, with friends, listening to music, watching movies, etc.) and how often you do so (e.g., daily, frequently, sometimes, rarely).

Activity/circumstances	Frequency

In your perception of your own English, **how much of an accent** would you say you have on a scale from 1-10 (1 being nearly indistinguishable from native English speakers)? _____