

The continuous or categorical effects for HH vs. HL and HH vs. LH in lexical pitch accent contrasts of Korean

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ABSTRACT

The current research examines whether pitch contour shapes in North Kyungsang pitch accent contrasts provide a phonetic dimension for phonological discreteness in a mimicry task. Two pitch accent continua resynthesized were created for HH vs. HL and HH vs. LH. To confirm a phonetic dimension for accounting for pitch accent categories in North Kyungsang Korean, the mimicries of speakers of two dialects (i.e., North Kyungsang & South Cholla) were compared. One of the findings showed that, for North Kyungsang speakers, the range of mean f_0 peak times was a phonetic dimension undergoing a continuous shift within a stimulus continuum for both HH vs. HL and HH vs. LH. On the other hand, for South Cholla speakers, there were no apparent shifts around categorical boundaries for either HH vs. HL or HH vs. LH. Regarding individual mimicries on f_0 peak timing, there are many variations. For HH vs. LH, three North Kyungsang speakers showed a discrete pattern reflecting a shift in phonological categories, but for HH vs. HL, there was no such distinction showing a categorical shift, though there were statistically significant differences for two speakers. Interestingly, one of the North Kyungsang speakers showed a continuous phonetic dimension for both HH vs. HL and HH vs. LH. Lastly, the f_0 valley timing did not exhibit a discrete or gradient phonetic dimension for speakers of either dialect. On the basis of these results, what is interesting is that the tonal target such as high tone in North Kyungsang pitch accent categories within the autosegmental-metrical (AM) theory may be realized within individual cognitive systems for representing the interaction of perception and production.

Keywords: lexical pitch accent, pitch contour, a mimicry task, North Kyungsang speakers, South Cholla speakers

1. Introduction

The importance of fundamental frequency (f_0) contour shapes has been investigated in terms of the phonological distinction for the meaning of intonation (Pierrehumbert & Steele, 1989; Gussenhoven, 1999; Gussenhoven, 2004; Dilley & Brown, 2007; Dilley, 2010). The pitch contours in lexical pitch accent contrasts of a North Kyungsang dialect in Korean are typically assumed to have a phonologically specified shape (Kim, 1976; Kim, 1988; Chung, 1991; Kim, 1997; Kenstowicz & Sohn, 1997; Jun et al., 2006). This paper examines pitch range variation as a basis for

phonological contrasts in North Kyungsang Korean, focusing on the contrasts, HH vs. HL, and HH vs. LH. Two pitch accent continua (i.e., HH vs. HL, HH vs. LH) with pitch range variation were constructed as intonational units with phonological representations under the autosegmental-metrical (AM) theory of intonation (Pierrehumbert, 1980; Liberman & Pierrehumbert, 1984; Beckman & Pierrehumbert, 1986; Pierrehumbert & Beckman, 1988).

The assumption that intonation contours represent discrete tones has been supported by considerable research, in particular, on the alignment of f_0 points, peaks, and valleys (Bruce, 1977; Pierrehumbert & Steele, 1989; Arvaniti et al., 1998; Xu, 1998; Ladd et al., 1999, 2000; Xu, 1998, 2001; Ladd & Schepman, 2003; Dilley & Brown, 2007; Dilley, 2010). With respect to segmental anchoring of f_0 movements, Ladd et al. (1999)

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showed that the alignment of a rising pitch accent is anchored to specific points in the segmental string even under changes in speech rates. Ladd et al.'s studies (1999, 2000) described that, in rising pitch accents, f_0 movements with phonetic segments are conditioned under constant peak alignment. Xu (1998) revealed that, in Mandarin, f_0 contours of lexical tones carry on a consistent alignment to the syllable regardless of speaking rate. Regarding f_0 variation associated to phonological categories, Dilley and Brown (2007) suggested that, in an imitation task related to rising-falling or falling-rising intonation, there are categorical shifts in f_0 peak and valley timing.

Discreteness in pitch range variation was observed in perceptual studies reflecting semantic distinctions (Purcell, 1976; Bruce, 1977; Kohler, 1987; Ladd & Morton, 1997; D'Imperio, 2000; Niebuhr, 2007). For example, Kohler (1987), in the paradigm of categorical perception, illustrated a change in meaning with a corresponding shift in the position of an f_0 peak. The identification function showed an f_0 peak shift along the physical continuum and, in the discrimination functions, the peak of discrimination occurred at the category boundary of the identification function. Ladd and Morton (1997) investigated the categorical distinction of phonetic "emphasis" (i.e., normal vs. emphatic accents) and found evidence of categorical shifts in an identification task as pitch range increases. Niebuhr (2007) focused on timing variables in f_0 peaks in the perception of intonational categories and supported intonational contrasts in early and medial peaks in German.

The literature on f_0 contours includes many proposals that pitch range is phonologically represented. The types of pitch range investigated in the literature are involved with rising and falling contours. However, the continuous distinctions in f_0 contours also play a major role in the intonational system. For instance, Dilley (2010) also found that pitch range with contrastive representations such as H^* vs. $L+H^*$, H^* vs. L^*+H , and $\%H L^*$ vs. L^* under the AM theory shows continuous variation. Liberman and Pierrehumbert (1984) showed that the variability of the peak-point values was more than that of the associated lows. Subjects produced the f_0 low values constant for overall pitch ranges. Pierrehumbert and Steele (1989) implied that although there was a shift for imitations through the stimulus continuum, the responses within two categories were not strongly distinct for all subjects. In other words, there was a general tendency to track the values for the stimuli.

Tonal patterns in North KyungSang Korean have consistently been assumed to be critically distinguished by f_0 contours under

the AM theory. The present research aims to determine whether f_0 contours provide phonetic evidence of categorical effects related to distinct phonological categories. With respect to the tonal contrast, HH vs. HL and HH vs. LH, as seen in Figure 1, the actual f_0 values of pitch accent categories do not reflect invariantly and transparently the phonological descriptions that are typically used within the AM framework. In the pitch contours of HL and HH, the pitch fall of HL appears gradually on the second syllable, whereas the sequence of high tone for HH tends to show the rising contour. In the f_0 contours of HH and LH, the word-initial low f_0 values between HH and LH are different because the low f_0 value of the LH tone pattern tends to be more or less lower than that of HH.

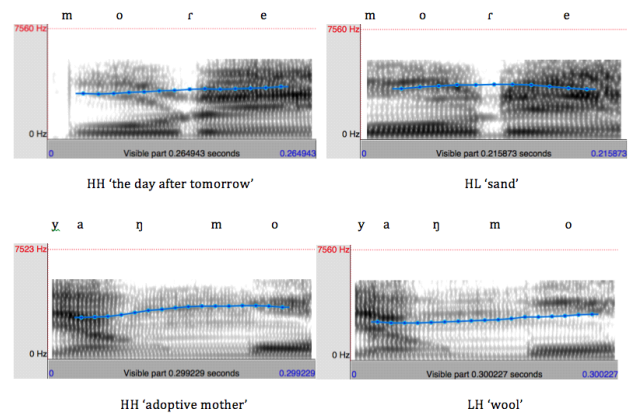


Figure 1. Pitch accent contours of minimal pairs (i.e., [mo.re] for HL vs. HH, [yaŋ.mo] for HH vs. LH) with two-syllable words. The word corresponding to each pitch contour was excerpted from the carrier sentence (e.g., [yɔŋmi-nin ____ hako malhes-ninteye] 'Youngmi said ____ .')

In spite of the phonetic properties in f_0 contours, the phonological studies of North KyungSang Korean claim that the location of high tone on a word typically shows a different classification of pitch accent patterns. Kim (1988) suggested two types of high tone in a phonological representation. For a North KyungSang dialect, the example in (1) illustrates how two types of high tone are linked to the target syllable in the phonological representation. The examples in (1) from Kim (1988) display the association of tone and syllable in the phonological representation. Based on Kim's analysis, in (1a), high tone is prelinked to the first syllable. High tone in (1b) and (1c) is available to two syllables as the tone-bearing units.

(1) Kim (1988)

a. mal mal + i H H L 'horse'	b. mal mal + i / H H H 'measure'	c. mal mal + i / H H: H 'word'
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Regarding the tonal contrast of HH and LH, Kim's (1988) example in (1) is interpreted differently by Kim (2000, 2003). Kim (1988) analyzed the tone pattern of 'word' as H:H with an initial long vowel as seen in (1c), but Kim (2000) suggested the rising tone (i.e., LH).

(2) Kim (2000, 2003)

mal + i [HL] 'horse'
[HH] 'measure'
[LH] 'word'

So far, we have discussed the phonological analysis of HH vs. HL and HH vs. LH in North Kyungsang Korean. As a phonetic study, Jun et al. (2006) conducted a production experiment of lexical pitch accent categories with adult North Kyungsang participants and suggested the phonological representation of lexical pitch accent patterns, which are phonetically grounded. In Jun et al.'s (2006) study, the underlying tonal pattern is the starred H tone with a trailing L tone (H*+L). The high tone is realized around the accented syllable and the low tone is realized after the accented syllable. A low boundary tone (%L) is inserted at the left edge of a prosodic word. The tone analysis of Jun et al. (2006) interpreted the pitch accent patterns of North Kyungsang Korean as a single underlying tonal representation, though there are different associations between tone and syllable for the different classes of lexical items.

With respect to supporting the pitch accent contrasts of HH vs. HL and HH vs. LH in North Kyungsang Korean, phonetic evidence can come from both production and perception tasks. In production tasks, Kim (2010) revealed that the turning point of f_0 differs between two types of pitch accent categories, HH vs. HL and HH vs. LH. Additionally, Kim (2012a) showed, through a mimicry task, that there is phonetic evidence, such as the shift near the middle of each stimulus series, by measuring the difference of f_0 values at the midpoint of the first and second syllables. Perceptual evidence of pitch accent contrasts of HH vs. HL and HH vs. LH is taken to correspond to distinctiveness in an identification and discrimination function, given continuous phonetic dimension (Kim, 2011, 2013). The current research is

an extension of Kim's (2012b) study, which, through a mimicry task, observed the categorical effect in the timing of the HL and LH pitch accent patterns. Kim's (2012b) study showed that, in the categorical effect of HL and LH, there was an abrupt shift at the middle part of the stimulus continuum between contrastive minimal pairs. However, when the same experimental method is applied to the pitch accent pairs, HH vs. HL and HH vs. LH, it is not clear whether there is the same phonetic evidence as shown in Kim (2012b). Therefore, the purpose of this paper is to find a phonetic dimension in the form of the phonological discreteness of pitch range, focusing on the contrast of HH vs. HL and HH vs. LH, using a mimicry method.

The current study was conducted with three research questions. First, regarding the North Kyungsang tonal contrasts, HH vs. HL and HH vs. LH, are there any categorical effects in the imitation of gradient stimuli for speakers from the North Kyungsang region? Second, to observe some amount of phonetic evidence, is there a difference in f_0 peak and valley timing between the two groups of speakers coming from two different regions (i.e., North Kyungsang and South Cholla)? The experimental results from South Cholla speakers may confirm the fact that North Kyungsang speakers use lexical pitch accent in their speech in the comparison of speakers who do not use lexical pitch accent. Finally, are there any individual differences corresponding to pitch range variation for both HH vs. HL and HH vs. LH? On the basis of these research questions, the current research investigates whether pitch range differences show phonetic discontinuities reflecting phonologically distinct categories, considering continuous phonetic variation.

2. Experimental Method

2.1 Participants

Five North Kyungsang speakers from Daegu and five South Cholla speakers from Kwangju, with no reported history of speaking or hearing impairments, took part in this experiment. There were three female and two male North Kyungsang speakers and five female South Cholla speakers. The participants from the two dialect groups lived in their hometown (i.e., Daegu & Kwangju, respectively) for their whole life. All were paid for their participation.

2.2 Stimuli

Two-syllable words with specific pitch accent patterns (i.e.,

[more] (Kim, 1988): HH ‘the day after tomorrow’ vs. HL ‘sand,’ [yaŋmo]: HH ‘adoptive mother’ vs. LH ‘wool’) were selected for this experiment. These speech materials were produced by a native speaker of North Kyungsang Korean. To create the stimulus series, f0 contours for each word were resynthesized using a “pitch-synchronous overlap and add” (PSOLA) algorithm in Praat (Boersma & Weenink, 2002-2009). The stimulus series were created by changing the f0 level in 9 equal steps. The endpoints in the stimulus series corresponded to HH and HL for [more], and to HH and LH for [yaŋmo]. The entire pitch contours were resynthesized. The peak points at interval of 30 ms were resynthesized on the duration of the entire pitch contour. The pitch points resynthesized for HH-HL were every 13.77 points on the duration of pitch contour. And the pitch contour of HH-LH was resynthesized every 15.34 pitch points.

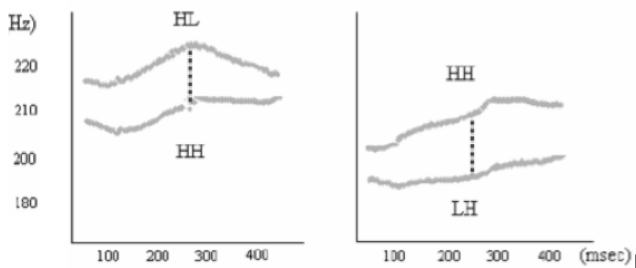


Figure 2. Hypothetical f0 contours for HL-HH in [more] and HH-LH in [yaŋmo] are illustrated. The intervals between the endpoints of contrastive pitch accent pairs were resynthesized as 9 step continua, as shown in the dotted line.

2.3 Procedure

The experimental method for the mimicry of pitch range contrasts, HH vs. HL and HH vs. LH is identical to that of Kim (2012a). In the current paper, participants imitated each stimulus presented over high-quality headphones in a quiet room. Stimuli recorded consist of the four stimulus blocks. The mimicry task contained 180 trials with 4 blocks of 45 trials (i. e., 9 steps x 5 repetitions). This task consists of HH-HL, HL-HH, HH-LH, and LH-HH. The order of trials within each stimulus block was presented in random order. A set of practice trials was conducted before each stimulus block.

2.4 Data analysis

The normalized f0 peak and valley locations were measured in order to obtain the values of continuous or contrastive phonetic dimension for the pitch contours, HH vs. HL and HH vs. LH. As analyzed in Kim (2012b), the normalized peak and

valley locations were computed by the difference between the onset time (T1) and the f0 peak or valley time (T2) of a two-syllable word divided by the total duration of a word (D), as seen in the formula of (3). Normalized f0 peak or valley time in (3) was used to minimize any effects of the differences which can be triggered by speech rate across participants. Onset time (T1) is the start of [m] in [more] and the start of [y] in [yaŋmo]. T2 is the time related to the f0 peak and f0 valley.

$$(3) \text{ Normalized f0 peak or valley time} = (T1 - T2) / D$$

To assess how accurately participants had imitated the f0 difference between pitch contours for the HH vs. HL and HH vs. LH patterns, a one-way analysis of variance (ANOVA) was run. The independent variables are the lexical pitch accent categories (i.e., HH vs. HL and HH vs. LH), and the dependent variables are the effect of stimulus. In addition, to see where the mean differences for the effect of stimulus lie, the Tukey post-hoc tests were conducted. The mean values of the f0 peak and valley times were compared between stimuli 1-3, stimuli 4-6, and stimuli 7-9. More specifically, in order to consider about the categorical boundary in the mimicry responses, the stimulus continuum was separated into three parts (i.e., stimuli 1-3, stimuli 4-6, and stimuli 7-9). For example, stimuli 1-3 represents the endpoints for HH and stimuli 7-9 for HL. There may be the categorical boundaries around stimuli 4-6 between HH and HL. On a basis of the Tukey post-hoc tests about these parts, the results can alternatively confirm that the stimulus continuum between each minimal pair reflects the phonological distinction.

3. Results

3.1 HH vs. HL

3.1.1 F0 peak times

The values of mean f0 peak times were assessed by a one-way ANOVA and Tukey post-hoc test. The effect of stimulus on mean f0 peak time for the North Kyungsang speakers differed significantly ($F(2,42) = 6.881, p < .01, MSE = .08198$). In particular, a post-hoc Tukey test showed a significant difference at $p = .006$ for stimuli 1-3 versus stimuli 4-6 and at $p = .007$ for stimuli 1-3 versus stimuli 7-9. But a post-hoc Tukey did not differ significantly in mean f0 peak times for stimuli 4-6 versus stimuli 7-9 ($p = .998$). Figure 3 shows the normalized f0 peak times for the North Kyungsang speakers. In Figure 3, the normalized f0 peak times fall into the range 0.38-0.63 for stimuli

1-3, 0.11-0.52 for stimuli 4-6, and 0.25-0.70 for stimuli 7-9. The normalized f0 peak times appear as a continuous shift around stimuli 1-9, though the f0 peak times at stimulus 9 show much variation. Figure 4 shows the confidence interval for the mean differences in the normalized f0 peak times for stimuli 1-3 versus stimuli 4-6 (i.e., b-a), stimuli 1-3 versus stimuli 7-9 (i.e., c-a), and stimuli 4-6 versus stimuli 7-9 (i.e., c-b). Only the confidence interval for c-b contains 0, indicating that the mean difference in normalized f0 peak times is similar for stimuli 4-6 and stimuli 7-9.

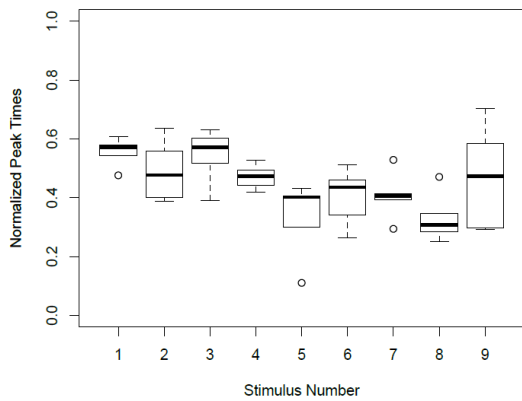


Figure 3. Normalized peak locations in the continuum of HH vs. HL for North Kyungsang speakers

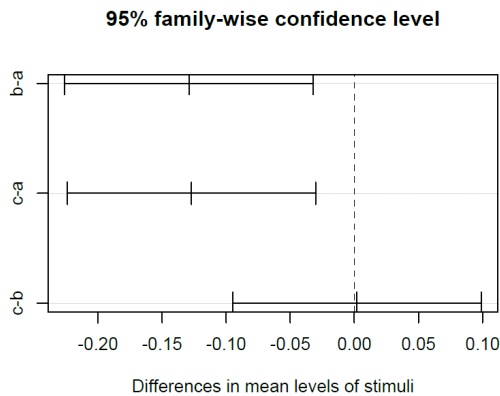


Figure 4. Mean differences in the normalized f0 peak times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for North Kyungsang speakers

In the comparison of the imitations of speakers of two dialects, speakers from the South Cholla region did not show a significant difference in the effect of stimulus on the mean f0 peak times ($p = .415$). A post-hoc Tukey test revealed no differences between stimuli 1-3 and stimuli 4-6 ($p = .966$), between stimuli 1-3 and stimuli 7-9 ($p = .422$), and between stimuli 4-6 versus stimuli 7-9 ($p = .570$). Figure 5 shows the normalized f0 peak times for South Cholla speakers. The mean

f0 peak times fall within the range 0.40-0.85 for stimuli 1-3, 0.33-0.86 for stimuli 4-6, and 0.31-0.85 for stimuli 7-9. The range of variation for South Cholla speakers is much larger on the mean f0 peak times of each stimulus, compared to those shown by North Kyungsang speakers. In Figure 6, there are no mean differences because the confidence interval includes 0 for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), for stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and for stimuli 7-9 versus stimuli 4-6 (i.e., c-b).

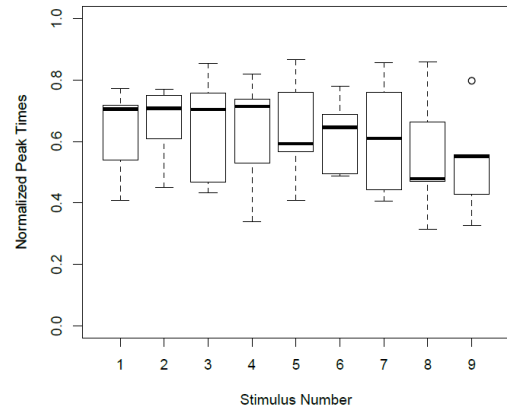


Figure 5. Normalized peak locations in the continuum of HH vs. HL for South Cholla speakers



Figure 6. Mean differences in the normalized f0 peak times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for South Cholla speakers

3.1.2 F0 valley times

Unlike the statistical result of mean f0 peak time for North Kyungsang speakers, the effect of stimulus on mean f0 valley time did not differ significantly in a one-way ANOVA ($p = .501$). A post-hoc Tukey test did not confirm the mean difference in confidence interval for stimuli 4-6 versus stimuli 1-3 ($p = .500$), stimuli 7-9 versus stimuli 1-3 ($p = .962$), and stimuli 7-9 versus stimuli 4-6 ($p = .662$). As shown in Figure 7,

the mean f0 valley times appear within the range 0.03-0.28 for stimuli 1-3, 0.01-0.18 for stimuli 4-6, and 0.01-0.49 for stimuli 7-9, indicating there is no categorical or continuous shift on the stimulus continuum. Figure 8 confirmed no mean difference because the confidence interval contained 0 for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and for stimuli 7-9 versus stimuli 4-6 (i.e., c-b).

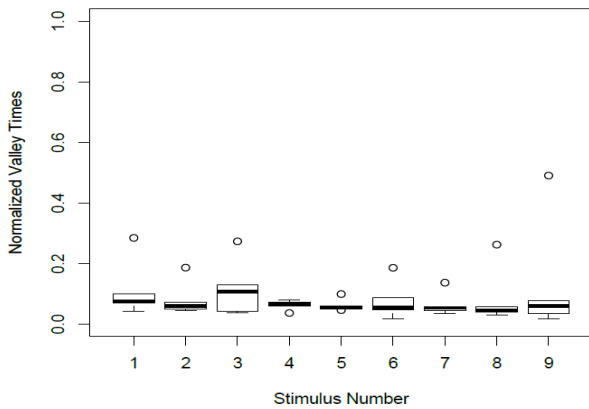


Figure 7. Normalized valley locations in the continuum of HH vs. HL for North Kyungsang speakers

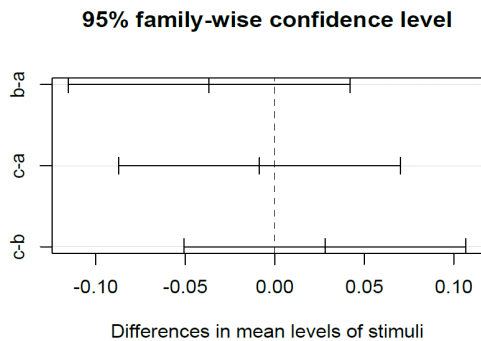


Figure 8. Mean differences in the normalized f0 valley times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for North Kyungsang speakers

The effect of stimulus on mean f0 valley time for South Cholla speakers did not differ significantly ($p = .803$). Specifically, a post-hoc comparison did not show a significant difference for stimuli 4-6 versus stimuli 1-3 ($p = .828$), stimuli 7-9 versus stimuli 1-3 ($p = .840$), and stimuli 7-9 versus stimuli 4-6 ($p = .999$). In Figure 9, the mean f0 valley times fall into the range, 0.01-0.17 for stimuli 1-3, 0.01-0.13 for stimuli 4-6, and 0.008-0.09 for stimuli 7-9, indicating that the responses of South Cholla speakers showed less variation than those of North Kyungsang speakers. Figure 10 confirms that there was no mean difference because the confidence interval includes 0 for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3

(i.e., c-a), and stimuli 7-9 versus stimuli 4-6 (i.e., c-b).

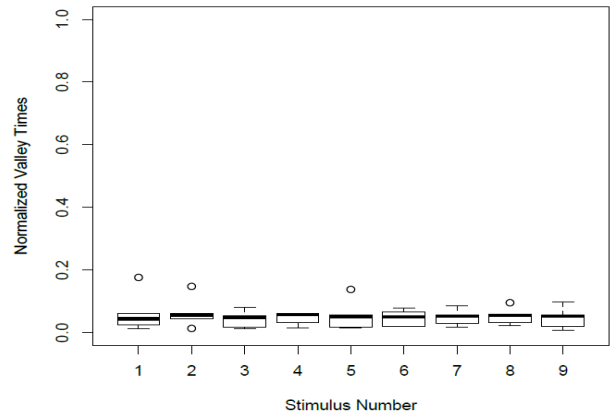


Figure 9. Normalized valley locations in the continuum of HH vs. HL for South Cholla speakers

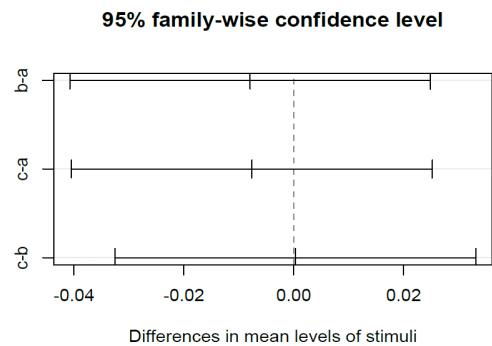


Figure 10. Mean differences in the normalized f0 valley times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for South Cholla speakers

3.1.3 Individual differences in f0 peak times

The effect of stimulus on f0 peak times showed much variation in individual mimics for the two dialect groups. Figure 11 presents each speaker's normalized f0 peak times. The effect of stimulus on normalized f0 peak time differed significantly for two North Kyungsang speakers (KS2: $F(1,7) = 25.23$, $p = .00152$, $MSE = 15824$, KS4: $F(1,7) = 13.61$, $p = .00776$, $MSE = .02818$) and two South Cholla speakers (CL2: $F(1,7) = 9.515$, $p = .0177$, $MSE = .022969$, CL3: $F(1,7) = 18.22$, $p = .00371$, $MSE = .04220$). As shown in Figure 11, for KS2, the range of f0 peak times for stimuli 1-3 showed much variation, compared to that of stimuli 4-9. The normalized f0 peak times for KS4 showed a continuous shift around the stimulus continuum, though there was more variation for stimuli 1-5 than stimuli 6-9. As for CL2, the shift in the range of f0 peak times was not distinct, though there was a statistically significant difference on the effect of stimulus. But CL3 in Figure 11 showed the difference of the range on f0 peak times,

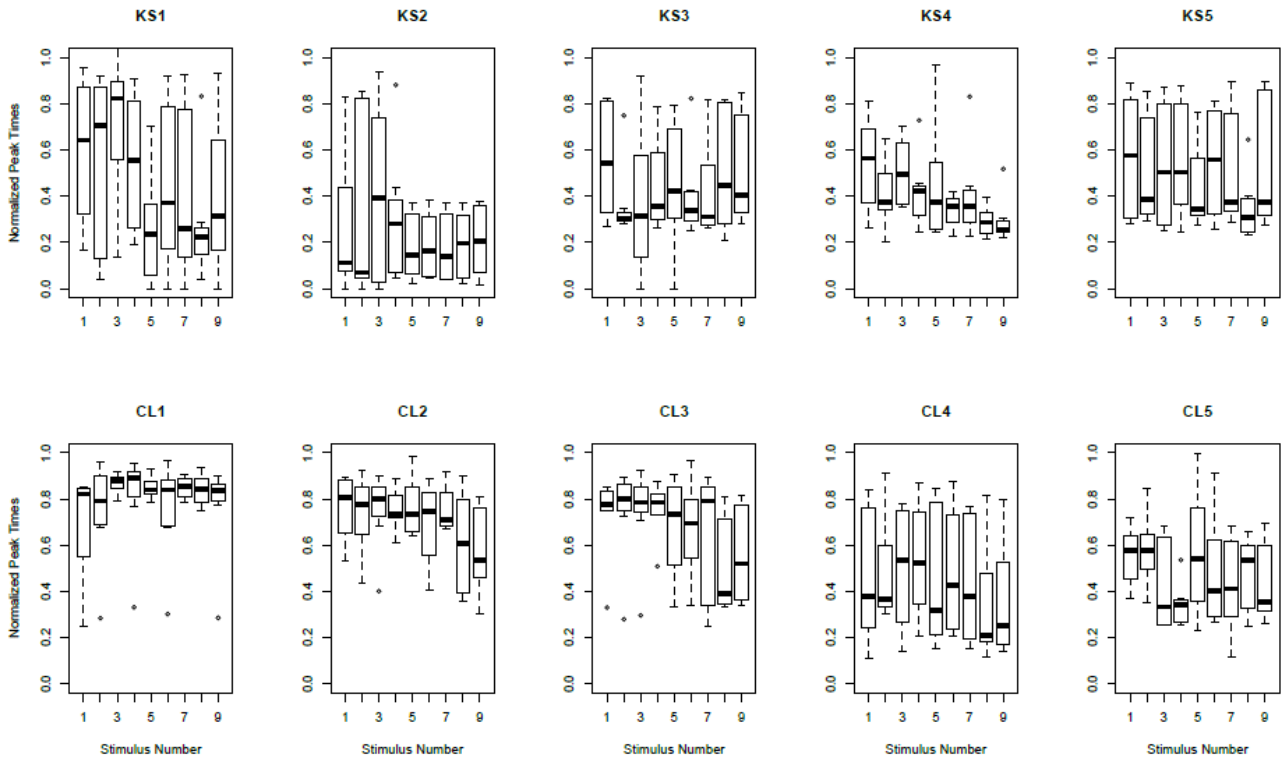


Figure 11. Individual differences in the normalized peak times of HH vs. HL for KS and CL speakers

indicating that the range on f_0 peak times for stimuli 1-4 was much narrower than that of stimuli 5-9. The other individual mimics from the two dialect groups showed more or less irregular patterns on the locations of f_0 peak times. However, the responses from North Kyungsang speakers (i.e., KS1, KS3, and KS5) tended to show more variation across the stimulus continuum, compared to the responses of South Cholla speakers (i.e., CL1, CL4, and CL5). The effect of stimulus on f_0 peak times did not differ significantly for KS1 ($F(1,7) = 0.341, p = .577, MSE = .01302$), KS3 ($F(1,7) = 0.026, p = .877, MSE = .0000656$), KS5 ($F(1,7) = 0.526, p = .492, MSE = .003799$), and CL1 ($F(1,7) = 2.269, p = .176, MSE = .005084$), CL4 ($F(1,7) = 3.304, p = .112, MSE = .013096$), CL5 ($F(1,7) = 1.124, p = .324, MSE = .007464$).

3.2 HH vs. LH

3.2.1 f_0 peak times

The responses of North Kyungsang speakers showed a significant difference for the effect of stimulus on mean f_0 peak times ($F(2,42) = 22.87, p < .001, MSE = .18862$). A post-hoc Tukey test confirmed a significant difference in mean f_0 peak time for stimuli 4-6 versus stimuli 1-3 ($p = .002$), stimuli 7-9 versus stimuli 1-3 ($p = .000001$), and stimuli 7-9 versus stimuli

4-6 ($p = .007$). Figure 12 shows the normalized f_0 peak times obtained from North Kyungsang speakers. The mean f_0 peak times fall into the range, 0.43-0.72 for stimuli 1-3, 0.50-0.82 for stimuli 4-6, and 0.57-0.92 for stimuli 7-9, indicating that there is a continuous shift across the stimulus continuum. Figure 13 shows the confidence interval on the clear difference of mean values for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and stimuli 7-9 versus stimuli 4-6 (i.e., c-b). In particular, in Figure 13, the 95% confidence interval in c-a presenting stimuli 7-9 versus stimuli 1-3 shows a clearer difference for mean values than b-a and c-b.

The effect of stimulus on mean f_0 peak time for South Cholla speakers did not differ significantly in a one-way ANOVA ($F(2,42) = 0.893, p = .417, MSE = .002231$). A post-hoc comparison showed no significant differences between stimuli 4-6 and stimuli 1-3 ($p = .650$), between stimuli 7-9 and stimuli 1-3 ($p = .398$), and between stimuli 7-9 and stimuli 4-6 ($p = .907$). Figure 14 shows the normalized f_0 peak times for South Cholla speakers. The mean f_0 peak times appear with the range, 0.70-0.88 for stimuli 1-3, 0.74-0.87 for stimuli 4-6, and 0.74-0.89 for stimuli 7-9, indicating there is no shift across the stimulus continuum. Moreover, Figure 15 confirms that there is no mean difference because the confidence interval includes 0 for stimuli

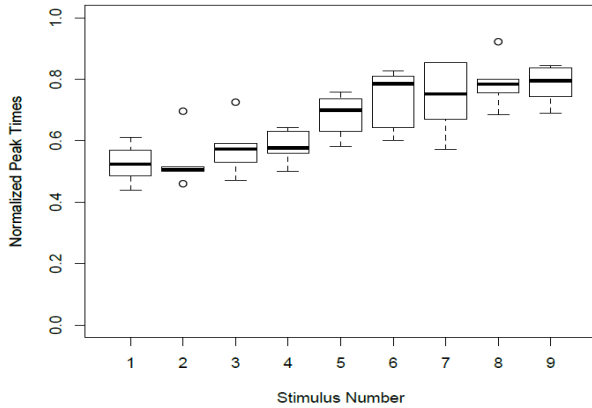


Figure 12. Normalized peak locations in the continuum of HH vs. LH for North Kyungsang speakers

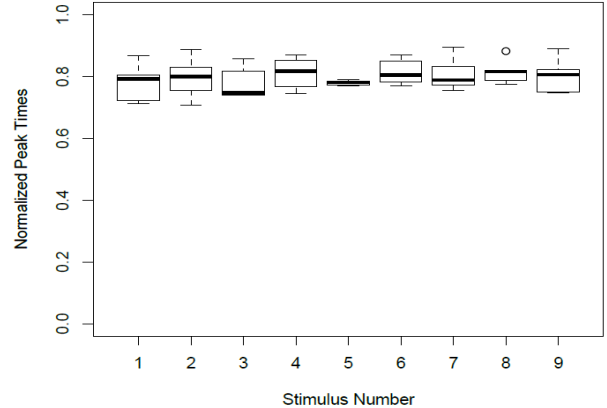


Figure 14. Normalized peak locations in the continuum of HH vs. LH for South Cholla speakers

95% family-wise confidence level

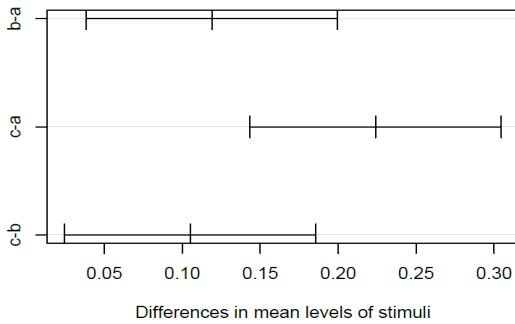


Figure 13. Mean differences in the normalized f0 peak times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for North Kyungsang speakers

95% family-wise confidence level

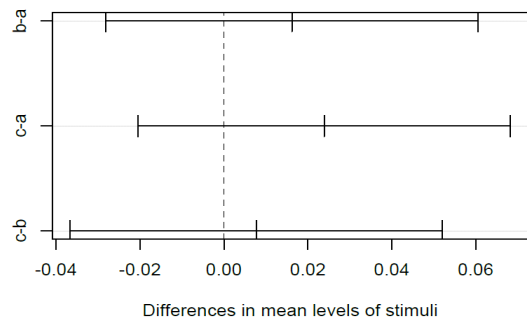


Figure 15. Mean differences in the normalized f0 peak times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for South Cholla speakers

4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and stimuli 7-9 versus stimuli 4-6 (i.e., c-b).

3.2.2 F0 valley times

The mimics of North Kyungsang speakers did not differ significantly in the effect of stimulus on mean f0 valley time ($p = .0556$). Tukey multiple comparisons of means did not show a significant difference for stimuli 4-6 versus stimuli 1-3 ($p = .183$), stimuli 7-9 versus stimuli 1-3 ($p = .054$), and stimuli 7-9 versus stimuli 4-6 ($p = .823$). Figure 16 shows the normalized f0 valley times for North Kyungsang speakers. As shown in Figure 16, the mean f0 valley times fall within the range, 0.02-0.13 for stimuli 1-3, 0.03-0.17 for stimuli 4-6, and 0.03-0.18 for stimuli 7-9, showing that there is no distinct shift around stimuli 1-9. Figure 17 confirms that there is no mean difference in confidence interval for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and stimuli 7-9 versus stimuli 4-6 (i.e., c-b), because the confidence interval contains 0.

In the comparison for stimuli 7-9 versus stimuli 1-3, the p -value and confidence interval is a borderline case for the cut-off level of 0.05. But, in this case, the result is unlikely to have occurred by chance, given the observed difference in the mean f0 peak time ($p < .001$).

The effect of stimulus for South Cholla speakers did not differ significantly in mean f0 valley time ($p = .618$). Tukey multiple comparisons of means did not show any difference between stimuli 4-6 and stimuli 1-3 ($p = .865$), stimuli 7-9 and stimuli 1-3 ($p = .588$), and stimuli 7-9 and stimuli 4-6 ($p = .883$). Figure 18 shows the normalized f0 valley times for South Cholla speakers. The mean f0 valley times in Figure 18 appear within the range, 0.01-0.10 for stimuli 1-3, 0.006-0.13 for stimuli 4-6, and 0.01-0.11 for stimuli 7-9, showing that there is no systematic shift across the stimulus continuum. Figure 19 confirmed that there is no mean difference, indicating that the confidence interval includes 0 for stimuli 4-6 versus stimuli 1-3 (i.e., b-a), stimuli 7-9 versus stimuli 1-3 (i.e., c-a), and stimuli

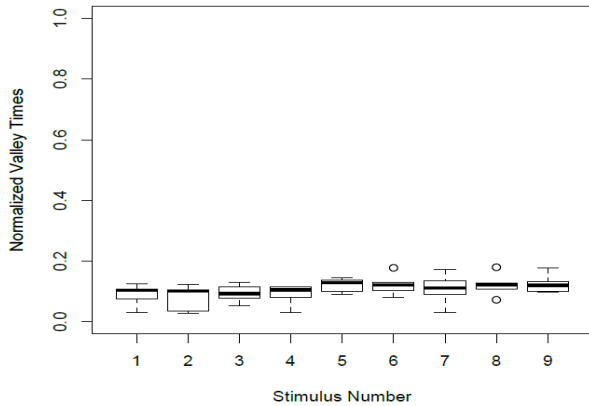


Figure 16. Normalized valley locations in the continuum of HH vs. LH for North Kyungsang speakers

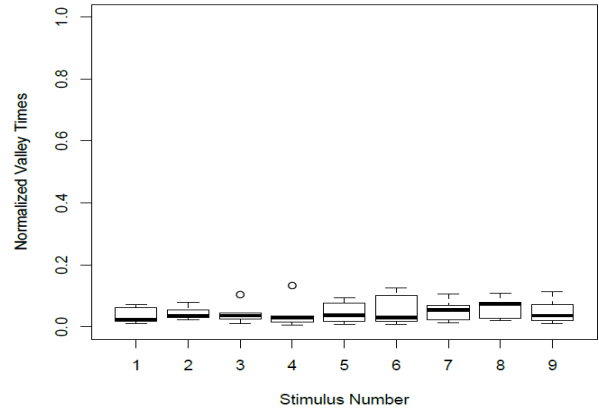


Figure 18. Normalized valley locations in the continuum of HH vs. LH for South Cholla speakers

95% family-wise confidence level

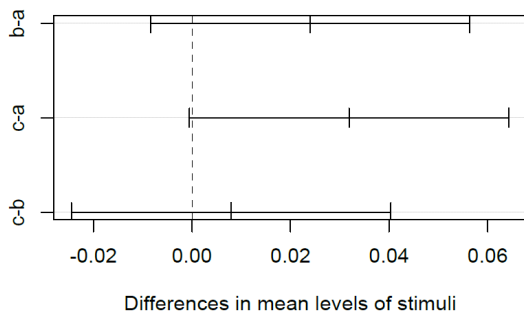


Figure 17. Mean differences in the normalized f0 valley times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for North Kyungsang speakers

95% family-wise confidence level

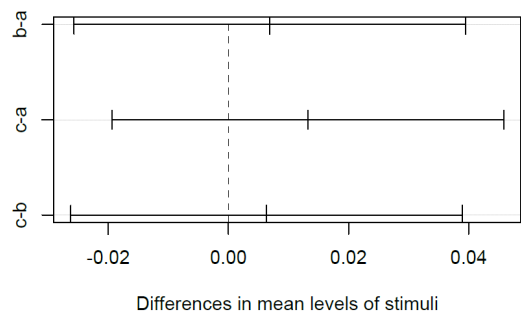


Figure 19. Mean differences in the normalized f0 valley times between each stimuli set (e.g., stimuli 1-3, 4-6, & 7-9) for South Cholla speakers

7-9 versus stimuli 4-6 (i.e., c-b).

3.2.3 Individual differences on f0 peak times

Figure 20 shows the individual mimics on the f0 peak times of HH vs. LH for North Kyungsang and South Cholla speakers. For four North Kyungsang speakers (i.e., KS1, KS2, KS4, KS5), the individual mimics showed a significant difference in the effect of stimulus on f0 peak times (KS1: $F(1,7) = 55.7, p < .001, MSE = .14778$, KS2: $F(1,7) = 28.49, p < .01, MSE = .18760$, KS4: $F(1,7) = 34.48, p < .001, MSE = .03525$, KS5: $F(1,7) = 82.51, p < .001, MSE = .1896$). But the effect of stimulus did not significantly differ for KS3 ($F(1,7) = 0.076, p < .791, MSE = .000417$). As observed in Figure 20, the mimics of four North Kyungsang speakers show the systematic shift in f0 peak times across the stimulus continuum. KS1, KS2, and KS5 show more or less an abrupt shift around stimuli 4-6, indicating that there is a categorical effect. As for KS4, there seems to be a continuous effect for the locations of f0 peak

times, though the range of f0 peak times shows much variation at stimulus 4.

On the other hand, in Figure 20, the responses of South Cholla speakers did not show a distinct shift in f0 peak times around stimuli 1-9, although CL2 and CL5 showed a significant difference in the effect of stimulus (i.e., CL2: $F(1,7) = .7179, p < .05, MSE = .006086$, CL5: $F(1,7) = 10.21, p < .05, MSE = .01021$). In other words, for CL2 and CL5, there was no such f0 shift observed as in the mimics of North Kyungsang speakers. Moreover, the effect of stimulus on f0 peak times was not significantly different for CL1, CL3, and CL4 (i.e., CL1: $F(1,7) = .2292, p = .174, MSE = .0020662$, CL3: $F(1,7) = .0287, p = .609, MSE = .0003702$, CL4: $F(1,7) = 0.227, p = .648, MSE = .0002006$). Thus, the responses of South Cholla speakers showed constant locations in f0 peak times across the stimulus continuum.

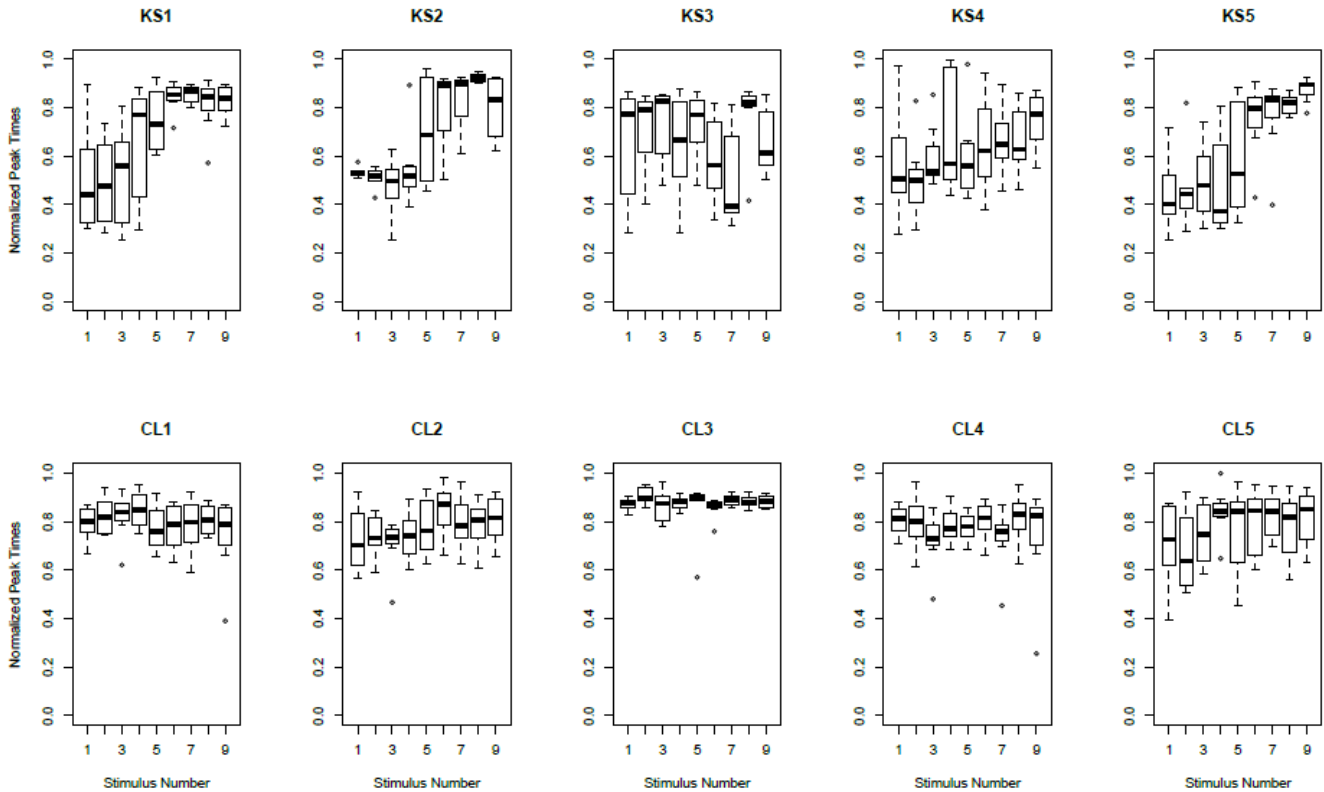


Figure 20. Individual differences in the normalized peak times of HH vs. LH for KS and CL speakers

4. Discussion

The purpose of this paper was to examine whether pitch range variation represents phonetic evidence of distinct phonological categories proposed for lexical pitch accent categories, HH vs. HL and HH vs. LH. To determine the phonological contrasts for HH vs. HL and HH vs. LH, the mimicry method suggested in Pierrehumbert and Steele (1989), Gussenhoven (2004), Dilley and Brown (2007), and Dilley (2010) was considered. The mimicry task was employed to detect phonological categories in intonation from the previous studies. On the basis of the current study, the phonetic evidence of pitch accent contrasts, HH vs. HL and HH vs. LH, provides additional evidence for distinguishing phonological categories for the lexical pitch accent system in Korean. That is to say, the findings of the current experiment are divided into four considerable points. First, regarding the mean f_0 peak times for HH vs. HL and HH vs. LH, North Kyung-sang speakers' mimicries showed phonetic evidence for discreteness consistent with phonological categories within the AM theory. In contrast, South Cholla speakers did not reveal significant differences around endpoints of f_0 contours for HH vs. HL and HH vs. LH. Second, in HH vs. HL and HH vs. LH,

there were, for North Kyung-sang speakers, no abrupt shifts for f_0 peak times at the middle part of the stimulus continuum, corresponding to the discreteness of the phonological categories. Third, the f_0 valley times for neither North Kyung-sang nor South Cholla speakers provided phonological distinction in the phonetic dimension of f_0 contours for HH vs. HL and HH vs. LH. Finally, for individual mimicries on f_0 peak times, there was more variation for HH vs. HL than HH vs. LH for speakers of the two dialects. These results are discussed in more detail below.

4.1 The continuous or categorical effect on mean f_0 peak times

North Kyung-sang speakers in the current research showed the categorical effect in the mimicry of f_0 contours for HH vs. HL and HH vs. LH. This categorization is presented in the contrast of mean f_0 peak times around the endpoints of stimuli (i.e., stimuli 1-3 vs. 7-9). The mimicry effects of HH vs. HL and HH vs. LH for North Kyung-sang speakers were confirmed in the contrast of mean f_0 peak times compared with those of South Cholla speakers. The mean f_0 peak times across stimuli 1-9 for South Cholla speakers were constant, revealing similar values for

the range of mean f_0 peak times on each stimulus. The categorical responses of HH vs. HL and HH vs. LH for North Kyungsang speakers can be considered an additional piece of evidence for Kim's (2012b) finding, which showed the categorization on mean f_0 peak timing between HL and LH. Moreover, as observed in the English intonation system (Pierrehumbert and Steele, 1989; Gussenhoven, 2004; Dilley and Brown, 2007; Dilley, 2010), the imitations for lexical pitch accent contrasts in Korean worked as evidence of discreteness on an intonation continuum.

In particular, as an issue of interest in the findings obtained from North Kyungsang speakers, the phonological contrasts of HH vs. HL and HH vs. LH showed the phonetic dimension representing the continuous effect around the middle of the stimulus continuum. That is, North Kyungsang speakers' mimics on mean f_0 peak times tend to reflect a gradient f_0 shift across the stimuli for the whole 9-step continuum. Unlike this result, in the study of Kim (2012b), there was an apparent shift in the middle of stimuli 1-9, indicating the categorical responses for HL vs. LH. On the basis of these findings, there seems to be a different effect in mimicry for the types of lexical pitch accent. The f_0 peak timing for HL vs. LH was more distinct than that for HH vs. HL and HH vs. LH. In the comparison of HH vs. HL and HH vs. LH, the mean f_0 peak times differed at the level of statistical significance. HH vs. HL showed a significant difference at $p < .01$ and HH vs. LH at $p < .001$. The current results between HH vs. HL and HH vs. LH reflect the difference of f_0 peak locations on pitch range shape. That is, the location of the mean f_0 peak time for HH vs. HL is not as large as that for HH vs. LH. The finding of the current research suggests that when the f_0 peak location on the pitch range is similar or overlaps for pitch accent contrasts, the probability for the phonetic difference between the two pitch accent categories gives rise to reducing in a mimicry task. The continuous effect in categorization of HH vs. HL and HH vs. LH in the mimicry of North Kyungsang speakers can be added to explain the lexical pitch accent contrasts assumed within the AM theory. The pitch range for HH vs. HL and HH vs. LH revealed continuously differentiable contrasts, rather than discreteness. Moreover, North Kyungsang speakers' mimics of HH vs. HL and HH vs. LH conveyed by continuous pitch range differences on mean f_0 peak times may be regarded as the continuous effect observed in vowel categorization (Kuhl et al., 1997; Burnham & Kitamura, 2002; Viechnicki, 2002).

4.2 The role of f_0 valley times

In order to account for the relation between variation in f_0 contour shape and phonological contrast, the current research investigated possible categorical timing differences for mean f_0 valley times obtained from North Kyungsang and South Cholla speakers. The results of mean f_0 valley times between speakers of the two dialects were not statistically supported. The mean f_0 valley times did not play a role in phonological distinction for HH vs. HL and HH vs. LH. But in the study of Kim (2012b), the mean f_0 valley times between HL and LH for North Kyungsang speakers statistically differed at $p < .01$, though the effect size for mean f_0 valley time was much lower than that of mean f_0 peak time. Nevertheless, as for HL vs. LH, it is uncertain whether North Kyungsang speakers clearly perceived the difference in f_0 valley timing. In the experiment of the current study, participants failed to imitate categorical timing in f_0 valleys for HH vs. HL and HH vs. LH. However, there were, in a production task, distinctions among lexical pitch accent types associated with low f_0 values as well as peak f_0 values in North Kyungsang Korean (Jun et al., 2006). Further, the f_0 valley timing for L+H* vs. L* in American English showed discreteness in the imitation-based approach (Dilley & Heffner, 2013). For North Kyungsang Korean, the role of f_0 valley timing should be further investigated in future research.

4.3 The individual mimics on f_0 peak times

With respect to f_0 peak timing, it is also worth noting that the result in the current study gives rise to some evidence for individual variation. First, there were, for individual North Kyungsang speakers, differences between pitch accent types, HH vs. HL and HH vs. LH. The patterns of f_0 peak times for HH vs. LH obtained from individual North Kyungsang speakers tended to show more or less apparent shifts around the middle of stimuli 1-9, excluding one speaker (i.e., KS3). In particular, three North Kyungsang speakers (i.e., KS1, KS2, & KS5) showed clear f_0 shifts around the middle of the stimulus continuum, indicating that there are categorical effects for HH vs. LH. One of the North Kyungsang speakers (i.e., KS4) revealed a continuous f_0 change occurring around stimuli 1-9. On the other hand, for HH vs. HL, the individual North Kyungsang speakers' patterns on f_0 peak timing were irregular across the stimulus continuum, though there was statistical evidence from two speakers (i.e., KS2 & KS4). Individual mimics for North Kyungsang speakers are likely to involve the mapping system of perception and production exposed to their

dialect environment (e.g., Kim & De Jong, 2007). But the mimicry responses shown in several North Kyungsang speakers differed between pitch accent types, HH vs. HL and HH vs. LH. Individual North Kyungsang speakers tended to exhibit the more systematic mapping of perception and production, representing the mimicry of HH vs. LH. The responses for two North Kyungsang speakers (i.e., KS1 & KS5) were not consistent between HH vs. HL and HH vs. LH. As a matter of interest, one North Kyungsang speaker (i.e., KS4) showed the continuous effect around stimuli 1-9 for both HH vs. HL and HH vs. LH. By contrast, the other speaker in this dialect group showed the irregular patterns of f0 peak times on stimulus series for both HH vs. HL and HH vs. LH. Overall, individual North Kyungsang speakers tended to respond more in the contrast of HH vs. LH than that of HH vs. HL.

While the responses of North Kyungsang speakers showed individual differences, those of South Cholla speakers did not reveal much variation. The variations on f0 peak times occurring around stimuli were not categorical or continuous effects for both HH vs. HL and HH vs. LH, although there were statistically significant differences for some speakers. Most of speakers exhibited flat patterns rather than changes. There was categorical evidence in HH versus HL for only one speaker (i.e., CL3), indicating an f0 shift occurring in the middle of the stimulus continuum. However, it is uncertain whether this f0 shift reflects the semantic distinction of two pitch accent categories. The patterns of an f0 shift for South Cholla speakers need to be further investigated in future research.

5. Conclusion

The current research concerns whether f0 peak and valley timing play a role in distinguishing phonological categories for HH vs. HL and HH vs. LH, pursuing as phonetic evidence an f0 shift in the stimuli. The findings in this experiment suggest, for North Kyungsang speakers, continuous variation across all stimuli for two endpoint categories (i.e., HH vs. HL & HH vs. LH). Further, the categorical shift within a continuum for HH vs. HL was less distinct than for HH vs. LH. These findings provided more practical explanation based on the phonetic dimension for the observation drawn from previous studies that a high tone is assigned to a syllable as a tone bearing unit within the AM theory. In addition, the current study has interesting implications for the assignment of a high tone assumed in previous studies in that the tonal target in f0 contour shape reflects various mapping

systems of perception and production through individual mimicries under a certain dialect environment.

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