Categorical perception of lexical pitch accent using contrastive f0 variations by (non-)native listeners*

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Kim, Jungsun. 2013. Categorical perception of lexical pitch accent using contrastive f0 variations by (non-) native listeners. *Studies in Phonetics, Phonology and Morphology* 19.2. 233-253. The purpose of this paper was to determine the nature of categorical perception of lexical pitch accent; the case language was North Kyungsang Korean. This paper follows the traditional paradigm of categorical perception, but the relationship of the between-category and within-category results differs from that of previous studies. That is, for North Kyungsang Korean, which features phonemically contrastive f0 variation, between-category discrimination showed higher scores than within-category discrimination; however, as a counterexample to traditional categorical perception, within-category discrimination also showed higher scores for North Kyungsang listeners than for South Cholla listeners, whose dialect features non-contrastive f0 variation. The present paper is the first to represent the categorical perception of the Korean prosodic system(s) and to show that stringent categorical perception accommodates the processing of phonetic information for North Kyungsang listeners, whereas loose categorical perception is adequate for the less categorical behavior of South Cholla listeners. Overall, the results support the phonological status of lexical pitch accent for speakers of the North Kyungsang dialect (but not for South Cholla). (**Yeungnam University)**

Keywords: categorical perception, between-category discrimination,
within-category discrimination, Kyunsang and Cholla Korean

1. Introduction

The current study investigates the categorical perception of lexical pitch accent between dialectal variants. The categorical perception of lexical pitch accent in Korean has not previously been examined effectively via the responses to identification and discrimination tasks. The current study accomplishes this task, focusing on differences in the prosodic structure of Korean phonology between two dialects spoken in different geographical regions, namely the North Kyungsang and South Cholla dialects. The current study is intended to chart the categorical perception of North Kyungsang pitch accent contrasts by North Kyungsang listeners, as compared to that by South Cholla listeners, who do not have contrastive pitch accent.

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The fundamental purpose of categorical perception is to derive phonological units from acoustic variables. The listeners' ability to perceive speech sound differences is limited to native sounds (Liberman et al. 1957). A great body of studies associated with categorical perception has shown that the ability to identify or discriminate a phonological contrast of speech on an auditory basis requires phonological knowledge, determined or modified by the phonological environment. The concept of categorical perception represents a listener's experience of perceiving (in)variance along an acoustic continuum. In other words, categorical perception accounts for how listeners identify or discriminate a certain phonological contrast in the mapping between various acoustic patterns and phonological categories (Francis et al. 2003, Klatt 1979, Pisoni 1973, 1975, Pisoni and Lazarus 1974, Studdert-Kennedy 1973). In the paradigm of categorical perception related to the correlation of the identification and discrimination results, the location of the categorical boundary in identification response corresponds to peak discrimination accuracy. In discrimination performance, the peaks are matched with the between-category responses. Thus, between-category discrimination is done more easily and reliably than within-category discrimination. As shown in Figure 1, acoustic differences that cross the categorical boundary are termed as 'between-category' and similar acoustic patterns that belong to the same category are termed as 'within-category'.

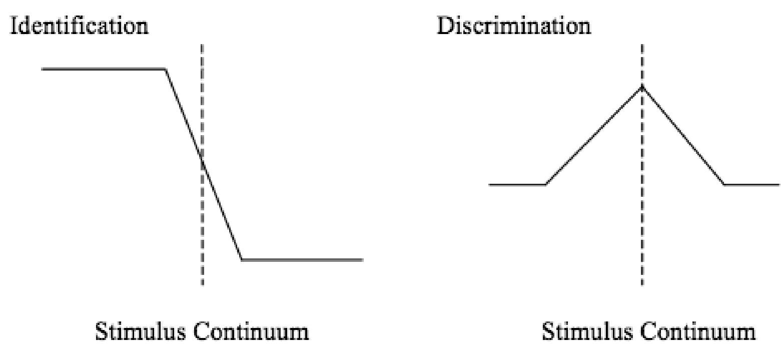


Figure 1. The properties of categorical boundary with hypothetical identification and discrimination curves are illustrated. The dotted lines indicate 'between-category'. The endpoints of curves indicate 'within-category'.

In the classical categorical perception literature, consonants and vowels represent a model of discrete vs. continuous perception; reliable categorical perception of consonants, especially stops (on the basis of VOT), has often been shown, but a large number of studies have failed to show the same for ambiguous vowels (Fry et al. 1962, Liberman et al. 1957, Pisoni 1973, 1975, Pisoni and Lazarus 1974). It is apparent that consonant features are more precisely categorized than those of vowels, a situation that can be accounted for by two types of discrimination: auditory and phonetic. The former refers to the psychological representation of sounds, while the latter refers to abstract representation of speech sound categories. Auditory and phonetic information are coded differently in the perceptual process of distinguishing between consonants as opposed to that of distinguishing between vowels (Pisoni 1973). Within-category discrimination secures results above chance levels in discrimination of vowels but close at chance levels for consonants (Pisoni 1973). That is, auditory memory coding of vowels and that of consonants differ.

Categorical perception of suprasegmental features has also been widely investigated (Francis et al. 2003, Hallé et al. 2004, Peng et al. 2010, Xu et al. 2006). Studying tone perception among Taiwanese Mandarin as opposed to French listeners, Hallé et al. (2004) found that the perception of the Mandarin listeners was affected by their native tone categories, whereas French listeners did not perceive contrastive tone sounds as phonological units. Interestingly, however, the French listeners in this study showed a considerable amount of sensitivity to fundamental frequency (f0) differences. For both groups, the discrimination scores were above chance—88% for Mandarin listeners and 74% for French listeners. Similarly, Xu, Gandour and Francis (2006) show obvious evidence for categorical tone perception in (Mainland Chinese) Mandarin listeners but not English listeners. Further, in an investigation of Cantonese lexical tones (Francis et al. 2003) examining three tone types, the respondents tended to precisely identify the category boundary in identification responses but showed weaker responses for a discrimination task.

Categorical perception depends on the properties of the phonetic categories that are specific to a language (Liberman et al. 1957, Studdert-Kennedy 1973). The hypothesis that linguistic environment influences auditory and phonetic perception has been well developed in various experimental studies (Best et al. 1988, Eimas et al. 1971, Kuhl et al. 1992, Werker et al. 1981, Werker and Tees 1983, 1984, Whalen and Liberman 1987), and the accumulated experimental evidence from the field of language acquisition holds that perceptual categorization is part of the biological-cognitive capacity of humans (Eimas 1975, Whalen and Liberman 1987). Eimas et al. (1971) found that sixteen-month-old infants can discriminate speech sounds in the same manner as adults discern a phonetic category boundary. Werker and Tees (1984) showed that the perceptual acquisition of a native sound occurs within the first year of infants' life. Best et al. (1988) found that infants being brought up in an English-speaking environment showed good discrimination of Zulu click contrasts at 12-14 months. More generally, Kuhl et al. (1992) demonstrated that the phonetic perception abilities of people from many different language communities do not show different patterns at the beginning of life. Different languages merge with the discovery of different phonetic distinctions, driving the emergence of phonological contrasts, through the experience of what will become one's native language.

This knowledge is of course specific to a language and affected by a language environment, and thus acquisition of phonology is a process of assimilation of one's (incipient) native speech sounds under the pressure of a phonological environment (Kuhl et al. 1992).

Building on these ideas, the current research considers how the phonological-environmental effect affects auditory/phonetic perception of a suprasegmental contrast. Preston (1986) conducted a map-drawing task in which native speakers drew and labeled American regions after hearing people from those regions speak. He found that adults from four regions (Indiana, Michigan, New York, and Hawaii) were sensitive to dialectal variations. That is, the participants accurately labeled the regions where their dialect was spoken.

The relation of phonetic perception and cognitive representation has drawn the attention of a variety of researchers using various linguistic and paralinguistic tasks. Miller and Grosjean (1997) examined the use of temporal and spectral information in vowel perception between standard French and Swiss French. They found that temporal information (vowel length) plays a much bigger role in the phonological system of Swiss French than that of standard French. Similarly, Otake and Cutler (1999) found that even speakers with a local accentless dialect who had been extensively exposed to Tokyo Japanese showed influence of the lexical properties of their local dialect on their perception of pitch accent in Tokyo Japanese. That is, in the perceptual judgment of two words with different pitch accents, the responses of participants from the accentless region were different from those of people from Tokyo, and the perception of lexical items featuring the high pitch accent was not equivalent to those of Tokyo participants. In other words, ability of the participants from the pitch accentless region to perceive the location of high pitch accent was less consistent than that of Tokyo Japanese speakers.

Pitch Accent in North Kyungsang Korean

The dimensions of perceptual phonetic processing vary across dialects. The current study concerns the categorical perception of (non-)lexical pitch accent patterns in the Korean prosodic system, across two dialects. In the pitch accent system of Korean, the study of dialectal variants has been mainly focused on production. In the eastern varieties of Korean (e.g., Kyungsang and Hamkyung dialects) the location of pitch accent is lexically determined (e.g., [kaci] in North Kyungsang dialect with different tonal transcriptions means respectively 'kind' (HL), 'eggplant' (LH), or 'branch' (HH). In western varieties, there are no such lexical contrasts marked by accent location. For example, Jun (1993, 1998) shows that the tone pattern of an accentual phrase in South Cholla dialect shows two different tonal alternations. The typical tone pattern of South Cholla exhibits a sequence of high tones in words beginning with consonants with laryngeal features.

Without any laryngeal features (i.e., in words beginning with lenis consonants or sonorants), the tone pattern starts with a low tone preceding a high tone. The relation of lexical and non-lexical pitch accent in Korean has been researched in the fields of phonetics and phonology, but most studies have focused on production data (Chung 1991, Jun 1993, 1998, Jun et al. 2006, Kenstowicz and Sohn 1997, Kim 1976, Kim 1988, Kim 1997, Kim 2010). However, in recent studies, lexical pitch accent has also been investigated using various experimental techniques. Kim and de Jong (2007) and Kim (2012a) revealed that the use of pitch in North Kyungsang Korean is related to the representation yielded in the correlation of identification, production, and mimicry tasks. Kim (2010, 2011, 2012a) showed using each of these methods (respectively) that pitch information across dialects of Korean maybe influenced by the process of phonological acquisition. Kim (2012b) found that lexical pitch accent using a mimicry paradigm in resynthesized speech is perceived and produced in terms of the shift of a high tone rather than the precise timing of a high tone on a syllable. This study shows that this shift of high tone is phonological in nature.

Hypothesis

The current study hypothesizes that (1) the category boundary that emerges from the identification task is identical or very near to the sensitivity peak in the discrimination task; (2) North Kyungsang listeners will strictly categorize tokens in identification and in discrimination tasks, reflecting a phonological contrast; and (3) that South Cholla listeners will only loosely categorize pitch accent in either task.

2. Experimental method

2.1 Subjects

Subjects were native speakers for their region (i.e., North Kyungsang and South Cholla). Subjects had lived more than 20 years on average in their hometowns. There were 12 North Kyungsang subjects (for the identification task, age range 19-33 [mean 23.25, SD 4.2] and for the ABX discrimination task, age range 20-33 [mean 23.91, SD 3.98]); all came from Daegu. There were 10 South Cholla subjects (for ID, age range 34-40 [mean 36.2, SD 2.29] and for ABX, age range 34-40 [mean 36.1, SD 1.91]), all from Kwangju. Subjects were given financial consideration by the author. No subjects had any hearing or speaking disabilities.

2.2 Stimuli

The stimuli were natural utterances of bisyllabic nouns with contrastive f0 patterns in North Kyungsang Korean. Stimuli were comprised exclusively of voiced sonorant segments so as to avoid acoustic perturbation in resynthesis. Three minimal pitch accent pairs were used, as shown in (1).

(1) Three minimal pairs in North Kyungsang Korean
a. HL vs. LH: [mo.i] ‘feed’, ‘conspiracy’
b. HL vs. HH: [mo.ɾe] ‘sand’, ‘the day after tomorrow’
c. LH vs. HH: [yaŋ.mo] ‘wool’, ‘adoptive mother’

Tokens of (1b) were extracted from (Kim 1988), while (1a) and (1c) were collected from the spontaneous speech of North Kyungsang speakers; for both (1a) and (1b), the items have different orthographies but identical sounds.[1] The target words were recorded in a carrier sentence by a North Kyungsang speaker, at 44,100 Hz using Praat software (Boersma and Weenink 1992–2009). The target words were resynthesized by a pitch-synchronous overlap and add (PSOLA) algorithm in Praat. Two continua, with different endpoints, were constructed for each minimal pair, meaning that the six pitch contours were divided into nine-step continua. Pitch contours were resynthesized at peak points at interval of 30 ms. For the HL-LH contour, the resynthesized points came every 13.77 points on the pitch contour, for HL-HH, every 12.84 points, and for HH-LH, every 15.34 points. The peak points were divided by the duration of the entire pitch contour. The stimuli thus had the entire pitch contour resynthesized, rather than specific points such as f0 peaks or lows.

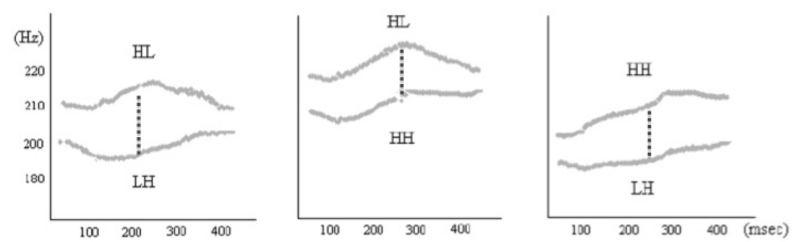


Figure 2. The pitch contours of North Kyungsang Korean, for HL-LH, HL-HH, HH-LH. The dotted lines between pitch contours are the intervals between the contrastive pitch accent pairs, which act as the endpoints of the contours. The spaces between endpoints were resynthesized into nine-step continua.

2.3 Procedures

An identification task was followed by a discrimination task. First, subjects read materials carrying the target words, intended to help the stimuli be

[1] Before the experiment, subjects were instructed to hear and pronounce the sounds of each minimal pair, showing no difference between the phonetic and orthographic forms.

understood in the two tasks.

Identification task: This task was conducted in a quiet room, in which stimuli were presented through high-quality headphones. This task consists of 432 trials (one block of 72 trials each for each pitch accent patterns: HL-LH/LH-HL, HL-HH/HH-HL, HH-LH/LH-HH); trials within a block were presented in random order. Each stimulus block was preceded by a practice phase of 16 trials. Subjects were asked to press one of two buttons displayed on a computer screen. Each button was labeled with the number "0" or "1", representing each minimal pair. Two picture cards, representing the meanings of two endpoint pitch accent patterns for each continuum, were attached below the button. Subjects were instructed to press the button corresponding to the correct word. For the identification task, the subjects had no feedback on their responses.

Discrimination task: The discrimination task used an ABX two-step discrimination technique, where subjects are asked to judge whether the third item in a sequence is the same as the first or as the second. Thus, ABX trials have four possible combinations: ABA, ABB, BAB, and BAA. For each continuum, there were seven A-B pairs, 1-3, 2-4, 3-5, 4-6, 5-7, 6-8, and 7-9 in forward order; and 3-1, 4-2, 5-3, 6-4, 7-5, 8-6, and 9-7 in reverse order. The stimuli were presented in pairs with a 500-ms interstimulus interval; the intertrial interval was 1s. This task consisted of 336 trials in three blocks of 112 trials each, HL-LH, HL-HH, HH-LH, presented in random order. Each stimulus block was preceded by a practice phase of 28 trials. Responses for 336 trials were collected and scored automatically. For the discrimination task, the subjects did not receive feedback on their responses.

2.4 Data analysis

The analysis used three statistical procedures: logistic regression function and correlation of discrimination scores obtained (i.e., between-category and within-category) and predicted (i.e., the derived identification scores), for both dialects. Analysis of variance (ANOVA) was also conducted to determine the degree of consistency in pitch contour difference by meaning.

Identification function and category boundary: The logistic regression model is to predict categorical outcomes based on predictor variables. For each lexical pitch accent pair, identification responses were statistically analyzed using a logistic regression model between the identification score derived from the two dialect listeners and continuum step number as a predictor variable. A logistic regression model using intercept and slope coefficients was applied to determine the category boundaries for each listener. The fitted identification curve is predicted to be a function of stimulus number, as in (2); this formula is based on a previous paper using logistic regression for perception data (Xu et al. 2006). Y is the probability and EXP is the base of natural logarithms. *a* is a constant, *b* is a predictor, and *x* is a predictor variable. The 50% probability of a categorical identification score boundary is parameterized in the form of (3). The categorical boundary x was derived by the formula in (3), and the regression coefficients (a, b) for the constant and predictor, corresponding to intercept and slope, were estimated by binary logistic regression to predict membership of only two categorical outcomes.

(2) $Y = 1/(1 + EXP\text{-}(a+bx))$
(3) $x = -a/b$

Obtained discrimination scores: The ABX discrimination scores were obtained by ALVIN perception test software (Hillenbrand and Gayvert 2005). Between-category discrimination was assessed on the basis of the scores corresponding to the categorical boundaries of identification functions, while within-category discrimination was assessed on the basis of scores at the ends of the continuum, on the basis of previous studies (Liberman et al. 1957, Pollack and Pisoni 1971, Xu et al. 2006).

Predicted discrimination from identification: The predicted discrimination scores were determined by formula (4), on the basis of which the correlation of observed and predicted discrimination and identification scores was calculated. Discrimination scores are determined by the probability that two stimuli are differently identified (Liberman et al. 1957, Pollack and Pisoni 1971, Xu et al. 2006). In (4), P* is the probability of a discrimination score, and P_A-P_B is the difference in probability between the two identification responses. P_A is the probability of stimuli scored as "A" at continuum step and P_B is the probability of stimuli scored as "B".

(4) $P^* = [1+ (P_A-P_B)^2]/2$

3. Results

3.1 Identification category boundary

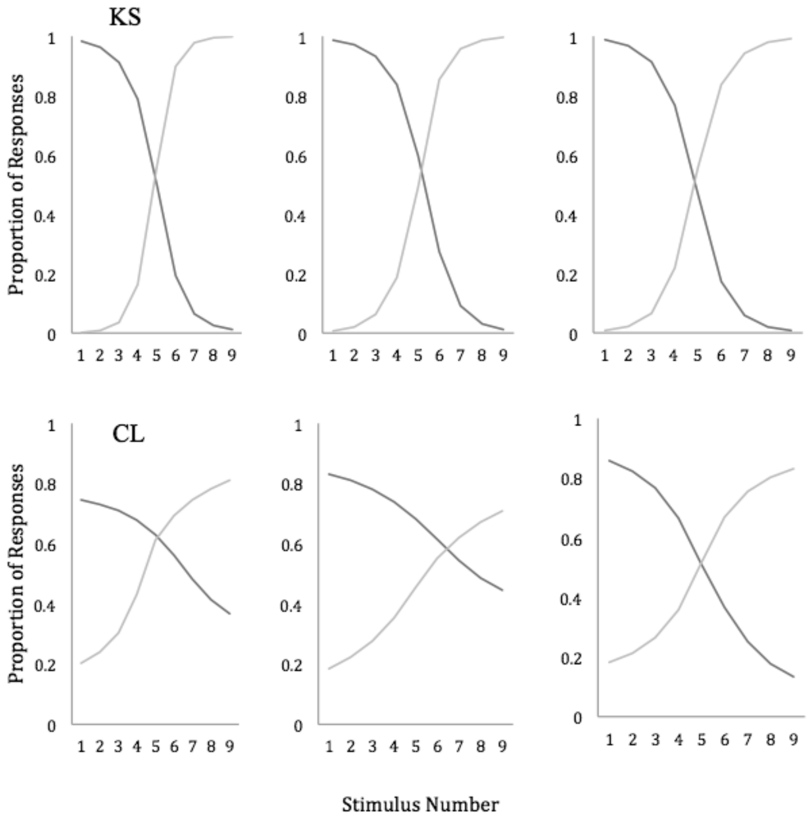
Category boundaries in an identification function were assessed on the basis of responses from both dialects. Logistic regression analysis was able to provide a fitted curve using regression coefficients (i.e., intercepts and slopes). At the curve, 50% crossover was affected by the different responses of subjects from the two dialect regions. The intercepts, slopes, and category boundaries, pooled across individuals, are summarized in Table 1. The intercept and slope values on the two continua, for each of the three minimal pitch accent pairs, overlapped. Based on the slopes in Table 1, the two dialect groups were significantly different for each minimal pair, ($F(1,44)=6.375$, $p<.05$) for HL-LH/LH-HL, ($F(1,44)=5.979$, $p<.05$) for HH-HL/HL-HH, and ($F(1,44)=4.503$, $p<.05$) for HH-LH/LH-HH. The slopes of category boundaries for North Kyungsang listeners were sharper than those for South Cholla listeners, as seen in Figure 3. Similarly, intercepts were different at a significant level (*F*(1,44)=5.682, *p*<.05) for HL-LH/LH-HL, (*F*(1,44)=6.072, *p*<.01) for HH-HL/HL-HH, and (*F*(1,44)=4.445, *p*<.05) for HH-LH/LH-HH. The locations of category boundaries for both groups, as seen in Table 1, were not different, presenting around boundary location 4 or 5, for all stimuli. The locations of the boundaries between the two groups, as computed by individual logistic regressions, tended to be positioned very close to the middle of the continua. However, the intercepts and slopes needed to keep the curve representing a categorical boundary showed the difference between the two dialects. In Table 1, North Kyungsang listeners showed higher values for intercept and lower ones for slope than did South Cholla listeners.

Table 1. Intercepts, Slopes, and Category Boundaries for KS and CL
(KS=North Kyungsang listeners, CL=South Cholla Listeners)

Group	Pitch Accent Pair	Intercept	Slope	Categorical Boundary
KS	HL-LH/LH-HL	16.72785	-3.30746	4.984615
	HH-HL/HL-HH	15.06892	-2.96596	5.107692
	HH-LH/LH-HH	14.96662	-2.96946	4.930769
CL	HL-LH/LH-HL	4.21215	-0.66205	5.785
	HH-HL/HL-HH	2.42975	-0.4038	5.641667
	HH-LH/LH-HH	3.7772	-0.743	4.495

Additionally, the slopes of the three pitch accent pairs did not differ between North Kyungsang (*p*=.949) and South Cholla (*p*=.299) listeners, and similarly, pooled intercepts did not exhibit a difference between North Kyungsang (*p*=.953) and South Cholla (*p*=.326).

The fitted curves in an identification function for the two dialect groups are plotted in Figure 3, derived from the logistic regression model applied to the current analysis. For North Kyungsang listeners, the fitted curve represents contrastive pitch accent pairs, whereas for South Cholla listeners, the curves are less fitted by regression coefficients (i.e., less diagonal). The three pitch accent types do not show different shapes in the identification function.



a) HL-LH/LH-HL b) HL-HH/HH-HL c) HH-LH/LH-HH

Figure 3. Identification functions plotted from the regression coefficients for the mean logistic response functions between North Kyungsang and South Cholla listeners.

3.2 Between- vs. Within-Category discrimination in the ABX task

In this section, I compare North Kyungsang listeners' discrimination performance to that of South Cholla listeners. A one-sample *t*-test showed performance above the chance level in both groups, between- (KS: $t(35)=12.925$, $p<.001$, CL: $t(29)=3.072$, $p=.005$) and within categories (KS: $t(35)=5.219$, $p<.001$, CL: $t(29)=2.083$, $p=.046$). Discrimination scores were significantly above chance for both dialects.

To differentiate between- and within-category discrimination scores, a one-way ANOVA was used, showing a significant difference between the groups for between-category scores ($F(1,64)=30.6$, p=6.29e-07). This indicates that North Kyungsang listeners are more likely to perceive contrastive f0 variation than are South Cholla listeners. Within-category discrimination scores also showed a significant difference between the two dialect groups ($F(1,64)=6.525$, $p=.013$), indicating that the responses of the North Kyungsang speakers were more accurate than those of the South Cholla speakers. The difference between between-category and within-category scores was statistically significant ($F(1,64)=11.7$, $p=.0011$), indicating that North Kyungsang listeners show higher peak discrimination than South Cholla listeners. Thus, North Kyungsang listeners scored 19% higher than South Cholla listeners on between-category discrimination and 5.5% higher on within-category discrimination as shown in Figure 4. These results are not congruent with our prediction of higher within-category discrimination scores for South Cholla listeners than for North Kyungsang listeners.

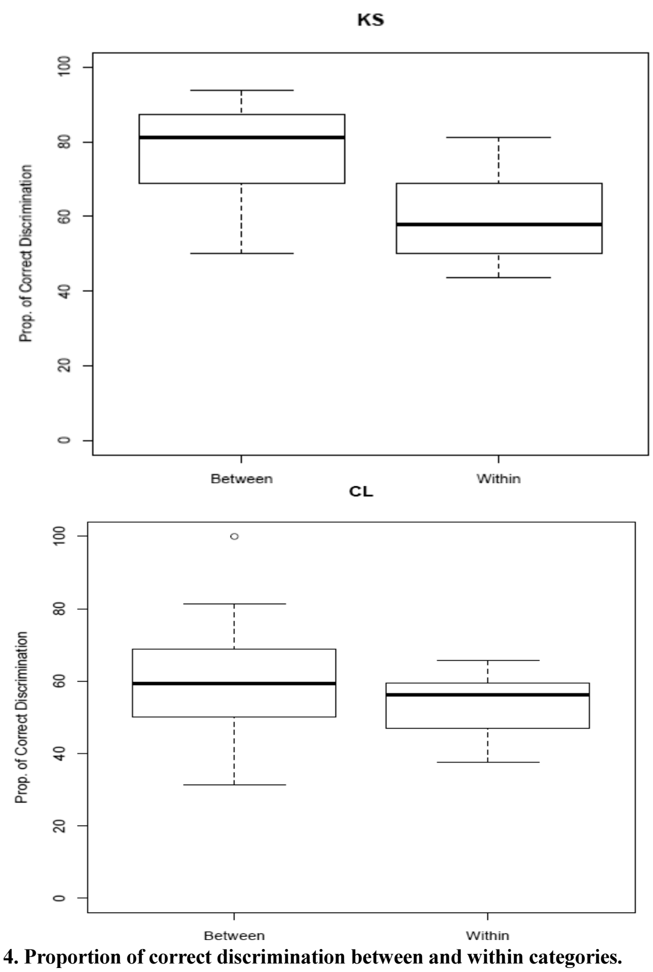


Figure 4. Proportion of correct discrimination between and within categories.

3.3 The relation of obtained and predicted discrimination scores to identification

The obtained and predicted discrimination scores were compared to see how well peak discrimination under each matched the category boundary in an identification function. Predicted discrimination was calculated using (4), which shows the probability difference between two alternatives in a sequence of identification responses.

Figure 5 display the obtained and predicted discrimination curves. To assess the difference between obtained and predicted discrimination scores across the two dialect groups, one-way ANOVA was conducted. The locations of peak predicted and observed discrimination were consistent along the acoustic continuum, and significantly different between dialects for HL-LH ($F(1,12)=18.37$, $p=.00106$), HH-HL($F(1,12)=5.912$, $p=.0316$), and HH-LH ($F(1,12)=13.21$, $p=.00342$). In other words, peak obtained discrimination was higher than peak predicted discrimination around stimulus number 4 for North Kyungsang listeners, whereas for South Cholla listeners, there was no peak, nor were the obtained curves for South Cholla listeners much higher than chance. This difference seems to be a matter of sensitivity of within-category discrimination, as mentioned in Hallé et al. (2004). It is hard to account for the sensitivity for the predicted curves because the chance level was fixed between two alternatives. That is, the predicted curve can be described as the difference between two identification responses, as in formula (4), rather than a chance result between two alternatives.

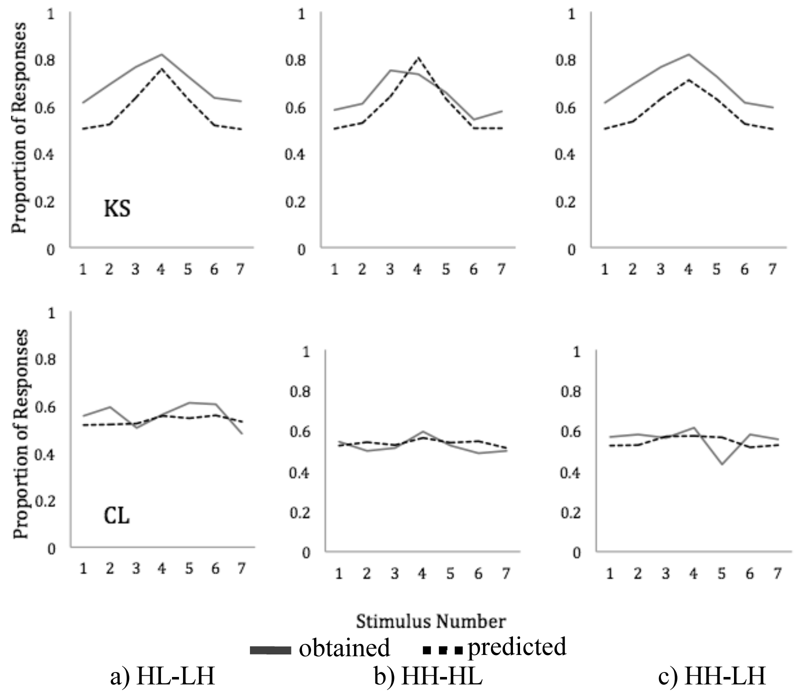


Figure 5. The relationship between obtained and predicted discrimination curves for North Kyungsang and South Cholla listeners.

The mean distance between obtained and predicted discrimination scores is seen in Table 2; it is greater for North Kyungsang listeners than for South Cholla listeners, indicating that the obtained chance level is higher than the predicted discrimination level. Thus, for North Kyungsang listeners, the mean distance toward the within-category discrimination was greater than around the peak of discrimination. Moreover, the mean distance obtained by the North Kyungsang speakers exhibits the lowest scores around stimulus number 4 for the HL-LH and HH-HL patterns and 5-6 for the HH-LH pattern. This difference supports the categorization in perceptual identification for the North Kyungsang speakers. However, for the South Cholla speakers, the mean distance appears random across the continuum for each pitch accent pattern. Thus, the mean distance values are inconsistent among the three types of pitch accent pattern for South Cholla listeners.

Table 2. Mean Distance Between Obtained and Predicted Discrimination Scores for Each Group

Group	KS		
Stimulus	HL-LH	HH-HL	HH-LH
1	0.11164	0.07942	0.11068
2	0.17062	0.08201	0.15773
3	0.13083	0.10955	0.13526
4	0.06146	-0.069533	0.10747
5	0.09594	0.02569	0.0952
6	0.11831	0.03591	0.09073
7	0.11784	0.07273	0.09151
Group	CL		
Stimulus	HL-LH	HH-HL	HH-LH
1	0.03906	0.01904	0.04275
2	0.07337	-0.041458	0.05341
3	-0.018209	-0.016125	-0.008233
4	0.00658	0.03113	0.03954
5	0.06601	-0.015584	-0.133594
6	0.04766	-0.05969	0.06447
7	-0.051044	-0.012921	0.02925

On a basis of the above, I can summarize the pattern of categorical perception of prosodic units in North Kyungsang Korean, as illustrated in Figures 3 and 5, as one in which the identification and discrimination functions can be superimposed. The categorical boundary in identification responses correspond to the accuracy peaks of observed and predicted discrimination curves. In contrast, there was no consistency in identification category boundary or peak discrimination for South Cholla listeners, near the categorical boundary or elsewhere. That is, the discrimination performance of South Cholla listeners was essentially flat, in sharp contrast to that for North Kyungsang.

4. Discussion

The current study investigated the patterns of categorical perception of lexical pitch accent in two Korean dialects, specifically the identification and discrimination of this phonological contrast. Overall, the identification responses corresponded to the peak discrimination accuracy in a matrix of categorical perception for North Kyungsang listeners. However, there was no consistent prosodic pattern of categorical perception for South Cholla listeners, for identification or discrimination. From these findings, I will consider three points: (1) the identification category boundary, (2) between-category and within-category discrimination, and (3) strictness of categorical perception and the discrimination accuracy predicted by identification responses.

4.1 The identification function and the category boundary

The difference in identification category boundaries between dialects was accounted for using different intercepts and slopes, rather than by positing category boundaries at different fixed locations. In logistic regression analysis, different intercepts and slopes indicate variable of categorical perception. In these results, North Kyungsang listeners showed less variability of intercepts and slopes, and as seen in Table 1, the higher intercepts and lower slopes for North Kyungsang listeners indicate a more precise category boundary than for South Cholla listeners (for whom the variable intercepts and slopes provided no consistent responses). This phonological distinction in categorical perception of lexical pitch accent is the same as that found in other perceptual studies for lexical tone (Hallé et al. 2004, Xu et al. 2006). In a tone perception task conducted by Hallé et al. (2004), the location of intercepts differed only subtly between Taiwanese and French listeners, although there was variability for both groups. The larger difference in slopes showed that they played a greater role in determining the phonological behavior of Taiwanese listeners. However, the current study displayed a greater difference in intercepts between speakers of two dialects of the same language, one with lexical pitch accent and one without. In the current study, unlike Hallé et al.'s study, there was no training session and only a short practice session on identification and discrimination. This may help account for these results. Xu et al. (2006) also used logistic regression to determine intercepts and slopes, but showed only a small difference between coefficients.

The current results show evidence that the noticeable difference in intercepts and slopes accounts for this prosodic variation between dialects of Korean, and that North Kyungsang and South Cholla listeners are engaging in different kinds of phonological behavior. This is the first perceptual experiment building on traditional phonological analysis. The current study also improves on Miller and Grosjean's (1997) analysis (of vowel length in two French dialects) by basing its findings on both identification and discrimination accuracy to show dialectal variation in categorical perception, while proving support for their findings from another language and considering another phonological feature.

4.2 Between- and Within-Category discrimination

The ABX discrimination task used in this study is based on short-term memory, because the third item is related to the first or the second item, presented previously. Thus, the finding that North Kyungsang listeners obtained higher scores in between- and within- discrimination responses than did South Cholla listeners seems contrary to common-sense expectation on categorical perception as well as those reported in previous studies (Pisoni 1973, Xu et al. 2006), where within-category discrimination (of segmental or suprasegmental information) was less sensitive than between-category discrimination and non-native listeners were more sensitive within categories than native listeners. Some previous studies on f0 variation in suprasegmental perception report that native speakers of a tone language ignore a small amount of irrelevant f0 variation to achieve tone categorization, while non-native listeners do not (Stagray and Downs 1993, Xu et al. 2006).

However, it has been found that Cantonese listeners, who have more tones and richer tone differentiation than Mandarin listeners, show a categorical boundary at a similar location in nonspeech as well as speech conditions, whereas Mandarin listeners perceive tone differently between speech and nonspeech (Peng et al. 2010). Peng et al. (2010) argue that Cantonese listeners' use of richer tonal differentiation in speech could be transferred to their perception of a nonspeech continuum. This argument is supported by previous studies (Deutsch et al. 2009, Deutsch et al. 2006) showing that native Mandarin-speaking musicians acquire absolute pitch less easily than native Cantonese-speaking musicians. Thus, North Kyungsang listeners may be more attentive to f0 variations than are "non-native" South Cholla listeners. That is, sensitivity to f0 may be greater for listeners native to a lexical pitch accent dialect, for both between-category and within-category discrimination. Investigations into within-category variation such as Miller (1997), McMurray et al. (2002), and McMurray and Aslin (2005) have observed variation within categories even for infants. Within-category variations differed by acoustic continuum, and the primary difference perceived within categories was acoustic scale. Gradient within-category effects should also be investigated in detail in the categorical perception of North Kyungsang listeners; their higher scores here might imply the existence of a gradient structure of response to f0 variations in lexical pitch accent in this dialect. More research on this topic is needed in the future.

4.3 Strictness of categorical perception: Predicted discrimination from identification responses

For identification and discrimination tasks, North Kyungsang listeners showed classical categorical patterns of speech perception, but South Cholla listeners perceived the stimuli at an auditory (psychophysical) level in the discrimination task. Identification and discrimination of lexical pitch accent by North Kyungsang listeners are clearly based on its phonologically contrastive property in their dialect of Korean. These listeners discriminated between categories more successfully than within categories discrimination, whereas South Cholla listeners did not, though they did show some auditory sensitivity to all of pitch accent contour variations. The relationship between obtained and predicted discrimination indicates that categorical perception is more stringent. That is, for North Kyungsang listeners, the proportion of identifications that were successful corresponded to both obtained and predicted discrimination accuracy (Liberman et al. 1957, Francis et al. 2003), and the location of category boundaries in identification performance corresponded to peaks in obtained and predicted discrimination.

This paper has examined the relationship between identification and discrimination by the prediction of discrimination between sounds from their identification (placement) on a synthetic acoustic continuum. The strictness of categorical perception can be understood to refer to the correspondence of peak sensitivity of discrimination to a categorical boundary in identification - this can canonically be seen in the differentiation of stops along a continuum of place of articulation, from /b/ to /d/ to /g/ (Liberman et al. 1957). According to Macmillan (1987), loose categorical perception can be considered to describe cases where peak discrimination is in the neighborhood of but not exactly matching a phonetic boundary.

As we have seen, categorical perception of lexical pitch accent in Korean dialect variations was flexible at the identification category boundary and the peaks of the obtained and predicted discrimination curves. More interestingly, in the long term, the stringency of categorization of lexical pitch accent should increase through the development of language process. The process of audition and labeling has been the focus of numerous experiments (Francis et al. 2003, Liberman et al. 1957, Pisoni and Lazarus 1974, Pisoni 1975, Xu et al. 2006); with regard to strictness of categorical perception, the question is how phonetic and/or auditory category boundaries can be extended to account for the memory codes used by listeners. The short-term memory code is key to the acquisition and perception of lexical pitch accent. In the current study, ABX discrimination, which requires the use of short-term memory, sheds light on the issue of stringent categorical perception. The correspondence of obtained and predicted discrimination for North Kyungsang listeners is regarded as a phonetic memory code, whereas the loose relationship seen in South Cholla listeners shows that they use auditory memory in making this distinction. It can be assumed that the auditory process is encoded in short-term memory but can be permanently encoded in long-term memory through early experience of native sounds (Pisoni 1975, 1993). In other words, the auditory memory code for North Kyungsang listeners was encoded as a long-term, phonetic memory code.

In this research, the auditory discrimination of both North Kyungsang and South Cholla listeners was above chance levels, while their phonetic discrimination scores differed in both between- and within-category discrimination. The long-term lexicalization of pitch accent in North Kyungsang Korean will be repeated as part of the process of language development, while, of course, this process will not take place in South Cholla speakers. Auditory processing can be stimulated by a small amount of f0 variation, but for South Cholla listeners, this variation does not stimulate phonological interpretation.

Thus, the different dialectal variants were shown to have different suprasegmental phonologies with regard to the lexicality of pitch accent. Lexical development can motivate phonetic as opposed to auditory discrimination. The development of phonological categories depends on categorical perception, which should be stringent, and which is acquired as part of language/dialect acquisition in children.

Particularly important in these results is the fact that the large difference between dialect groups appears to be reflected by increased discriminability around category boundaries in the North Kyungsang listeners. Thus, in the pitch accent systems of Korean, the lexicality of pitch accent is determined by the interaction between linguistic experience and long-term lexical representation.

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