Categorical Perception of Pitch: Effect of Linguistic Background, Linguistic Meaning and Pitch Contour

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Abstract: The aim of the present study was to assess the effect of linguistic background, linguistic meaning and pitch contour for the perception of pitch. For this purpose, the participants were divided into two groups based on their linguistic background. Group one involved 30 native Mandarin (tonal language) speakers and group two consisted of 30 native Kannada (non-tonal language) speakers. Six syllables common to both Mandarin and Kannada phonology was selected as stimuli. The syllables [ta], [ha] and [da] were considered, where pitch contrast changes the lexical meaning of the syllable in Mandarin, and syllable [to], [lo] and [do] were selected as, pitch variation does not convey differential meaning in Mandarin. Categorical perception for the pitch continua was assessed for identification task to investigate the effect of linguistic background, linguistic meaning and pitch contour. Results showed no significant effect of linguistic background and linguistic meaning but the mean values were significantly different across pitch contour among the two groups.

I. INTRODUCTION

Categorical perception (CP), refers to the phenomenon where gradually morphed sounds in a stimulus continuum tend to be perceived as discrete representations. According to this phenomenon, human beings tend to perceive the speech segments into different perceptual categories. The perception for the differences in the speech sounds belonging to different categories are enhanced and that belonging to the same category is deemphasized (Goldstone & Hendrickson, 2010). While most of the CP studies focuses on segmental features like consonants and vowels (Jain, Nataraja, & Nair, 2014, 2015; Liberman, Harris, Hoffman, & Griffith, 1957; Liberman, Harris, Kinney, & Lane, 1961; Livingston, Andrews, & Harnad, 1998), recent interest has been focused on investigating CP for suprasegmental features such as vowel duration contrasts (Nenonen, Shestakova, Huotilainen, & Näätänen, 2003; Wu et al., 2015; Ylinen, Shestakova, Alku, & Huotilainen, 2005) and lexical tone contrasts of tonal languages (Francis, Ciocca, & Ng, 2003; Hallé, Chang, & Best, 2004; Xi, Zhang, Shu, Zhang, & Li, 2010; Xu, Gandour, & Francis, 2006). These researchers have showed that the perception of the nature of lexical tone depends on the trajectory of signal pitch, i.e. continuum of flat tones are not categorically perceived (Francis et al., 2003), whereas that involving contour tones are perceived categorically (Wang, 1976; Xu et al., 2006).

Pitch is the psychological correlate of the fundamental frequency. The quality of the sound is dependent upon the highness or lowness of a tone pitch. Pitch plays an important role in perception of speech sounds. The change in pitch does not differ the meaning of spoken word or sentence in most of the Indo-European languages like English, Hindi and Sanskrit etc., but in Sino Tibetan languages like Mandarin, Cantonese and Thai, the change in the pitch contours changes the meaning of the word. Such languages where the meaning of the word is dependent upon the pitch contour within a syllable are known as tonal languages. Pitch conveys loads of information and its perception is a topic of scientific enquiry. Researchers reported strong evidence of categorical perception for pitch contrasts in Mandarin (Chen & Peng, 2016; Huang & Johnson, 2010), Thai (Cooper, Wang, & Ashley, 2016), and Cantonese listeners (Zheng, Minett, Peng, & Wang, 2012). As mentioned, Mandarin Chinese is one such tonal language involving contour tones which is perceived categorically.

In certain cross linguistic research, the tone perception abilities by Chinese and American language subjects revealed that the tone is perceived categorically by tonal language listeners (Chan, 1975; Wang, 1976) but not with English language listeners (Xu et al., 2006). Another cross linguistic study between listeners of Taiwanese and English also revealed similar findings (Sun &
Huang, 2012). On the other hand, research assessing the influence of linguistic experience on the categorical perception of pitch contours between listeners of Mandarin, Cantonese and German reported no significant difference across the position of the identification boundary between them (Peng et al., 2010). Other researchers also investigated the perception of pitch in listeners of tonal and non-tonal language; and the results are dichotomous (Baker et al., 2011; Kaan, Barkley, Bao, & Wayland, 2008; Klein, Zatorre, Milner, & Zhao, 2001; Liss, Uitianski, & Lansford, 2013; Zhang, Nissen, & Francis, 2008). It is also noted that most studies used pitch contours for sounds which convey linguistic meaning, but the pitch perception for continuum carrying non-meaningful sounds were sparsely investigated, and hence, ruling out the role of linguistic interference on categorical perception is difficult. Researchers clearly indicated different perceptual processes for meaningful and non-meaningful speech (Kuhl, Williams, & Meltzoff, 1991; Yoo et al., 2012). Thus, there is a need to investigate the categorical perception of pitch in speakers of tonal language for meaningful and non-meaningful stimuli. Considering the need, the present study assessed the effect of linguistic background (language tone), linguistic meaning and pitch contour for the perception of pitch.

II. METHODOLOGY

In a standard group, the participants are divided into two groups based on their linguistic background. Group one involved 30 native Mandarin (tonal language) speakers and group two consisted of 30 native Kannada (non-tonal language) speakers. The Mandarin speakers are available in Karnataka as a part of student exchange program of our University.

Six syllables common to both Mandarin and Kannada phonology was selected as stimuli. The syllables [ta], [la] and [da] were considered, where pitch contrast changes the lexical meaning of the syllable in Mandarin, and syllable [to], [lo] and [de] were selected as they convey no meaning in Mandarin. All the six syllables are present in the Kannada phonetic inventory. Each syllable token was recorded and synthesized and two set of continua with varying F0 slope were constructed. The resultant was a 16 step continuum with rising to falling tone contour (rising F0 at one end point and falling F0 at other end point) where slope of pitch tire was varied systematically from +0.75 to -0.75. Similarly, a 16 step falling to rising tone contour was constructed with the slope varying from -0.75 to +0.75, such that stimulus with falling F0 was at one end point and rising F0 at other end point. Both the continua were complimentary to each other with pitch tire in the opposite directions. Categorical perception for the pitch continua was assessed for identification task to investigate the effect of linguistic background, linguistic meaning and pitch contour.

![Figure 1](image1.png)

**Figure 1:** The onset and offset F0 values for each step along rising to falling continuum. The falling to rising continuum was complimentary and reciprocal to this, with step 1 here served as step 16 there and step 16 here served as step 1 there, with the remaining in between.

III. RESULTS

Univariate ANOVA showed no significant effect of linguistic background [F(1,592)=2.051; p>0.05] and linguistic meaning [F(1,592)=0.317; p>0.05], but the mean values were significantly different across pitch contour [F(1,592)=11.889; p = 0.001]. Pair wise comparison revealed that the categorical
boundary was shifted more towards the perception of stimulus with rising pitch, for both rising to falling and falling to rising pitch contours.

![Figure 2](image-url)  
**Figure 2:** Mean fundamental frequency scores measured for pitch perception abilities across linguistic background, linguistic meaning and pitch contours. The error bars in the figure is showing standard deviation values.

In depth analysis, results revealed that the categorical boundary is wider for Kannada language group than for Mandarin language group. The standard deviation was significantly more for Kannada than Mandarin participants. Among Mandarin participants, standard deviation of $F_0$ was more for non-meaningful stimuli than for meaningful stimuli, but no such difference was observed within Kannada participants. Descriptive statistics results indicate substantial difference in the standard deviation within linguistic meaning for Mandarin language group but not for Kannada language group. The range of responses at the categorical boundary was also observed in terms of steps along the continuum, and categorized across linguistic background and linguistic meaning. For Mandarin participants, the categorical boundary varied from step 7 to step 11 for the meaningful stimuli, and from step 6 to step 13 for non-meaningful stimuli, in the rising to falling contour. In falling to rising contour, the boundary varied from step 5 to step 7 for meaningful stimuli, and step 4 to step 9 for non-meaningful stimuli. On the other hand, the categorical boundary range was wider for Kannada group, starting from step 5 to step 15 in the rising to falling contour, and step 3 to step 13 in falling to rising contour, irrespective of linguistic meaning of the stimuli.

**IV. DISCUSSION**

The results indicate that neither linguistic background nor meaning significantly varies the perception of pitch. However, increased standard deviation at the categorical boundary point towards the differential perception along linguistic background and meaning. Increased width indicate poorer performance of the Kannada participants and is related to the effect of linguistic background. Since, in Kannada language, the pitch variation does not change the meaning of the speech sound, exact categorization is difficult for listeners of such language. The finding was further strengthened by observing the individual responses at the categorical boundary across the five trials. The categorical boundary was relatively stable for Mandarin participants but highly variable for Kannada participants, indicating that they have more difficulty labelling the sounds on the basis of pitch contrast. Thus, although non-significant, but perception of pitch is somewhat influenced by the linguistic background.

**V. CONCLUSION**

To conclude the findings of the present study, the pitch perception is minimally dependent upon the linguistic experience and linguistic meaning of stimuli. Pitch contour has effect on the perceptual process. The listeners of the tonal language perceives the pitch variation as distinct phonetic categories whereas those of non-tonal languages perceives pitch psychoacoustically.

**REFERENCES**


