DISCRIMINATION OF LEVEL TONES IN CANTONESE-LEARNING INFANTS*

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ABSTRACT

This study examines the perception of Cantonese tones in infants learning Hong Kong Cantonese as their native language, with particular focus on the discrimination of level tones. Our findings reveal that infants at the ages of 6- to 8-months old were capable of discriminating at least some of the level tonal contrasts in Cantonese. The results show evidence for a possible relationship between the ease of tone discrimination and the degree of acoustic similarity between the tones. Specifically, among the tone pairs tested in our study, the pair having the greatest F_0 difference, the high-level tone (T_1) and the mid-low level tone (T_6), was best discriminated as compared with the other two tone pairs which were acoustically closer in terms of F_0 values, i.e., the high-level tone (T_1) and the mid-level tone (T_3), the mid-level tone (T_3) and the mid-low level tone (T_6).

1. INTRODUCTION

In tonal languages, pitch serves to contrast words of different meanings. Speakers of a tonal language must be able to discriminate differences in fundamental frequency (F_0) and understand how variations in F_0 height and contour contribute to lexical contrasts. Although we are not certain of the exact onset of such discrimination ability in infants acquiring a tonal language, it is crucial for these abilities to manifest themselves at certain points in infants' development. In other words, infants' ability to perceive and discriminate linguistically relevant F_0 variations is believed to be a prerequisite for the acquisition of tonal contrasts.

This is an exploratory study on the perception of Cantonese tones in infants acquiring Hong Kong Cantonese as their native language. In this study, we investigated whether infants at the age of 6- to 8-months old possess the ability to discriminate tones. In particular, we focus on the ease of discrimination of the Cantonese level tone pairs, and propose possible explanations for such differences with reference to the acoustic properties of the Cantonese tones. We believe that the ease of tone discrimination is related to the degree of acoustic similarity of the tones, that is, the greater the acoustic difference between two stimuli, the easier the discrimination.

The study of tone perception by Cantonese-learning infants deserves special significance because even native Cantonese-speaking adults have been found to confuse some tonal contrasts in experimental tasks [7]. One might ask whether infants would show similar pitch confusion patterns as adults, and whether they are free from these limitations at an early age.

1.1. Infant speech perception

Studies in infant speech perception over the past three decades have revealed that infants can discriminate a wide range of speech and phonetic contrasts at an early age, such as distinctions in vowels, voicing, place of articulation, and manner of articulation [5, 6, 9].

Recent studies have also reported that infants are sensitive to some of the pitch/tonal contrasts in tonal/pitch-accent languages, such as the discrimination of bi-syllabic high-low/low-high Japanese words by 4- to 8-month-old Japanese infants [11], the discrimination between the Mandarin high-level (Tone 1) and the dipping tone (Tone 3) in Mandarin-learning infants [12], and the discrimination between contour-contour and level-contour Thai tone contrasts by both Chinese and English infants [10]. Six- to 8-month-old Yoruba infants have been found to be sensitive to pitch differentials of 20 Hz in isolated synthesized syllables only at a pitch region close to where adults could discriminate between the high and mid level tones in their language [8].

1.2. The Cantonese tonal system

Cantonese is a tonal language in which difference in pitch value is used to encode lexical contrasts. There are six lexical tones in Cantonese, which are represented on the relative five-point scale of Chao

[2], in which '5' represents the highest value and '1' represents the lowest value of the tonal scale. In our study we adopted the tone-letter scheme of [1]. The six tones are henceforth labeled as the high-level tone (T_1, /55/), the high-rising tone (T_2, /25/), the mid-level tone (T_3, /33/), the mid-low falling tone (T_4, /21/), the mid-low rising tone (T_5, /23/), and the mid-low level tone (T_6, /22/).

2. METHOD

We adopted the Conditioned Head Turn procedure [4] as our test paradigm in assessing tone discrimination ability in infants. This paradigm is one of the implementations of the 'visually reinforced infant speech discrimination paradigm (VRISD)' [4], originally used in clinical audiology for conducting hearing assessment in examining the frequency thresholds of infants. The paradigm was later modified and was then widely used in assessing speech discrimination in infants. It was found to be suitable for testing infants between the ages of 5.5 months and 18 months. Basically, this paradigm conditioned an infant to associate a change in a sound stimulus with the activation of a Visual Reinforcer (VR) by making head-turns towards the VR. Successful conditioning with correct head-turns is defined by the making of head-turns towards the VR after the change in sound stimulus but prior to the activation of the VR.

2.1. Subjects

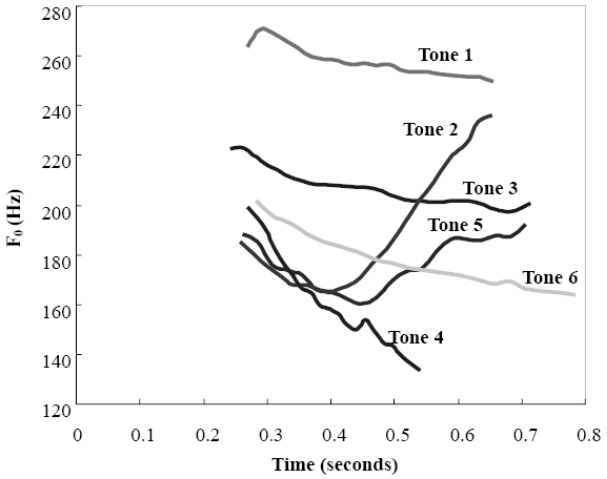
Five infants (four boys and one girl) participated in our study. They were at the ages of 23 weeks and 51 weeks. In order to minimize possible influence from the linguistic environment, all subjects came from Cantonese-speaking monolingual families, with both parents and/or their caretakers as native speakers of Cantonese who used Cantonese as the dominant language in daily communication with the child. All participants had also passed the hearing assessment test as conducted by the Department of Health of the Hong Kong SAR Government. Due to some logistic constraints, only two of the infants managed to complete the testing with the whole set of three pairs of Cantonese level tonal contrasts.

2.2. Stimuli

Our study focused on a selected set of tone pair contrast consisting of the Cantonese level tones, the high-level tone (T_1), the mid-level tone (T_3), and the mid-low level tone (T_6).

We use Cantonese monosyllabic words with the same CV sequence /si/, as all of the tones attached with this sequence yield lexical meanings in Cantonese. The three tone pairs consisting of the Cantonese level tones were: /si^{22}/ - /si^{55}/ (the mid-low level tone and the high-level tone), /si^{33}/ - /si^{55}/ (the mid-level tone and the high-level tone), and /si^{22}/ - /si^{33}/ (the mid-low level tone and the mid-level tone). The speech stimuli were recorded by a female adult native-speaker of Cantonese in a quiet room, who read according to a randomized list of test tokens. The speaker was required to produce the test tokens in a natural manner, with pauses between syllables. Ten tokens were produced for each of the three level tones, resulting in a total of 30 tokens for all of the tones. The F_0 trajectories were extracted using PRAAT. For each tone, the token with the Least Square Error from the mean value of that tone was selected as the test stimulus. The acoustic F_0 plot of the test tokens is given in Fig. 1. These test stimuli were also judged by randomly presenting them to 4 adult native-speakers, two males and two females. An accuracy rate of 100% was reached by all 4 subjects in a tone identification test.

Figure 1: F_0 plot of the speech stimuli.



2.3. Procedure

Each experiment involved two phases: the conditioning phase and the discrimination phase. An infant was conditioned to turn her head towards the VR upon a change of sound stimulus in the conditioning phase. During the first few trials in the conditioning phase, the VR was activated immediately following the presentation of the new sound stimulus S2 from S1. A delay in activation of the VR was gradually imposed until the infant learned to make anticipatory head-turns after detecting the sound change. An anticipatory head-turn was defined as a ninety-degree head-turn to the right side of an infant, after the change in sound stimulus from S1 to S2 but before the activation of the VR. In order to complete the conditioning phase

successfully, an infant had to reach the conditioning criterion by performing three consecutive anticipatory head-turns.

After successful completion of the conditioning phase, we moved on to the discrimination phase of the experiment. This phase was a discrimination testing on whether infants could detect a change in sound stimulus. In this phase, only head-turns in response to sound stimulus change were reinforced with VR activation.

3. RESULTS

A subject's performance in the conditioning phase and the discrimination phase (if the conditioning criterion was reached) would be considered in assessing her discrimination ability on a particular pair of stimulus. We interpreted the results based on the assumption that the ease of discrimination of a stimulus pair by an infant was positively related to (i) the ease with which an infant could be conditioned in a task; (ii) the rate of successful discrimination of a stimulus pair. Specifically, the ease with which an infant could be conditioned in a task was measured by the number of trials required by an infant to reach the conditioning criterion (i.e. three consecutive anticipatory head-turns) in the conditioning phase.

A baseline requirement of ten minimum trials was set arbitrarily for the completion of the conditioning phase, for the purpose of ensuring a uniform and adequate exposure to the stimulus pair among all subjects. During a change trial, if the infant made a head-turn towards the VR, her response would be recorded as "Hit". On the other hand, if the infant failed to make a head-turn within the time frame when S2 occurred, the response would be recorded as "Miss". During a control trial (no change in the sound stimulus from the 'background' stimulus), "Correct rejection" was defined as having no head-turn within the trial. If a head-turn occurred, it would be recorded as "False positive".

The rate of successful discrimination of a stimulus pair was assessed by the correctness score, as defined by Formula (1). N stands for the total number of response in all trials.

$$(1)\quad \text{Correctness Score} = \frac{\text{hits} + \text{correct rejections}}{\text{N}} \times 100\%$$

As three of the five subjects could not complete the whole set of test stimuli, we only reported performance of the two subjects, NHY and KWC (subjects indicated in terms of their initials), who have completed the full set of three test pairs in the current report. Tables 1 and 2 provide a summary of their performance respectively. Among the three pairs of Cantonese level tones, /si^{22}/-/si^{55}/ appears to be the best discriminated tone pair as it is the only pair for which NHY succeeded in reaching the criterion and it also required the least number of conditioning trials for KWC to be conditioned. In contrast, /si^{22}/-/si^{33}/ was the pair which required the greatest number of conditioning trials in both subjects. NHY did not produce the three consecutive anticipatory head-turns prerequisite for the entrance of the discrimination phase and KWC had the lowest score of correctness on this pair.

Table 1: Performance of KWC.

Age	**00;08;29**	**00;08;29**	**00;08;29**
Stimulus pair	/si^{22}/-/si^{55}/	/si^{33}/-/si^{55}/	/si^{22}/-/si^{33}/
No. of condition-ing trials	14	22	34
Correct-ness (%)	80	90	70

Table 2: Performance of NHY.

Age	**00;06;07**	**00;06;07 00;06;09 00;06;14**	**00;06;21**
Stimulus pair	/si^{22}/-/si^{55}/	/si^{33}/-/si^{55}/	/si^{22}/-/si^{33}/
No. of condition-ing trials	13	14 27 18	30
Correct-ness (%)	80	-- *	-- *

* conditioning criterion failed

4. DISCUSSION

The results of our study have shown evidence for a possible relationship between the ease of tone discrimination and the degree of acoustic similarity between the tones. The relative acoustic distance among the three Cantonese level tones is measured in terms of their F_0 difference, while the F_0 contours of these three tones are not considered as they are almost identically level. Among the three pairs of Cantonese level tones tested in our study, the pair having the greatest F_0 difference, the high-level tone (T_1) and the mid-low level tone (T_6), was best discriminated as compared with the other two tone pairs which were acoustically closer in terms of F_0 values, i.e., the high-level tone (T_1) and the mid-level tone (T_3), the mid-level tone (T_3) and the mid-low level tone (T_6). In contrast, the pair having the least acoustic separation (the mid-level tone T_3 and the mid-low level tone T_6) was least discriminated. Therefore, the preliminary results supported our

hypothesis that tones lying at the two ends of the relative pitch scale are easy to discriminate.

The current findings are consistent with previous findings on Mandarin [12], in which a pair of acoustically distinct Mandarin tones (Tone-1/Tone-3) was better discriminated than the other two tone pairs (Tone-2/Tone-3 and Tone-2/Tone-4), thus further pointing to the possibility that the ease of discrimination is affected by acoustic distinctiveness.

Some similarities in the ease of discrimination of particular tone pairs have been observed between infants who participated in our study and the Cantonese-speaking adults and children in other experimental tasks [3, 7]. For instance, the $T_3(33)$ – $T_6(22)$ contrast was found to be difficult to discriminate in all groups of subjects while the $T_1(55)$ – $T_6(22)$ contrast was easy to discriminate in comparison. Nonetheless, we should be cautious about the interpretation of results in understanding the potential incomparability among findings from different studies, as the implementation of various methodological paradigms could yield drastic differences in the task performance of the subjects.

5. CONCLUSIONS & FUTURE WORK

This exploratory study has provided us with a preliminary understanding on tone perception behavior in Cantonese-learning infants. Our tentative conclusion is that infants aged 6- to 8- months are capable of discriminating at least some of the level tonal contrasts in Cantonese.

The current findings support our hypothesis that the ease of tone discrimination is dependent on the acoustic distance between the tones. In particular, the acoustic distinctiveness of the high-level tone (T_1) might have enhanced its perceptual salience, making it easy to discriminate from other Cantonese tones. Results obtained in this study could contribute to the pool of available literature on infants' sensitivity towards the internal organization of syllables such as consonant and vowel contrasts, by affirming their discrimination ability on the suprasegmental feature of tone in a tonal language.

In future work we plan to document the developmental changes in tone perception by tracking the tone discrimination performance of subjects at different ages. We also wish to look for the possibility of association between tone discrimination performance at infancy and the acquisition of tonal contrasts during the stage of language learning, as the ability to perceive and discriminate linguistically relevant F_0 variations is believed to be a prerequisite for tone acquisition. We are interested in ascertaining to which extent the linguistic environment exerts an influence on the way infants perceive tones in tonal languages. Finally, we aim at extending our study to the full inventory of Cantonese tones with the recruitment of new subjects, for the purposes of having a better understanding of how far infants have developed in uncovering the complexity of the Cantonese tonal system, as well as a clearer picture on tone perception behavior in infants.

6. REFERENCES

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