Development of pitch cues in tone discrimination: evidence from Cantonese

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Previous research has shown that pitch cues including average pitch height, pitch contour, and pitch at critical points are important in tone perception [1,2], and listeners with different language background have different weightings of pitch cues. Specifically, average pitch height is an important pitch cue across languages [2,3], and non-tone language speakers attend more to pitch height than tone language speakers [4,5]. However, previous studies did not address the question concerning development of pitch cues in early years of life, i.e., (i) whether there is a language-general weighting of pitch cues prior to language exposure and (ii) when they start to change with language exposure. Although many studies on discrimination of lexical tones in infants have revealed different developmental patterns for tone and non-tone language learning infants [6-8], the relative role of pitch cues in tone discrimination is still not clear given the fact that multiple pitch cues are covarying with each other, and that tasks involving identification or judgment on multiple tone pairs could be difficult for infants. Therefore, the current study aims to investigate the role of 4 pitch cues, i.e., average height (AH), contour, onset pitch and offset pitch in tone discrimination in Cantonese-learning infants between the ages of 6m and 14m using manipulated tone pairs. Cantonese adults have been shown to weigh pitch height more importantly than pitch direction [3], and pitch offset more importantly than pitch onset in tone perception [2]. It is though yet to know whether Cantonese children behave the same as their adult counterparts. In order to answer this question, an experiment was conducted as follows.

To tease apart the relative role of each cue in the current study, we used one pair of sub-phonemic tone contrasts within each cue condition (Fig.1). Tone contrasts used in the *Contour* condition are two level tones with 7 Hz differences at every 500 ms interval. Tone contrasts in *AH*, *Onset* and *Offset* conditions included one rising tone and one falling tone sharing the same AH, onset and offset respectively (slope = ±14 Hz/s). This manipulation ensured one particular cue was kept constant in each condition. If that cue is important for perception, it would be relatively difficult for participants to perceive tone differences. Cantonese learning children at 6m (N = 72, 18/condition), 9m (N = 72), 12m (N = 72) and 14m (N = 80) were tested using a discrimination task with these four pairs of pitch trajectories superimposed on the syllable [ma]. A habituation-based visual fixation paradigm was adopted.

The results were analyzed using linear mixed-effects (LME) model. A significant main effect of Trial (Habituated vs. Novel) and Age, as well as 3 significant interactions: Trial × Condition, Condition × Age, and Trial × Condition × Age (Table 1). A separate LME model was conducted for different age groups, and only a significant Trial × Condition interaction was found in 9m and 12m group (Table 2). Post-hoc paired-sample t-tests comparing mean looking time revealed that although children at 6 and 14 months of age can discriminate tone contrasts in all conditions, 9-month-old children cannot discriminate tone contrasts in AH condition, and 12-month-old group cannot discriminate tone contrasts in AH and Offset condition (Fig.2).

The results suggest that Cantonese learning infants at 12 months of age begin to rely on AH and Offset as important cues for tone perception like adults, whereas there is an earlier tendency to weigh AH more importantly than other cues, providing the possibility that AH might be inherently given more weight in tone discrimination than other cues. Successful discrimination of tone contrasts in any condition in 6m and 14m group demonstrates that Cantonese learning infants are able to integrate other pitch cues in the absence of any pitch cue in tone discrimination. This result is similar to the U-shape development pattern found in non-tonal language learning infants in previous studies [6,9], suggesting a generally higher sensitivity to acoustic differences before 6 and after 12 months of age. And a drop in discriminatory ability in the ages between are possibly due to perceptual reorganization affected by native phonetic properties. Incapability of inferring the relative importance of cues when infants can equally discriminate all contrasts is a limitation of the

current design. However, a further study testing discrimination of these tone pairs in infants learning other languages would be helpful to see whether AH is naturally the most important cue in tone perception regardless of language background.

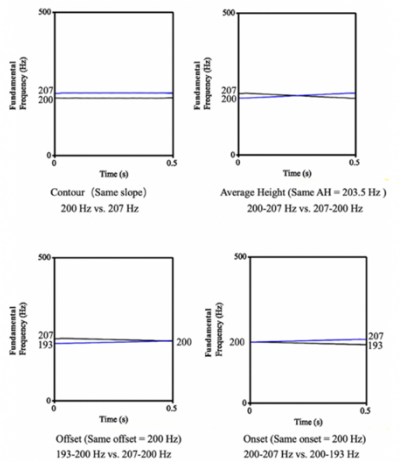

Fig.1 Acoustic details of tone contrasts in 4 cue conditions

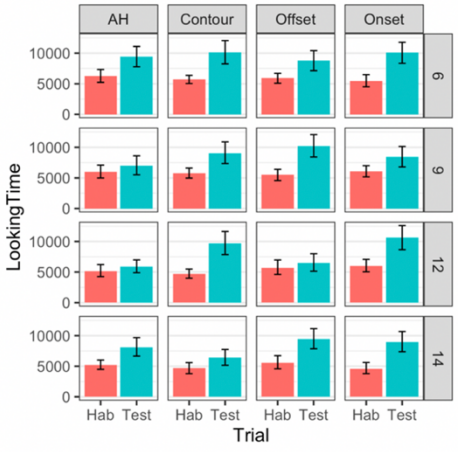

Fig.2 Mean looking time of habituation trials and novel test trials

Table 1 Results of LME assessing the effects of Trial, Age and Condition

	F	*df*	*p*
Trial	**143.79**	**872**	**<0.001*** **
Condition	0.87	280	0.465
Age	**3.75**	**280**	**0.011****
Trial×Condition	**2.63**	**872**	**0.049****
Trial	0.73	872	0.531
Condition×Age	**1.80**	**280**	**0.068***

Table 2 Results of LME conducted for separate age group

	F	*df*	*p*
6 months			
Trial	**42.49**	**212**	**<0.001*** **
Condition	0.26	68	0.853
Trial×Condition	1.14	212	0.333
9 months			
Trial	**27.92**	**212**	**<0.001*** **
Condition	0.64	68	0.593
Trial×Condition	**2.35**	**212**	**0.074***
12 months			
Trial	**29.67**	**212**	**<0.001*** **
Condition	**2.84**	**68**	**0.044****
Trial×Condition	**4.28**	**212**	**0.006*****
14 months			
Trial	**45.76**	**236**	**<0.001*** **
Condition	**2.24**	**76**	**0.091***
Trial×Condition	1.29	236	0.278

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