Can Dutch Monolingual Infants Distinguish Mandarin Chinese Tones and Use Tones in Word Learning?

Neurological Evidence from NIRS

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ABSTRACT
The research proposal suggests that separate brain areas are responsible for (lexical) tone perception, intonation perception and use of tone in word learning respectively. I propose to carry out two experiments with Dutch (non-tone learning) infants, the first for tone discrimination with three age groups (5-6 months, 9-10 months, and 17-18 months) and the second for word learning with two age groups (14-15 and 17-18 months). The two sets of age groups are in parallel with Liu and Kager's studies (2014; 2018). The two experiments will adopt near infrared spectroscopy (NIRS). In Experiment 1, I predict that (1) 5-6-months-old infants cannot distinguish tonal contrasts and therefore the response in the left hemisphere is not significantly different from the right hemisphere, while both hemispheres have some degrees of brain activation; (2) 9-10-months-old infants' brain activation demonstrates no difference when attending to two different tones; (3) 17-18-months-old infants may show left hemispheric dominance. In Experiment 2, when infants deal with a word learning task, I expect the temporo-parietal region, an area involved in the semantic mapping of tone, to be activated at 14-15 months while deactivated at 17-18 months.

1. Introduction

In tone languages such as Mandarin Chinese, pitch has the referential use to distinguish lexical meanings (Kager, 2018). For example, 'ma' with a high-level tone (tone 1) in Mandarin Chinese means 'mother', and it means 'horse' if pronounced with the fall-rising tone (tone 3). The phenomenon, where different lexical meanings can be marked by tones, is absent in non-tone languages such as Dutch. This absence in non-tone languages leads to the question: can non-tone learners distinguish tonal contrasts? If so, from what age do they demonstrate the ability, and do they differ from tone learners regarding the starting time of distinguishing tones and the mechanism of processing tones? Previous research has answered parts of the questions and found that tone learning infants and non-tone learning infants present different developmental trajectories (Liu & Kager, 2014; Liu & Kager, 2018). The question about the underlying mechanisms for tone processing in non-tone learning infants still has no concrete answer. The present study proposes to investigate brain mechanisms of tone perception and tonal word learning in non-tone learning infants throughout their developmental trajectories.

In the subsequent paragraph, I will summarize previous behavioral findings for infants' tone perception, including tone discrimination and the use of tone in word learning. Literature about neurological evidence of tone and intonation processing in both children and adults will be reviewed afterward. Next, two experiments are proposed to respectively test infants' ability to perceive tone and use tone in word learning. The last section is the discussion of the research proposal.

2. Literature Review

Abundant research has explored tone perception for different age groups in tone- and non-tone-language learning infants. Nazzi et al. (1998b) found that newborns were able to extract pitch contour information at the word level. During the first year after birth, tone- and non-tone-language learning infants demonstrate different developmental patterns. Tone-language learning infants retained their sensitivity to tones at the age of 4 months (Yeung et al., 2013), 6 months (Harrison, 2000; Mattock & Burnham, 2006) and 9 months (Mattock & Burnham, 2006). The sensitivity, however, declined after 4 months of age for non-tone language learning infants (Harrison, 2000; Yeung et al., 2013). Liu and Kager (2014) investigated tone discrimination by Dutch monolinguals and they suggested a U-shaped pattern of tone discrimination for non-tone language learning infants. Specifically, non-tone learning infants are able to discriminate tonal contrasts at 5-6 months and their tonal sensitivity deteriorates at around 9 months (Liu & Kager, 2014). However, the sensitivity rebounds at 17-18 months (Liu & Kager, 2014). This sensitivity is still shown by non-tone-language learners even in adulthood and it is suggested that non-tone language adult speakers perceive tones acoustically (Francis et al., 2008; Gandour et al., 2000; Hallé et al., 2004; Kaan et al., 2008; Xu et al., 2006). If adult non-tone language speakers perceive tones acoustically, one assumption is that non-tone-language learners' ability of tone perception is transferred from their knowledge of intonation in their native language. One purpose of the current paper is to find the neurological support for the previous assumption in infants.

Besides previous studies on infants' tone discrimination, further behavioral research examined whether non-tone-language learning infants can adopt tone in word learning. If they can, it may suggest that they perceive tones linguistically; if not, they may perceive tones acoustically (Liu & Kager, 2018). The findings are that non-tone-language learning infants can associate tones with lexical meaning at the age of 14-15 months, but not at 17-18 months (Liu & Kager, 2018), while tone-language learning monolinguals cannot use tone in word learning at the age of 12-13 months (Singh et al., 2016) or 14 months (Mugitani et al., 2019) but they can after 18 months (Mugitani et al., 2019; Singh et al., 2016). However, the fact that behavioral findings were not found in tone-language learning infants at a younger age, does not imply that there is no brain activation of lexical-semantic meaning responsible for word learning. Sato et al. (2009) found different neural patterns between 4-months-old and 10-months-old Japanese infants when presented with word pairs differing in Japanese lexical pitch-accent. The left hemisphere dominance found in 10-months-old infants suggests that the brain region of semantic processing may be involved, while this region's functionality for semantic processing has not been developed for infants at the age of 4 months (Sato et al., 2009). Thus, for tone-language learning infants, behavioral experiments found that they cannot use tone in word learning until 18 months, while neurological findings suggest that their semantic processing brain area is involved when using tone in word learning at the age of 10 months. Because of the discrepancy between neurological and behavioral findings, both kinds of studies are needed to further explore infants' learning mechanisms. Although we have seen neurological findings for Japanese infants, to my knowledge there is no corresponding research for non-tone learning infants. What we have seen so far, is that non-tone-language learning infants can use pitch for word learning before a certain age (e.g. Liu & Kager 2018). But do they activate the same brain areas as tone-learning infants when performing tone word learning tasks? If so, is this brain activation innate? Why and when do they develop this ability if tone is not lexically meaningful in their native language? Another motivation for the current research proposal is to examine the neural basis of non-tone learning infants for using tone in word learning.

Compared to the abundance of behavioral research on infants' tone perception, the amount of neurological research is limited due to the impracticality of fMRI and the lack of spatial resolution of EEG. Most studies in this field adopted near infrared spectroscopy (NIRS) (Homae et al., 2006; Maki et al., 1995; Sato et al., 2009), an effective method to examine the cortical hemodynamic responses in infants to stimuli lasting several seconds (Taga et al., 2003). The NIRS technology can be applied while infants are in a sleeping state and the activation pattern for speech sounds was found similar to the results obtained when infants are awake (Portas et al., 2000). Based on previous research, Sato et al. (2009) concluded that when the pitch cues for the lexical prosody are processed as linguistically relevant, left-lateralized activations are found and bilateral or no left dominance activation is seen when the same cue is processed non-linguistically. Therefore, in the present study, Dutch infants may demonstrate left-lateralized activation if they can process the difference between two pitch cues linguistically. On the contrary, they may show similar degrees of bilateral activation if the same pair is processed non-linguistically. Besides infant studies, a recent fMRI study by Chien et al. (2020) examined neural correlates of intonation and lexical tones in tone- and non-tone-language adult speakers. It found that for both tonal and non-tonal language speakers, left frontal-parietal areas were activated when processing either tone or intonation (Chien et al., 2020). When processing tone, but not intonation however, additional activity was evoked in bilateral temporo-parietal semantic regions and subcortical areas in tonal-language speakers only (Chien et al., 2020). The adult study provided a clear picture of the endpoint of the development pattern for processing pitch cues (lexical tones and intonation), which allows for the prediction in infants for the present research proposal.

The purpose of the research proposal is threefold:

1. To investigate brain mechanisms of tone perception in non-tone-language learning infants of different age groups,

2. To investigate brain mechanisms for using tone in word learning in non-tone learning infants of different age groups,

3. To examine if neurological evidence corroborates or contradicts previous behavioral findings, e.g., a U-shaped pattern (Liu & Kager, 2014).

3. Experiment 1: Perception of lexical tone

In Liu and Kager's (2014) study, they found in the first experiment that non-tone-language learning infants exhibit a U-shaped developmental pattern for tone perception. The stimuli in the experiment were the tonal contrast of tone 1 (T1) and tone 4 (T4) in Mandarin Chinese. Since the second experiment showed that infants can more easily differentiate if the tonal contrast is more salient, I propose to adopt the most salient contrast in Mandarin Chinese, that between T1 and T4, for the current study as well.

As discussed before in the literature review section, Liu and Kager (2014) adopted a behavioral approach, using the visual habituation paradigm. The infants in their experiment went through a habituation, a test, and a post-test phase (Liu & Kager, 2014). The infants kept listening to one tone until they were habituated, and then tokens of the different tone were presented. Infants are suggested to be able to distinguish tonal contrasts if there is a significant difference in looking time between the habituation and the test phase. The present study attempts to reduplicate the way of the stimuli presentation in Liu and Kager's (2014) study, but adopts a neurological approach by using the NIRS technology. This experiment seeks to answer the first and the third purpose.

3.1 Participants

In Liu and Kager's study (2014), there were 163 participants from 5 age groups and 23 infants' data were excluded. The present study proposes to include three age groups, which are 5-6 months old, 9-10 months old and 17-18 months old. The reason of incorporating three instead of five age groups like the study by Liu and Kager (2014) is that the vertex of the U-shaped pattern is on the group of 9-10 months old. For each group, 30 participants will be recruited with the expectation that around 10 participants' results will be excluded due to the practical reasons (e.g., crying). All participants will be Dutch monolinguals.

3.2 Stimuli

The experiments will use the stimuli recorded in the previous study (Liu & Kager, 2014). The four Mandarin Chinese lexical tones are shown in Figure 1. The stimuli, recorded by a Mandarin female speaker, will be the tonal contrast between high-level tone (T1) vs high-falling tone (T4) (Liu & Kager, 2014). The tone-bearing syllable will be /ta/. As shown in (1), both /ta1/ and /ta4/ are words in Mandarin. Figure 2 demonstrates the pitch contour of the T1-T4 pair of stimuli (Liu & Kager, 2014).

(1) a.搭 /ta1/ 'build'

b.大 /ta4/ 'big'

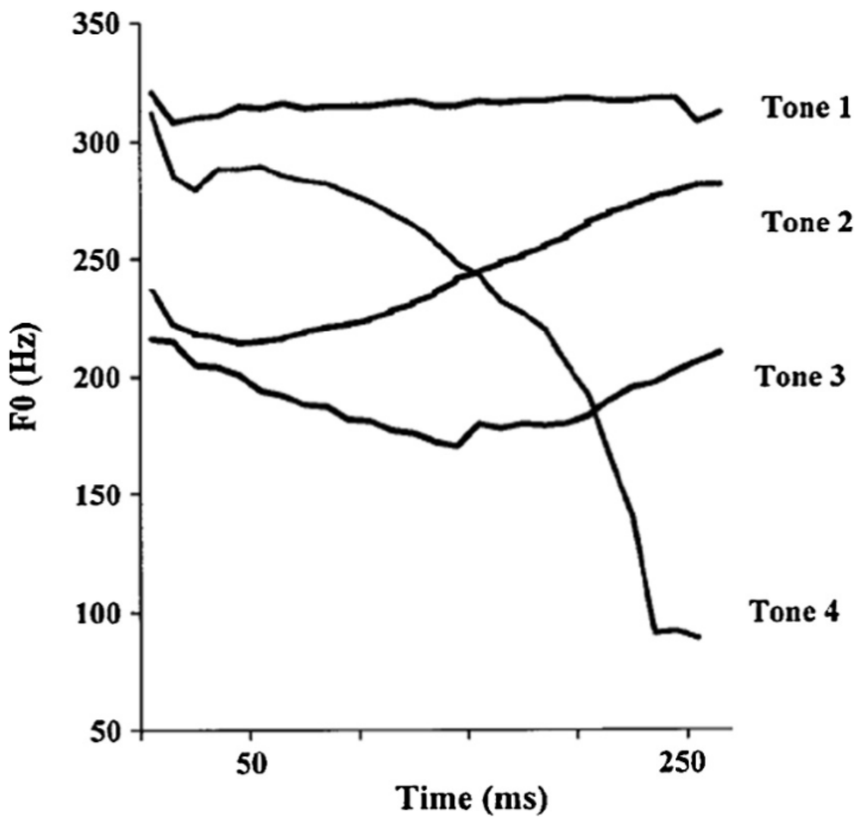

Figure 1. Tones in Mandarin Chinese (Wong et al. 2001).

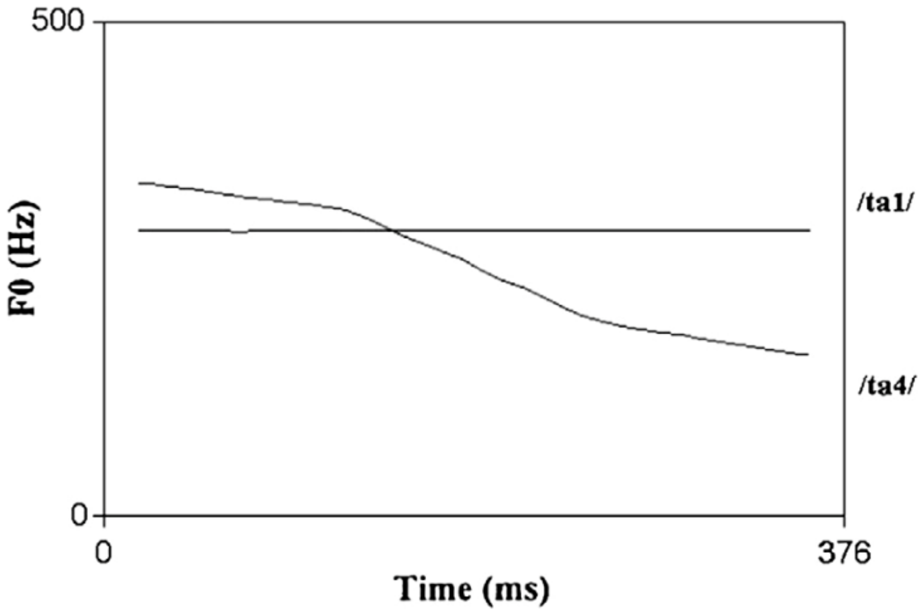

Figure 2. Pitch contour of the T1-T4 contrast (Liu & Kager, 2014).

3.3 NIRS recordings

The experiment will use two NIRS instruments, one for each hemisphere, and the measurement channels will be placed over the frontal and temporoparietal areas of each hemisphere (Homae et al., 2006). The 24 measurement channels, taken from Homae et al. (2006), are shown in Figure 3.

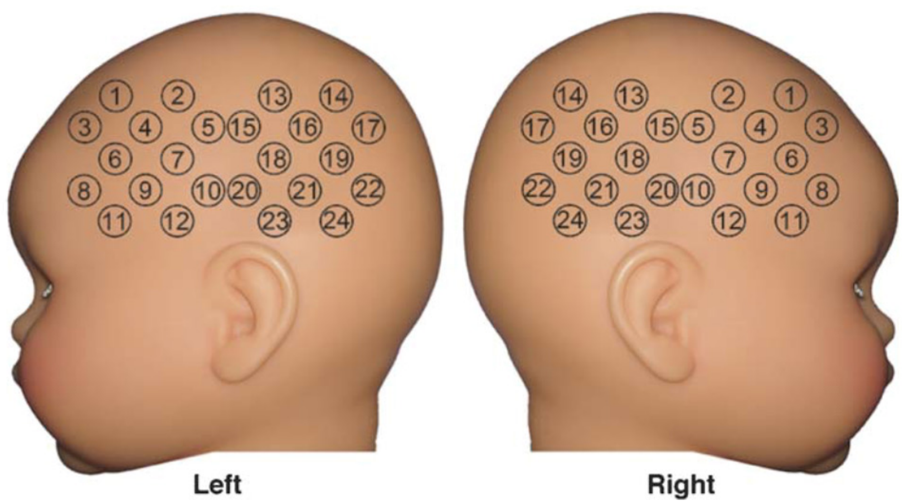

Figure 3. Measurement channels of both hemisphere (Homae et al., 2006).

3.4 Procedure

The experiment will be conducted in a soundproof room in the laboratory. The infants will be held in the caregiver's arm and brought to the laboratory while they are sleeping. The whole experiment is completed with infants in a sleeping state. T1 stimuli will first be presented consecutively for 30 seconds with 2 seconds between two T1 stimuli. T4 stimuli will then be presented for 10 seconds with 2 seconds between two T4 stimuli. The NIRS responses will be recorded before and after the presentation of T4 stimuli. The comparison between brain responses of infants listening to T1 and T4 will be analyzed subsequently.

3.5 Hypothesized results

The predictions following from this research proposal are as following::

1. 5-6-months-old infants show stronger bilateral brain responses when attending to T4 than T1, and there is no significant difference in the degrees of activation between two hemispheres;

2. 9-10-months-old infants demonstrate no significant difference in brain activation in any region for both hemispheres when listening to contrastive tone pairs;

3. Compared to listening to T1, there are stronger brain responses in the left hemisphere in 17-18-months-old infants when listening to T4 while no difference is expected in the right hemisphere. The left hemispheric activation will be mostly in frontal-parietal region, which may be areas 5 and 15 in the left hemisphere in figure 3.

4. Experiment 2: Tone in word learning

Liu and Kager (2018) investigated Dutch monolingual and bilingual (Dutch and a second non-tone language) infants' word learning ability on two novel label-object parings using syllables differing in Mandarin tones (T1 and T4), revealing that 14-15- months olds, but not 17-18-months-olds, used tone to learn words successfully. The current experiment investigates the neural mechanisms behind these behavioral findings and thus tries to accomplish purpose 2 and 3.

4.1 Participants

This experiment will include 2 age groups, at 14-15 months and 17-18 months. 30 participants will be recruited for each group with the expectation that around 10 participants' results will be excluded due to the practical reasons (e.g., crying). All participants will be Dutch monolinguals.

4.2 Stimuli

The sound stimuli will be the same as those in Experiment 1. Like the previous study by Liu & Kager (2018), a ball will be selected as the familiar stimulus, and there will be two novel objects. The picture is shown in figure 4 (Liu & Kager, 2018).

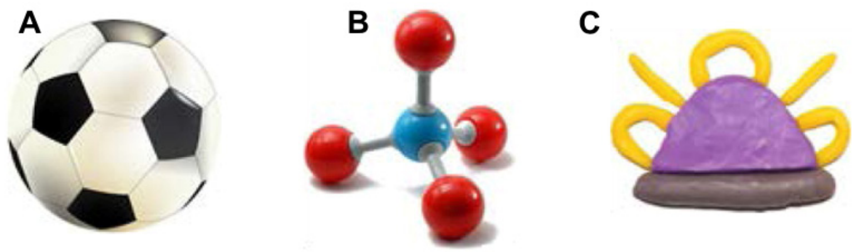

Figure 4. Pictures of familiar and novel objects (Liu & Kager, 2018).

4.3 NIRS recordings

Same as in Experiment 1.

4.4 Procedure

The infant will be held in the caregiver's arm and they will be guided to the experiment room by the experimenters. The infants will be awake during the whole experiment. The following procedures will be expected to be the same as those in Liu and Kager's experiment (2018), where a version of the label-object mapping paradigm will be adopted (Graf Estes & Hay, 2015; Hay et al., 2015). There will be 4 phases, including a pre-test, a habituation, a test and a post-test phase. A significant difference in looking time between Same and Switch trial can indicate successful novel word learning (Liu & Kager, 2018). In the pre-/post-test, the infants will see the familiar object, object A in figure 4, while listening to ten tokens of the word "ball". Then in the habituation phase, infants will be habituated by two novel objects with two Chinese Mandarin tones. During the test phase, there will be the Switch trial and the Same trial. Stimuli in the Same trial will be presented the same as in the habituation phase. In the Switch trial, the association between objects and sounds will be reversed. For example, in the Same trial if object B associates with T1 and object C with T4, in the Switch trial Object B will associate with T4 and object C with T1 and vice versa. Brain responses will be recorded during the test phase and the comparison will be carried out between the Switch and Same trial.

4.5 Hypothesized results

In line with the data previously gathered by the behavioral study (Liu & Kager, 2018), infants in the group of 14-15-months-old are expected to demonstrate that they are able to use tone in word learning, while 17-18-months-old infants are expected not to. Neurologically, the NIRS recording of 17-18-months-old infants is expected to be similar to that of the same age group in Experiment 1 (i.e., frontal-parietal activation in the left hemisphere), since this group is assumed to be able to disambiguate tones, while not using tone in word learning. In contrast, the brain responses in 14-15-months-old infants will be different from those in the older infant group. Specifically, besides the activation of regions responsible for tone discrimination (left frontal-parietal response), areas related to word learning, including bilateral temporo-parietal and subcortical regions, are hypothesized to be activated. The NIRS, however, can record responses in temporo-parietal but not subcortical regions. Therefore, the hypothesized results are:

1. the frontal-parietal regions, area 5 and 15, are expected to be activated in the left hemisphere in 17-18-months-old infants, like in Experiment 1;

2. in 14-15-months-old infants, besides areas 5 and 15 in the left hemisphere, bilateral temporo-parietal regions, areas responsible for linking meaning with tones, around 18, 19, 20 and 21 in both hemispheres, are likely to be activated.

5. Discussion

The present research proposal hypothesizes that separate brain regions are responsible respectively for lexical tone perception, intonation perception, and word learning. 5-6-months-old non-tone-language learning infants (Dutch in the current proposal) are able to differentiate tones in Mandarin, since infants at a young age have not fully tuned in to their native language. Therefore, the brain mechanism for tone disambiguation at the age of 5-6 months between tone- and non-tone-language learning infants is argued to be identical. Consequently, the first result in experiment 1 (non-tone-language learning) is assumed to be similar to the finding in 4-months-old Japanese (tone-language learning) infants (Sato et al., 2009), where not lateralized but bilateral responses may be found. The perceptual attunement for lexical tones, however, occurs at 9 months in non-tone learning infants (Mattock and Burnham, 2006; Mattock et al., 2008; Liu and Kager, 2014), and therefore 9-10-months-old Dutch monolingual infants in experiment 1 are predicted to demonstrate no significant difference in brain activation when processing contrasting lexical tones. After Dutch infants tune out of non-native lexical tonal contrasts, they tune in to their native sound system, to a stage where they are attentive to their native intonation (Chen & Fikkert, 2007). One identical feature between intonation and lexical tones is that both are modulated by pitch contours. For this reason, one possible account is that Dutch infants may start using intonation knowledge to perceive non-native tones in their second year (Chen & Fikkert, 2007). From a neural perspective, the present paper suggests that during the second year of Dutch infants, with the tuning in to their native intonation, brain areas responsible for intonation processing will be gradually activated. These areas are especially responsible for pitch processing, including the left fronto-parietal region in the previous study (Chien et al., 2020). The left fronto-parietal region for pitch processing used for native intonation, is assumed to be adopted for non-native lexical tone differentiation as well. Therefore, although Dutch groups of both 5-6 and 17-18-months-old are able to behaviorally distinguish non-native Mandarin tones (Liu & Kager, 2014), the neural basis for each group to perform the task is different. The former group is expected to demonstrate bilateral response while the latter is assumed to show left hemispheric dominance. However, the assumption from a neurological perspective supports the U-shaped pattern found in the study by Liu and Kager (2014).

Studies on tone discrimination cannot clarify whether Dutch infants perceive lexical tones psycho-acoustically or linguistically. Therefore, experiments in novel word learning like Experiment 2 were designed to exemplify that. Previous behavioral results showed that both monolingual and bilingual non-tone learning Dutch infants can use tones in word learning at the age of 14-15 months while they cannot at 17-18 months (Liu & Kager, 2014). To be in line with the behavioral difference, the research proposal assumes different neural mechanisms between two age groups when performing novel word learning tasks. Specifically, areas for word learning, where the semantic interpretation of word meaning will be involved, are suggested to be activated for 14-15-months-old infants while not for 17-18-months-old infants. The so-called semantic area is assumed to be the bilateral temporo-parietal region, in line with the adult study by Chien et al. (2020). The semantic area, however, cannot be activated for word learning using tones after infants reached the age of 17-18 months. The plausible explanation is that 14-15-months-old Dutch infants have not completed the perceptual attunement for using tone in word learning while the attunement has been obtained before 17-18 months. The explanation will be supported if the NIRS recordings in Experiment 2 turn to be what is expected.

In summary, the main hypothesis of the research proposal is that brain areas responsible for lexical tones, intonation, and word learning are separate from one another, and that this separation should correspond to non-tone-language learning infants' developmental patterns for prosody. Despite the abundance of behavioral research on tone perception in both tone and non-tone learning infants, it is crucial to provide neurological evidence to further support or modify previous assumptions, which is one of the purposes of the current research proposal. Further, the hypothesized neurological results correspond with previous studies, particularly the U-shaped developmental pattern (Liu & Kager, 2014). Also, the two proposed experiments are highly relevant to offer more insights into the learning mechanism of prosody for non-tone learning infants: before tuning out non-native contrasts, 5-6-months-old non-tone-language learning infants are able to discriminate tonal contrasts, with a similar neural pattern to same age tone learning infants. The sensitivity deteriorates at the age of 9-10 months when the perceptual attunement for tone is accomplished, and there is no brain activation for non-native tone contrasts for non-tone learning infants. The perceptual ability rebounds and 17-18-months-old non-tone learning infants adopt the brain areas activated by native intonation perception to non-native tone perception. At the age of 14-15 months, an additional semantic brain area, responsible for using tone in word learning, is expected to be activated, while the area is deactivated at the age of 17-18 months.

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References

Chen, A., & Fikkert, P. (2007). Intonation of early two-word utterances in Dutch. In 16th International Congress of Phonetic Sciences (ICPhS 2007) (pp. 315-320). Pirrot.

Chien, P. J., Friederici, A. D., Hartwigsen, G., & Sammler, D. (2020). Neural correlates of intonation and lexical tone in tonal and non-tonal language speakers. Human Brain Mapping, 41(7), 1842-1858.

Francis, A. L., Ciocca, V., Ma, L., & Fenn, K. (2008). Perceptual learning of Cantonese lexical tones by tone and non-tone language speakers. Journal of Phonetics, 36(2), 268-294.

Gandour, J., Wong, D., Hsieh, L., Weinzapfel, B., Lancker, D. V., & Hutchins, G. D. (2000). A crosslinguistic PET study of tone perception. Journal of Cognitive Neuroscience, 12(1), 207-222.

Gandour, J., Wong, D., & Hutchins, G. (1998). Pitch processing in the human brain is influenced by language experience. Neuroreport, 9(9), 2115-2119.

Graf Estes, K., & Hay, J. F. (2015). Flexibility in bilingual infants' word learning. Child development, 86(5), 1371-1385.

Hallé, P. A., Chang, Y. C., & Best, C. T. (2004). Identification and discrimination of Mandarin Chinese tones by Mandarin Chinese vs. French listeners. Journal of Phonetics, 32(3), 395-421.

Harrison, P. (2000). Acquiring the phonology of lexical tone in infancy. Lingua, 110(8), 581-616.

Hay, J. F., Graf Estes, K., Wang, T., & Saffran, J. R. (2015). From flexibility to constraint: The contrastive use of lexical tone in early word learning. Child Development, 86(1), 10-22.

Homae, F., Watanabe, H., Nakano, T., Asakawa, K., & Taga, G. (2006). The right hemisphere of sleeping infant perceives sentential prosody. Neuroscience Research, 54(4), 276-280.

Kaan, E., Barkley, C. M., Bao, M., & Wayland, R. (2008). Thai lexical tone perception in native speakers of Thai, English and Mandarin Chinese: An event-related potentials training study. BMC Neuroscience, 9(1), 53.

Kager, R. (2018). How do infants disaggregate referential and affective pitch? Frontiers in Psychology, 9, 2093.

Klein, D., Zatorre, R. J., Milner, B., & Zhao, V. (2001). A cross-linguistic PET study of tone perception in Mandarin Chinese and English speakers. Neuroimage, 13(4), 646-653.

Liu, L., & Kager, R. (2014). Perception of tones by infants learning a non-tone language. Cognition, 133(2), 385-394.

Liu, L., & Kager, R. (2018). Monolingual and bilingual infants' ability to use non-native tone for word learning deteriorates by the second year after birth. Frontiers in Psychology, 9, 117.

Maki, A., Yamashita, Y., Ito, Y., Watanabe, E., Mayanagi, Y., & Koizumi, H. (1995). Spatial and temporal analysis of human motor activity using noninvasive NIR topography. Medical Physics, 22(12), 1997-2005.

Mattock, K., & Burnham, D. (2006). Chinese and English infants' tone perception: Evidence for perceptual reorganization. Infancy, 10(3), 241-265.

Mattock, K., Molnar, M., Polka, L., & Burnham, D. (2008). The developmental course of lexical tone perception in the first year of life. Cognition, 106(3), 1367-1381.

Mugitani, R., Kobayashi, T., Hayashi, A., & Fais, L. (2019). The Use of Pitch Accent in Word–Object Association by Monolingual Japanese Infants. Infancy, 24(3), 318-337.

Nazzi, T., Bertoncini, J., and Mehler, J. (1998a). Language discrimination by newborns: toward an understanding of the role of rhythm. Journal of Experimental Psychology: Human Perception and Performance, 24, 756–766.

Nazzi, T., Floccia, C., and Bertoncini, J. (1998b). Discrimination of pitch contours by neonates. Infant Behavioural Development, 21, 779–784.

Portas, C.M., Krakow, K., Allen, P., Josephs, O., Armony, J.L., Frith, C.D., 2000. Auditory processing across the sleep–wake cycle: simultaneous EEG and fMRI monitoring in humans. Neuron 28, 991–999.

Sato, Y., Sogabe, Y., & Mazuka, R. (2007). Brain responses in the processing of lexical pitch-accent by Japanese speakers. Neuroreport, 18(18), 2001-2004.

Sato, Y., Sogabe, Y., & Mazuka, R. (2010). Development of hemispheric specialization for lexical pitch–accent in Japanese infants. Journal of Cognitive Neuroscience, 22(11), 2503-2513.

Singh, L., Poh, F. L., & Fu, C. S. (2016). Limits on monolingualism? A comparison of monolingual and bilingual infants' abilities to integrate lexical tone in novel word learning. Frontiers in Psychology, 7, 667.

Taga, G., Asakawa, K., Maki, A., Konishi, Y., & Koizumi, H. (2003). Brain imaging in awake infants by near-infrared optical topography. Proceedings of the National Academy of Sciences, 100(19), 10722-10727.

Wang, Y., Jongman, A., & Sereno, J. A. (2001). Dichotic perception of Mandarin tones by Chinese and American listeners. Brain and Language, 78(3), 332–348.

Wang, Y., Sereno, J. A., Jongman, A., & Hirsch, J. (2003). fMRI evidence for cortical modification during learning of Mandarin lexical tone. Journal of cognitive neuroscience, 15(7), 1019-1027.

Xu, Y., Gandour, J. T., & Francis, A. L. (2006). Effects of language experience and stimulus complexity on the categorical perception of pitch direction. The Journal of the Acoustical Society of America, 120(2), 1063-1074.

Yeung, H. H., Chen, K. H., & Werker, J. F. (2013). When does native language input affect phonetic perception? The precocious case of lexical tone. Journal of Memory and Language, 68(2), 123-139.