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Young infants' discrimination of subtle phonetic contrasts

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ABSTRACT

It is generally accepted that infants initially discriminate native and non-native contrasts and that perceptual reorganization within the first year of life results in decreased discrimination of non-native contrasts, and improved discrimination of native contrasts. However, recent findings from Narayan, Werker, and Beddor (2010) surprisingly suggested that some acoustically subtle native-language contrasts might not be discriminated until the end of the first year of life. We first provide countervailing evidence that young English-learning infants can discriminate the Filipino contrast tested by Narayan et al. when tested in a more sensitive paradigm. Next, we show that young infants learning either English or French can also discriminate comparably subtle non-native contrasts from Tamil. These findings show that Narayan et al.'s null findings were due to methodological choices and indicate that young infants are sensitive to even subtle acoustic contrasts that cue phonetic distinctions cross-linguistically. Based on experimental results and acoustic analyses, we argue that instead of specific acoustic metrics, infant discrimination results themselves are the most informative about the salience of phonetic distinctions.

1. Introduction

Infants' perceptual system undergoes a gradual reorganization as a result of their native language experience. In the first half of the first year of life, infants discriminate a wide range of native and non-native phonetic contrasts (Anderson, Morgan, & White, 2003; Eimas, 1974, 1975; Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Jusczyk, 1997; Streeter, 1976; Trehub, 1976; Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Tees, 1984, 1999). Language experience then serves to maintain (Anderson et al., 2003; Best, 1995; Kuhl, 1998; Tsushima et al., 1994; Werker & Tees, 1984), or enhance the perception of native language categories (Kuhl et al., 2006; Polka, Colantonio, & Sundara, 2001; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005; Sundara, Polka, & Genesee, 2006; Tsao, Liu, & Kuhl, 2006), or realign boundaries between phonetic categories (Aslin, Pisoni, Hennessy, & Perey, 1981; Burns, Yoshida, Hill, & Werker, 2007). At the same time, infants' ability to discriminate non-native contrasts declines, in some cases because one or more of the sounds are absent in the native input (Anderson et al., 2003; Kuhl et al., 2006; Werker & Tees, 1984), in others because the distributions of the phonetic forms overlap in the native language (Feldman, Myers, White, Griffiths, & Morgan, 2013). Together these developmental patterns are best explained by Attunement theories of perceptual development (Aslin & Pisoni, 1980; Aslin, Werker, & Morgan, 2002), where language experience serves to modify existing category boundaries, but not to induce them.

Recently, Narayan et al. (2010) presented a novel developmental pattern in the perception of phonetic categories. They showed that English- and Filipino-learning 6- to 8-month-olds discriminate Filipino /ma/-/na/, but not the subtle /na/-/ŋa/ contrast. Younger infants, English-learning 4- to 5-month-olds as well, successfully discriminated /ma/-/na/, but not /na/-/ŋa/. Only Filipino-learning 10- to 12-month-olds, who are exposed to /ŋ/ in syllable-initial position, the position in which infants were tested, succeeded at this task. Based on these results, Narayan et al. claim that only with language experience are infants able to distinguish subtle phonetic contrasts like Filipino /na/-/ŋa/.

Although Narayan et al.'s (2010) data clearly show that discrimination improves with language experience, their claim that such experience is *necessary* for discrimination is problematic on

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methodological grounds. Narayan et al. use a habituation procedure to test infants, but interpreting null results from habituation procedures is known to be problematic (e.g., Werker et al., 1998). Infants get one trial to demonstrate discrimination; and the novelty of the new stimulus itself is their only reward. For this reason, habituation procedures are not typically used to assess the limits of infants' discrimination abilities.

To compound matters, Narayan et al. (2010) used a non-infant-controlled procedure in which stimuli were presented for fixed periods of time, regardless of the infant's behavior. Procedures that use looking time to assess preference implicitly assume that subjects recognize a contingency between their own looking behavior and stimulus presentation. In studies of visual preference (e.g., Fantz, 1958, 1964), this is straightforward: looking away removes the stimulus from the visual field. Studies of auditory preference face additional complications: in everyday life, averting one's gaze does not cause sound to stop. As a result, a variety of procedures have been devised to facilitate infants' understanding of within-experiment contingencies between looking and auditory stimuli. For example, in conditioned head turn procedures (Werker, Polka, & Pegg, 1997), looking *while* hearing a particular stimulus is required for reinforcement, whereas in infant-controlled preference procedures, the auditory stimuli for a trial stop shortly after the infant looks away from a central screen. By contrast, in non-infant-controlled procedures there is no such facilitation. Under such conditions, some infants may grasp the contingency, and others may not. A failure by some infants to learn the contingency is likely to yield significant differences for robust effects but not more subtle ones.

Narayan et al.'s (2010) claims are also problematic for theoretical reasons. A developmental time course where the ability to distinguish certain contrasts is induced by language experience is *prima facie* consistent with Learning theories of perceptual development (Aslin & Pisoni, 1980; Aslin et al., 2002). However, Narayan et al. claim that their findings support Attunement theories. They do so by arguing that infants are initially sensitive to coarse but not fine differences in a two-dimensional acoustic space and refine these abilities only with language experience. This initial coarse sensitivity allows them to discriminate /ma/-/na/ but not the subtle /na/-/ŋa/ contrast. Thus, Narayan et al. blur the distinction between Perceptual Learning and Attunement theories.

In Experiment 1, we reassess Narayan et al.'s (2010) claim that young infants are unable to distinguish /na/-/ŋa/ without language experience. In Experiment 2, we test young infants on two additional subtle phonetic contrasts - dental vs. retroflex place differences for nasals (/n̪/-/ɳ/) and laterals (/l/-/ɭ/). Our results show that 6-month-olds successfully discriminate all three subtle phonetic contrasts, even in the absence of language experience. Our findings are best explained by Attunement Theories where language experience serves to maintain or modify existing categories, but not to induce them. Nonetheless, these contrasts are not equally easy for infants to discriminate (see also Aslin et al., 2002). In Experiment 3, we explore alternative ways to compare the psychoacoustic salience of contrasts.

2. Experiment 1

In Experiment 1, we tested the hypothesis that the younger infants tested by Narayan et al. (2010) failed due to methodological reasons. Like Narayan et al. we used visual habituation; however, its implementation was different in three ways. Most importantly, we used a fully infant-controlled paradigm unlike Narayan et al.'s implementation, which was not contingent on infant looking. To provide greater opportunity for infants' understanding of the looking-hearing contingency, we used a more stringent habituation criterion (50% vs. 60%). We also included longer habituation trials (19 s vs. 14 s), more tokens (15 vs. 9) and a somewhat shorter ISI (800 ms vs. 1000 ms). We tested English-learning 6-month-olds as well as 4-month-olds on Narayan et al.'s stimuli.

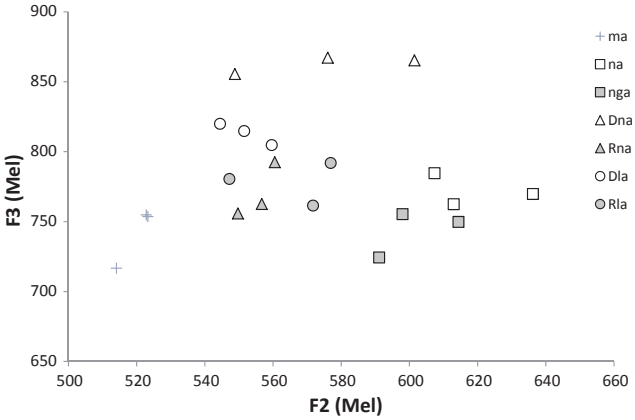

Fig. 1. F2 and F3 frequencies measured at consonant-vowel juncture for dental (*Dna, Dla*) and retroflex (*Rna, Rla*) Tamil nasals and laterals. Additionally, the nasals (*ma, na, nga*) from Narayan et al.'s study are presented for reference.

2.1. Materials and methods

2.1.1. Participants

Two groups of English-learning infants, 22 4-month-olds (12 girls, mean age: 4;10, range: 3;21–4;27) and 22 6-month-olds (11 girls, mean age: 6;0, range: 5;12–6;21) participated in the study. Only infants with at least 90% exposure to English on a parental language questionnaire were included. English-learning 4-month-olds had an average of 99.5% exposure to English. The other language these infants were exposed to was Spanish (6) or Hungarian (1). English-learning 6-month-olds had an average of 98.4% exposure to English. The other language(s) these infants were exposed to was Spanish (3), Farsi (2), Italian (1) or Filipino (1). Eleven additional infants were tested but excluded because the parent moved the infant out of camera view (2), fussiness/crying (5), never looking at the screen (1), not habituating in 25 trials (1) or not dishabituating to the post-test trial (2).

2.1.2. Stimuli

Three tokens each of /na/ and /ŋa/ produced by the female Filipino speaker used by Narayan et al. (2010) served as stimuli for this experiment. The acoustic properties of these syllables are presented in Fig. 1. We generated 19-s stimulus files, each containing five instances of the three exemplars in random order (15 tokens) with an average inter-stimulus-interval (ISI) of 801 ms (range 649:958).

2.1.3. Procedure

Infants sat on their caregiver's lap facing a monitor in a soundproof booth. Loudspeakers were located below the screen on each side, and a video camera filmed the infant's behavior. An experimenter observed the infant from an adjacent control room on a monitor connected to the camera. Stimulus presentation was controlled by Habit X (Cohen, Atkinson, & Chaput, 2004).

A fully infant-controlled version of the visual fixation procedure (Sundara & Scutellaro, 2011; Werker et al., 1998) was used to test infants. At the beginning of each trial, a looming bulls-eye appeared on the monitor to attract the infant's attention. Once the infant looked at the attention-getter, a black-and-white checkerboard appeared, accompanied by auditory stimuli. Infants' listening time was recorded manually on-line. Trial length was infant-controlled, ending when the infant looked away from the screen for more than one second or at the end of the trial (max = 19 s). Trials with listening times less than two seconds were repeated. The attention-getter reappeared at the beginning of each new trial. Throughout testing, the caregiver and the experimenter listened to music over sound-attenuating headphones.

The experiment comprised four phases: pre-test, habituation, test, and post-test. Pre- and post-tests consisted of a single trial in which

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