1264

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Discussion

Revealing the mother tongue's nurturing effects on the infant ear

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It is an honor and a pleasure to offer my reflections on Werker and Tees' (1984) landmark report about language environment influences on infant speech perception. The paper stands as a model of research design, from its careful stimulus development, to its thoughtful adaptation of testing procedures, to its inclusion of both cross-sectional and longitudinal data. More important, however, is the substantive impact it has had on research and theory in early speech/language development. Its basic finding has become a widely-accepted developmental fact: the language environment dramatically affects infants' perception of non-native phonetic contrasts by sometime in the second half-year of life. Numerous studies in Werker's and other labs have extended this line of investigation to other non-native consonant and vowel contrasts. Those findings, in turn, have led to a deeper, more refined understanding of the developmental pattern, and to the positing of several theoretical accounts of experiential effects in infant speech perception. From a broader, retrospective view, their report has played an instrumental role in the shift of infant speech research from the preceding near-exclusive focus on inborn, universal phonetic abilities, to the complementary emphasis on infants' dawning recognition of key properties of the ambient language which remains at the core of much contemporary investigation on the early ontogeny of language. All the more remarkable, Werker was still a graduate student when she put together an infant speech perception lab to pursue with Tees this insightful extension of his work on the effects of early experience on basic visual and auditory perception.

Here is the historical context that set the stage for their research. From the first, highly influential report on infant speech perception (Eimas, Siqueland, Jusczyk, & Vigorito, 1971) through the mid-1980's, the primary goal of researchers was to identify which phonetic perception

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abilities are innately specified, and what sorts of mechanisms could account for them (i.e., specialized linguistic mechanisms vs. general auditory mechanisms). On the methodological side, the vast majority of studies employed computer-synthesized speech, which allowed precise control of stimulus acoustic features. In addition, regardless of whether the stimuli were synthetic or (more rarely) natural, the standard approach was to test discrimination between a single token of one type and a single token of another type, i.e., the tasks and stimuli tended to tap into low-level or acoustic-based discrimination. An important departure from single-token discrimination was introduced by Kuhl (1979) when she began studying perceptual constancy in infants' responses to contrasting phonetic categories, i.e., their ability to recognize the common category membership among multiple tokens of a phoneme despite clearly audible variations in speaker (man, woman, child) and/or in fundamental frequency (vocal pitch). Kuhl's innovation influenced Werker and Tees' decision to employ multiple tokens of their contrasting stimulus categories, thus tapping into some degree of perceptual constancy in infants' performance, both in the 1984 paper and in the preceding reports that served as its foundation (Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Tees, 1983).

As for the language experience issue, only a handful of studies at the time had presented infants with non-native phonetic contrasts. A couple of these had used natural stimuli (Eilers, Gavin, & Oller, 1982; Trehub, 1976), but most stimuli were synthetic (Eilers et al., 1982; Eimas, 1975; Lasky, Syrdal-Lasky, & Klein, 1975; Streeter, 1976). Either way, all had employed single-token discrimination, and none had directly assessed developmental change (i.e., each examined only one age group). Indeed, very few infant speech perception studies of any sort had compared multiple ages (and even some more recent claims for developmental effects of experience are based on a single age group: e.g., Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). More importantly, however, most of the studies had been designed to address innate phonetic perception abilities, had tested infants 6 months or younger, and had found that the non-native contrasts were discriminated. Thus, the general conclusion was that the findings favored the view that infants' ability to perceive phonetic distinctions is universal and innate. Exceptions to this conclusion came from two reports that 6–8-month-old Spanish-learning infants discriminated Spanish (and Czech) voicing contrasts better than English-learning infants (Eilers, Gavin, & Wilson, 1979; Eilers et al., 1982), which concluded that language experience may be necessary to *induce* discrimination of at least some contrasts. Unfortunately, however, several serious concerns were raised about certain of their methodological and analytical techniques, and it was argued that the evidence was insufficient to reject the notion that universal speech perception abilities are innate (Aslin & Pisoni, 1980a; Jusczyk, Shea, & Aslin, 1984).

It was within this context that Werker and Tees brought together their interest in early experiential effects, and shrewd insights about empirical and methodological factors, to undertake a systematic examination of developmental change in infants' perception of non-native consonant contrasts. Their focus on experiential influences instead of innate perceptual abilities helped to change the field's direction, moving it toward questions about infants' discovery of structure and meaning in native speech. To be sure, as Werker and Tees (1984) acknowledge, there were already signs of readiness for a shift in the zeitgeist (see, especially, Aslin & Pisoni, 1980b) even at the time of their first report (Werker et al., 1981). Yet, importantly, they

recognized the timeliness of the issue, and were well-prepared to move it forward. They did so with careful consideration of the key factors necessary to forge an elegant, systematic series of experiments.

Logically and methodologically, the research was a beautifully designed key step in a systematic line of inquiry. In their initial report, Werker et al., 1981 provided the first developmental extension of the classic finding that adults have difficulty in discriminating non-native phonetic contrasts (e.g., Abramson & Lisker, 1970; MacKain, Best, & Strange, 1981; Miyawaki et al., 1975). They found that English-speaking adults had difficulty discriminating two Hindi consonant contrasts that Hindi-speaking adults predictably discriminated quite well, yet that 6–8-month-old English-learning infants discriminated both Hindi contrasts. Their next report addressed whether the implied developmental decline in discriminability of the non-native Hindi contrasts occurred sometime between 4 and 12 years of age (Werker & Tees, 1983). The answer was no—by 4 years, English-speaking children were already failing on discrimination of the Hindi contrasts. Therefore, it appeared that the language environment begins to affect non-native speech perception even earlier, sometime between 6 months and 4 years.

To follow up, Werker and Tees began the research for their 1984 paper judiciously, first evaluating whether their finding of *good* discrimination at 6–8 months would generalize to a different type of consonant contrast from an unrelated non-native language. Consultation with linguistics colleagues led them to the rare contrast between velar and uvular ejective stops, found in a native language of south-central British Columbia known as Thompson Salish to linguists, but as Nthlakampx to its speakers. The authors tested this contrast on English-learning 6–8-month-olds and English- vs. Nthlakampx-speaking adults (using an adaptation of the infant procedure). Their earlier findings with the Hindi contrasts were replicated: few English-speaking adults were able to discriminate the Nthlakampx consonants, but nearly all of the infants did so, as did all the Nthlakampx-speaking adults. So Werker and Tees titrated their developmental investigation downward for the next experiment. When extensive pilot testing revealed that the perceptual change was probably in place before 12 months, they focused on the 6–12-month period. They presented the Nthlakampx contrast and their Hindi dental-retroflex stop contrast to groups of 8–10 and 10–12-month-old English-learning infants, and to the few 10–12-month-old Hindi- and Nthlakampx-learning infants they could locate and recruit to the lab. Comparing these results against their earlier 6–8-month and adult findings, they found that the decline in discrimination of both non-native contrasts was clearly underway by 8–10 months and virtually complete by 10–12 months, except for infants learning those two languages. Cautious to the end, Werker and Tees then re-ran the study longitudinally with a new group of English-learning infants, tested three times between 6–8 months and 10–12 months of age, to insure that the developmental change was real and robust even within-subjects. It was.

Werker and Tees' care with key methodological details of the investigation surely contributed to the clarity of their findings, and set a high standard for cross-language infant speech research. As in their first two papers, the authors employed multiple natural tokens of each stimulus category, reasoning that multiple natural tokens would better approximate normal language learning conditions than do single-token discrimination tests, especially those with synthetic stimuli. They recorded several native speakers, and conducted acoustic analyses to determine the one

for whom they could best select several well-matched tokens of each syllable. They did crucial waveform editing to assure that vowel color did not differentiate the contrasting syllables. This stimulus approach has been followed in many subsequent studies by researchers working on nonnative speech perception in infants and adults (e.g., Best, McRoberts, & Goodell, 2001; Best, McRoberts, & Sithole, 1988; Bohn & Polka, 2001; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Polka, 1992; Polka, 1994; Polka, Colantonio, & Sundara, 2001). In addition, Werker and Tees adapted the conditioned headturn (HT) procedure (see Eilers, Wilson, & Moore, 1977; Kuhl, 1979) to control for infant bias by randomly manipulating the timing of test, or category-change, trials. This, and the establishment of tight experimental control during the conditioning phase, allowed them to present 10 change trials per infant, and thus to determine each individual's discrimination by binomial tests of the change trial performance. Another critical innovation was their inclusion of tests with a native consonant contrast before and after the non-native test, to assure that failures on the non-native contrast were not due to flagging attention or inability to perform the HT task. Finally, their comparison of both cross-sectional and longitudinal data (a classic recommendation that is seldom followed in infant perception research) laid to rest any potential concern that age differences in performance might be biased by the fact that task completion rates had differed between the older and the younger cross-sectional groups of infants.

It is not surprising that Werker and Tees' (1984) report has had a strong impact in research on infant speech perception and early language development. It certainly was central to my own work, sparking research on infants' and adults' perception of another set of rare contrasts, the click consonants of Zulu (Best, 1988; Best, 1999; Best & Avery, 1999). That and subsequent research led me to develop the Perceptual Assimilation Model (PAM) of non-native speech perception (Best, 1993, 1994, 1995), which complements Werker's theoretical framework (see, e.g., Werker & Pegg, 1992). Werker and Tees' (1984) findings also helped pave the way for Jusczyk's shift of focus from universal speech perception abilities (e.g., Jusczyk, Copan, & Thompson, 1978; Jusczyk, Pisoni, Reed, Fernald, & Myers, 1983; Jusczyk & Thompson, 1978) to language-environment effects (e.g., Jusczyk, 1997; Jusczyk et al., 1993; Jusczyk, Luce, & Charles-Luce, 1994), and for Kuhl's cross-language research (Kuhl et al., 1992) and Native Language Magnet (NLM) model (Kuhl, 1993). The line of cross-language speech perception research has also inspired a number of younger researchers. More generally, Werker and Tees' findings are among the set that helped open the gateway for efforts over the past decade to identify the contributions of native-language phonological and prosodic properties to emerging word recognition, as well as to responsiveness to correlates of linguistic structure (e.g., morphological, syntactic).

To conclude, there are risks to "thinking outside the box" of current wisdom, in science as elsewhere. Your results may be null or uninterpretable; positive findings may be disbelieved or rejected; in any case, a high investment of time and resources are often required without assurance of a publishable outcome. The risks can be reduced, though not eliminated, by pilot testing and careful research design. Werker and Tees' (1984) research did benefit from that sort of care, and the impact of their findings on the field was well worth the risks. Their paper has become a classic, with citations increasing over time.[1] Hats off and thanks to Werker and Tees for launching a very fruitful research path, which still touches investigations of infants' early progression into the wonders of language!

Note

1. A respectable 22 citations had accumulated by 1987, yet the rate had increased to 21 per year for 1999 and 2001. Thanks to Doug Whalen for supplying this information.

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