Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning

Patricia K. Kuhl*, Feng-Ming Tsao, and Huei-Mei Liu†

Center for Mind, Brain, and Learning, and Department of Speech and Hearing Sciences, University of Washington, Mailstop 357920, Seattle, WA 98195

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Infants acquire language with remarkable speed, although little is known about the mechanisms that underlie the acquisition process. Studies of the phonetic units of language have shown that early in life, infants are capable of discerning differences among the phonetic units of all languages, including native- and foreign-language sounds. Between 6 and 12 mo of age, the ability to discriminate foreign-language phonetic units sharply declines. In two studies, we investigate the necessary and sufficient conditions for reversing this decline in foreign-language phonetic perception. In Experiment 1, 9-mo-old American infants were exposed to native Mandarin Chinese speakers in 12 laboratory sessions. A control group also participated in 12 language sessions but heard only English. Subsequent tests of Mandarin speech perception demonstrated that exposure to Mandarin reversed the decline seen in the English control group. In Experiment 2, infants were exposed to the same foreign-language speakers and materials via audiovisual or audio-only recordings. The results demonstrated that exposure to recorded Mandarin, without interpersonal interaction, had no effect. Between 9 and 10 mo of age, infants show phonetic learning from live, but not prerecorded, exposure to a foreign language, suggesting a learning process that does not require long-term listening and is enhanced by social interaction.

Language acquisition poses profound questions about the human mind and brain that have prompted an ongoing debate (1). Recently, experimental studies on young infants suggest a new view of the language acquisition process that goes beyond classic theories.

Studies show that, during the first year of life, infants acquire detailed information about the regularities of their native language (2–5). Moreover, there is increasing evidence that infant learning relies on sensitivity to the statistical properties contained in language input. By 6 mo, infants recognize native-language phonetic categories based on the distributional characteristics of the speech they hear (6, 7). Between 6 and 8 mo, infants segment words from ongoing speech by detecting transitional probabilities between syllables (8, 9) and extract the arithmetic regularity of syllable combinations from sentences (10). At 9 mo of age, infants are sensitive to the phonotactic rules governing words, responding to the probability of occurrence of phonetic sequences (11, 12). By the end of the first year of life, infants' perception of speech has been dramatically altered by exposure to their native language.

Exposure to a particular language has another consequence: it reduces sensitivity to foreign-language speech. At the phonetic level, exposure to a specific language reduces infants' abilities to discriminate foreign-language speech sounds. Early in life, infants readily discern differences among the phonetic units used in the world's languages (13, 14); as adults, we no longer do so (15, 16). The change occurs early in development; infants' abilities to discriminate foreign-language phonetic units decline sharply between 6 and 12 mo of age (17, 18). This transition is well documented but thus far unexplained.

Recent data show that during the same 6- to 12-mo period, there is a significant increase in native-language speech perception performance, indicating that phonetic development involves growth rather than the simple maintenance of phonetic abilities (19). Kuhl *et al*. (19) have argued that the decline in infants' foreign-language perception is directly related to native-language learning, proposing that exposure to a specific language results in "neural commitment" to the acoustic properties of that language. Neural commitment to the native language interferes with foreign-language processing, causing difficulty in foreign-language speech perception in infancy and adulthood (20, 21). On this view, infants are better than adults at acquiring a second language, because the native-language learning process, and thus neural commitment to its patterns, is incomplete.

The goal of the present experiments was to examine foreign-language phonetic learning in infancy. Because young children can acquire more than one language, we assume that the decline in foreign-language speech perception is not inevitable but preventable by exposure to a foreign language. Unknown, however, is when, how much, and what kind of foreign-language experience is necessary. Long-term exposure would produce a large statistical sample of speech stored in memory, which may be required. Alternatively, short-term experience during a period of neural readiness may be sufficient.

A second issue investigated in the present experiments is whether phonetic learning during this period is enhanced by social interaction. There is evidence in other species, such as songbirds, that learning is enhanced by social interaction (22). In humans, it has been argued that social interaction is critical for language learning (23), but few experimental data exist to test the hypothesis.

The present experiments address these two questions. In Experiment 1, we examined whether exposure to ≈5 h of natural infant-directed Mandarin Chinese between 9 and 10 mo of age is sufficient to reverse the decline typically seen in foreign-language phonetic perception. A control group also experienced 5 h of natural language but heard only English. The age of 9 mo was chosen to begin exposure, because infant studies show that the decline in foreign-language phonetic perception is well underway by this time (18). The results of Experiment 1 confirmed the hypothesis: infants exposed to Mandarin reversed the decline in Mandarin phonetic perception shown in the English control group. In Experiment 2, we tested whether social interaction contributed to learning. The same foreign-language material was presented to American 9-mo-old infants using either auditory-visual (AV) or auditory-only (A) DVDs. The results of Experiment 2 provided no evidence of phonetic learning, suggesting an important role for social interaction in early language learning, perhaps analogous to the role social interaction plays in avian song learning.

Abbreviations: HT, head-turn; AV, auditory-visual; A, auditory-only.

*To whom correspondence should be addressed. E-mail: pkkuhl@u.washington.edu.

†Present address: Department of Special Education, National Taiwan Normal University, Taipei 106, Taiwan, Republic of China.

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Experiment 1

Methods and Materials. ***Participants.*** The participants were 32 full-term infants, assigned randomly to one of two groups: 16 (eight boys) to the Mandarin exposure group and 16 (eight boys) to the English control group. Criteria for infant participants included: (*i*) English as the only language spoken in the household; (*ii*) no known physical, sensory, or mental handicap; (*iii*) gestational age at birth at 40 ± 3 weeks; and (*iv*) birth weight between 5.5 and 10 lb. The mean age of infant participants when the language exposure sessions began was 9.3 mo (=282.71 days) (range = 275–314 days) for the Mandarin exposure group and 9.3 mo (=284.59 days) (range = 265–319 days) for the English control group. Of the 32 infants who began the exposure sessions, 21 completed all 12 of the exposure sessions and the behavioral testing (10 in the Mandarin exposure group and 11 in the control group).

Language exposure sessions. Infants took part in 12 language sessions, each 25 min in duration, scheduled over a 4-wk period. During these sessions, native speakers of Mandarin (or English) read from children's books for 10 min and played with toys for 15 min using prescribed materials. Children's storybooks were translated into Mandarin for the reading period, and various toys (puppets, a train, and ring stacks) were provided for the adults to use during the play period. The same materials were used to interact with infants during each session. Four native Mandarin (or English) speakers (both male and female) took turns conducting the language sessions so that infants were exposed to a variety of speaking styles over the 12 sessions.

The language exposure sessions (both Mandarin exposure and English control) were designed to mimic natural adult–infant interactions. The speakers used infant-directed speech, or "motherese" (24–26), which infants prefer when given a choice (27, 28). Infant-directed speech has a higher pitch, extended intonation contours, and exaggerated phonetic cues (29). In computer modeling tests, infant-directed speech has been shown to be a more effective signal from which to learn phonetic categories when compared with adult-directed speech (30).

During the sessions, infants sat on a blanket in a sound-treated room, in groups of one to three, about 3 ft from the speaker. Speakers made frequent eye contact with infants and used each infant's name during the sessions. Mothers sat in the room during the exposure sessions but did not interact with their infants. Word counts of the recorded natural language sessions revealed that infants heard between 25,989 and 42,184 Mandarin Chinese syllables (M = 33,120) over the course of the 12 sessions.

Mandarin Chinese test stimuli. After completion of the 12 exposure sessions, infants were tested by using a computer-synthesized version of a Mandarin Chinese phonetic contrast that does not occur in English, an alveolo-palatal affricate (/tɕʰ/) and an alveolo-palatal fricative (/ɕ/). Spectrographic depictions of the two syllables are shown in Fig. 1. The two syllables were 375 ms in duration; had identical steady-state vowel formant frequencies of 293, 2,274, 3,186, and 3,755 Hz, respectively; bandwidths of 80, 90, 150, and 350 Hz, respectively; and a fundamental frequency of 120 Hz (high-flat tone, Tone 1 in Mandarin). The syllables differed only in the point of maximum rise in amplitude during the initial 130-ms frication portion. The affricate consonant had a fast amplitude rise, with maximum amplitude occurring at ≈30 ms; the fricative consonant had a slower amplitude rise time, with maximum amplitude occurring at ≈100 ms. Tokens were equalized in rms amplitude and played to infants at a comfortable listening level of 65 dBA. Mandarin native-speaking adults show near perfect discrimination of these two computer-synthesized Mandarin sounds, whereas American English native speakers are significantly worse (19). Syllable counts of the exposure sessions showed that among the natural syllables infants heard during the exposure sessions, the two Mandarin syllables accounted for 6.5% (range = 5.5–7.2%).

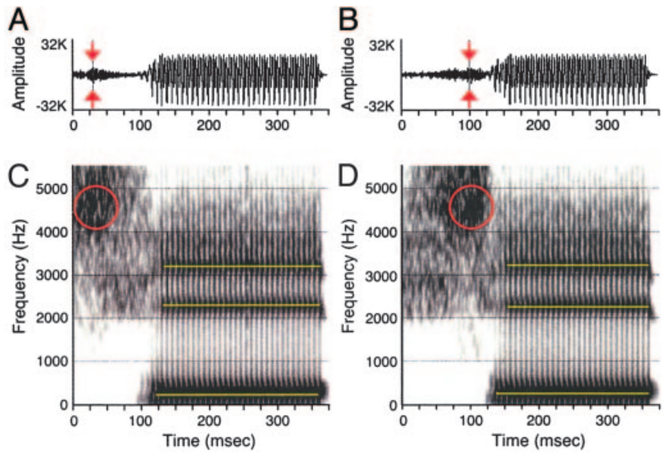

Fig. 1. Two Mandarin Chinese consonant-vowel syllables used to test infant learning in Experiments 1 and 2, an affricate (*A* and *C*) and a fricative (*B* and *D*) syllable. Waveforms (*A* and *B*) show amplitude over time, and spectrographic representations (*C* and *D*) show frequency over time. The syllables have identical vowel formant frequencies (indicated in yellow) and differ only in the time at which maximum amplitude is reached during the initial 130-ms frication portion of the syllables (marked with red arrows on the waveforms and red circles on the spectrograms).

Phonetic perception test. A head-turn (HT) conditioning procedure frequently used in tests of infant speech perception (31) was used to test infants' Mandarin speech discrimination. To ensure that both groups of infants were equally good at discriminating a native phonetic contrast, HT tests were also conducted using an American English/ra-la/contrast.

In the HT test, infants were trained to produce a HT when they heard a change from a repeating background sound (the fricative/ɕ/) to the target sound (the affricate/tɕʰ/). During change trials, the background sound changed to the target sound for a 6-sec period; HT responses during this period were reinforced with a 5-sec presentation of a mechanical toy (a bear pounding a drum or a monkey playing cymbals). During control trials, no sound change occurred, and infants' HTs were monitored. On change trials, HTs were scored as "hits," and a failure to turn was scored as a "miss;" on control trials, HTs were scored as "false alarms," and failure to turn was scored as a "correct rejection." Several controls were designed to prevent bias: (*i*) trial selection and all contingencies were under computer control; (*ii*) the experimenter (who judges HTs on-line) wore headphones that were deactivated during trials so the stimulus could not be heard, preventing scoring bias; and (*iii*) the parent and the assistant wore headphones and listened to music that masked the speech to prevent them from influencing infants' responses.

The HT procedure consisted of two phases: conditioning and test. In the conditioning phase, only change trials were run, so that infants learned the association between a change in the sound and the presentation of the visual reinforcer. During conditioning, the target sound was initially presented at a louder level than the background sound (+4 dB sound pressure level) to alert infants to the sound change, and the reinforcer was automatically activated after two target sounds were presented so the infant learned to associate a change in the sound with the reinforcer. After two consecutive correct HTs that anticipate the presentation of the toy, the intensity cue was removed. After three consecutive anticipatory HTs with no intensity cue, the test phase began.

In the test phase, both change and control trials occurred at 0.5 probability, with the restriction that no more than three

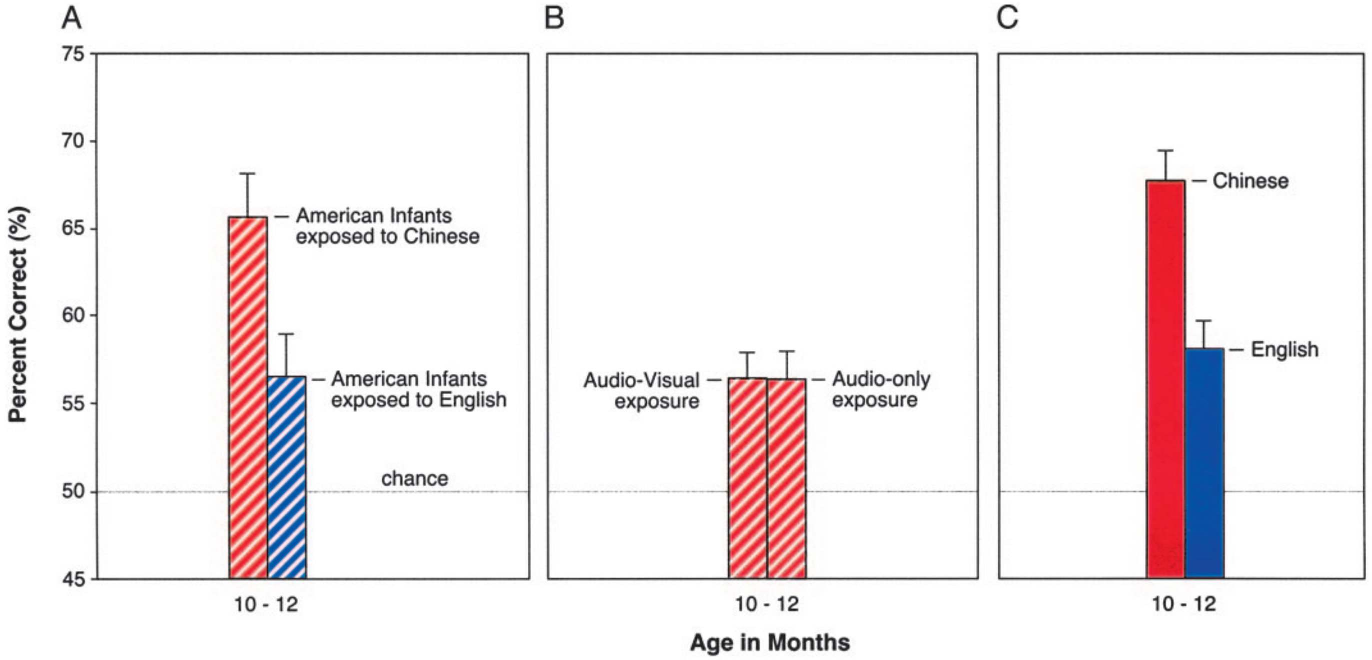

Fig. 2. (*A*) Experiment 1. Effects of live foreign-language intervention in infancy. Mandarin Chinese speech discrimination tests conducted on infants after exposure to Mandarin Chinese (red stripes) or American English (blue stripes) show significant learning for the Mandarin-exposed infants when compared with the English controls. (*B*) Experiment 2. Mandarin Chinese foreign-language exposure in the absence of a live person (AV or A) shows no learning. (*C*) Results of the same Mandarin speech discrimination tests on monolingual Mandarin-learning (red) and English-learning (blue) infants.

consecutive trials of one type could occur. The test phase continued until 30 trials were complete. Using signal-detection analysis methods, the data were used to calculate a percent correct measure [=(hit% + correct rejection%)/2] and a sensitivity index, d' [$= z(\text{hit}) - z(\text{false alarm})$].

Attention scores. Each infant's visual attention during the 12 exposure sessions was scored on a five-point scale (1 = inattentive, 5 = very attentive) by an assistant observing the infants via video monitor outside the soundproof booth. The rater coded the degree to which the infant focused attention on the foreign-language speaker or the books or toys the speaker used.

Results. The results demonstrate that live exposure to Mandarin Chinese at 9 mo of age reverses the decline typically seen in foreign-language speech perception, a decline experimentally verified by the English control group. The results demonstrate the effects of foreign-language intervention (Fig. 2*A*).

Performance on the Mandarin phonetic contrast differed significantly for infants in the Mandarin exposure ($M = 65.7\%$, $SE = 2.40$) and English control groups ($M = 56.7\%$, $SE = 2.29$), F (1, 19) = 7.34, $P < 0.05$. The same pattern of results was seen using the d' measure. Performance on the American English /ra-la/contrast did not differ for the Mandarin exposure and English control groups ($P > 0.10$), indicating that the two groups of infants were equally skilled at native-language phonetic perception. The attention scores demonstrate that infants in the Mandarin ($M = 3.53$, range = 2.71–4.00) and English ($M = 3.59$, range = 2.94–4.06) groups were highly attentive, and that their scores did not differ significantly ($P > 0.10$).

The current results can be compared with our previous findings of similarly aged children tested in Taiwan, who had been raised listening to their native Mandarin language (Fig. 2*C*) (19). The previous research compared Mandarin speech discrimination in Chinese and American infants tested in their home countries. The same experimenters, using the same Mandarin stimuli, conducted the study, allowing a direct comparison. The results show that performance of the American infants exposed to Mandarin in the present study was statistically equivalent to that of infants tested in Taiwan who had listened to Mandarin their entire lives, $t(57) = 0.67$, $P > 0.10$.

Additional analyses reveal that learning in the current experiments was not short-lived. There was a substantial range in the delay between an individual infant's last language exposure session and the test of Mandarin phonetic discrimination. Infants returned to the laboratory for their discrimination tests between 2 and 12 days after the final exposure session, with a median of 6 days intervening between final exposure and test. This allowed us to examine whether longer delays resulted in poorer discrimination performance. Infants were divided into two groups on the basis of whether their test took place before or after the median delay in days between exposure and test. The results showed that there were no significant differences between discrimination performance based on the length of time between exposure and test (Mann–Whitney U test = 6.50, $P > 0.10$).

Discussion. The results of Experiment 1 confirmed the hypothesis that foreign-language intervention at 9 mo of age would alter phonetic perception for a phonetic contrast of that language. Exposure to infant-directed speech by four speakers of Mandarin in 12 sessions between 9 and 10 mo of age was sufficient to reverse the decline seen in the English control group, a decline typically observed in the absence of experience for foreign-language phonetic contrasts. The American infants exposed to Mandarin Chinese performed at a level comparable to that of infants raised in Taiwan and significantly better than infants in the English control group who were not exposed to Mandarin. The finding suggests that short-term exposure to a foreign language is sufficient to induce learning at 9 mo of age.

Experiment 1 established a sufficient condition for altering the typical course of foreign-language speech perception in infants. The ease with which infants learned from foreign-language exposure in Experiment 1 raises a question about the learning process: Is phonetic learning simply triggered by auditory exposure to a natural language?

Previous research on statistical learning, including studies on phonetic learning, indicates that infants can learn from audio-only exposure when exposure consists of a small number of artificial language stimuli (7–9). However, the current experiment offers a far greater challenge for infants. In the present case, infants are exposed to tens of thousands of syllables embedded in natural language spoken by a range of speakers, with no isolation of the test sounds. We hypothesized that under this natural and more complex learning situation, social interaction would play a role in learning. Experiments show, for example, that an infant turning to follow an adult's line of regard, "gaze following" (32), is a predictor of an infant's social awareness and future language performance (33, 34).

In Experiment 2, we tested whether the presence of a live person is critical to phonetic learning in our experimental situation. The same foreign-language material was presented to infants via studio-quality DVDs that consisted of either AV or A information. Experiment 2 thus tested foreign-language learning in a "passive listening" situation, comparing the results with those of Experiment 1, which involved more "active listening," holding all other factors constant.

Experiment 2

Experiment 2 examined the role of social interaction in phonetic learning from a foreign language. If phonetic learning is triggered solely by linguistic input, then exposure to language material via DVD (AV or A) should result in learning. Alternatively, if learning from complex natural language exposure in humans is enhanced by social interaction, as it is in song learning for certain avian species, then exposure without human interaction may not be sufficient to induce phonetic learning.

Methods and Materials. ***Participants.*** The participants were 32 full-term infants, assigned randomly to one of two groups, 16 (eight boys) in each. Both groups were exposed to Mandarin Chinese, one via A and the other via AV input. Criteria for infant participants were identical to Experiment 1. The mean age of infant participants when the language exposure sessions began was 9.29 mo (=278.94 days, range = 272–287 days) for the AV group and 9.30 mo (=279.06 days, range = 273–287 days) for the A group. Of the 32 infants who began the exposure sessions, 28 completed all of the exposure sessions and the behavioral testing (15 in the AV group and 13 in the A group).

Language exposure sessions. As in Experiment 1, each infant took part in 12 language exposure sessions, each 25 min in duration, scheduled over a 4-wk period. During these sessions, 16 infants in the AV group received foreign-language exposure from DVD movies on a 17-in Panasonic (Seacaucus, NJ) television with both an audio and video signal. The 16 infants in the A group received foreign-language exposure via A exposure to the DVD movies.

The DVD movies provided studio-quality images and sound and were professionally produced. They were made by using the same four Mandarin speakers and materials used in Experiment 1. The movies showed a close-up of the speaker's face; the book or toy held by the speaker was visible. Speakers were filmed from the infants' perspective, so that the speaker on the video appeared to be looking at the infant seated on the blanket. Lighting for the film was excellent to ensure that infants could clearly observe the face and mouth movements of the speakers on the TV screen. Young infants detect the correspondence between lip movements seen on a TV screen and their matching auditory sounds, indicating they pick up information about speech production from 2D TV portrayals (35). The TV was placed at the infants' eye level, at a distance equivalent to that in Experiment 1. The sound was calibrated to be equivalent to Experiment 1.

Syllable counts of the DVD language sessions revealed that individual infants heard between 47,634 and 51,354 Mandarin Chinese syllables ($M = 49{,}866$) over the course of the 12 sessions. Natural versions of the Mandarin Chinese test syllables accounted for 7.0% (range = 5.6–7.8%) of the total number of syllables. Statistical comparisons revealed that infants heard significantly more syllables in Experiment 2 when compared with Experiment 1 ($P < 0.01$), but that the percentage consisting of the test syllables did not differ ($P > 0.10$).

Mandarin Chinese test stimuli. The identical Mandarin Chinese phonetic stimuli used in Experiment 1 were used to test infants in Experiment 2 (Fig. 1).

Phonetic perception test. The identical testing procedure, equipment, and testers used in Experiment 1 were used in Experiment 2.

Attention scores. As in Experiment 1, visual attention during the 12 exposure sessions was scored on a five-point scale by an assistant observing the infants via video monitor outside the soundproof room. The rater coded the degree to which infants focused their attention on the video screen during the AV and A sessions.

Results. The results of the Mandarin phonetic discrimination tests on infants in the AV and A groups are shown in Fig. 2*B*. Foreign-language intervention in the AV and A conditions of Experiment 2 had no effect on phonetic perception. A one-way ANOVA revealed a significant difference among the four infant groups tested across Experiments 1 and 2, live Mandarin, live English, Mandarin AV, and Mandarin A, $F(3, 45) = 3.94$, $P < 0.05$. Post hoc tests revealed that performance in the AV and A groups differed neither from each other nor from the English control group tested in Experiment 1 ($P > 0.10$ in all cases). AV and A group performance did, however, differ significantly from the live Mandarin exposure group tested in Experiment 1 ($P < 0.01$ in both cases).

The attention scores for infants in the AV and A groups revealed that they visually attended less than infants in the live exposure sessions of Experiment 1. For infants in the AV group, visual attention ratings were 2.79 (range = 2.14–3.33); for infants in the A group, the attention scores were 1.48 (range = 1.03–2.06). Across the two experiments, attention scores for the four groups differed significantly, $F(3, 45) = 101.76$, $P < 0.001$. Post hoc tests revealed that the AV and A group attention scores differed significantly from each other, and that both AV and A group attention scores differed significantly from the two live conditions (live Mandarin = 3.53; live English = 3.56) ($P < 0.001$ for all comparisons).

Discussion. The results of Experiment 2 demonstrate that 9-mo-old infants watching and listening, or simply listening, to studio-quality DVDs of foreign-language material do not show phonetic learning, even though infants of the same age learned from a live person (Experiment 1). Infants' speech perception scores in the AV and A groups did not differ from the scores of infants in the English control group who were not exposed to any foreign-language material. Attention scores revealed that in the absence of a live speaker, infants attended significantly less to the speakers and their materials. Moreover, infants in the AV group attended significantly more than infants in the A group, although the increase in attention did not result in an increase in learning.

The current results are consistent with a variety of studies on older children (preschool age) exposed to language material, both native and foreign, from children's TV shows. The results indicate that, although there is evidence that specific vocabulary items can be learned through exposure to television programs, the more complex aspects of language, such as phonetics and grammar, are not acquired from TV exposure (36).

PSYCHOLOGY

General Discussion

The experiments reported here examine the effects of foreign-language intervention on the decline normally observed in infants' perception of foreign-language phonetic units at the end of the first year of life. Experiment 1 asked whether first-time foreign-language exposure between 9 and 10 mo of age induces phonetic learning. Experiment 2 asked whether learning from foreign-language exposure at this age occurs in the absence of social interaction.

The results demonstrate that foreign-language intervention in infancy affects phonetic perception. Exposure to live Mandarin Chinese speakers in 12 laboratory sessions (totaling $\approx$5 h) at 9 mo of age resulted in phonetic learning and altered the typical developmental time course of foreign-language speech perception. The findings show that reversing the decline does not require long-term listening to the foreign language. The components critical to learning in the live situation of Experiment 1 likely include: (*i*) infant-directed speech (24, 25), a speech pattern that has been shown to attract and hold infant attention (27, 28); (*ii*) the use of multiple talkers, which increases variability in the acoustic cues to phonetic categories and results in better phonetic learning in adult listeners mastering a foreign language (37); and (*iii*) phonetic units whose acoustic cues are exaggerated, making them more distinct (29). The exaggeration of phonetic units by parents has been shown to be strongly associated with enhanced phonetic perception in infants (26); exaggeration is also reported to improve phonetic perception in children with dyslexia (38, 39). Experiment 1 demonstrates that when foreign-language speech is delivered live in this manner, phonetic learning occurs.

Experiment 2 tested whether phonetic learning at this age is simply triggered by hearing language. We tested this hypothesis by presenting the foreign-language material via machine, either in an AV or an A format. The results indicate limits on phonetic learning; 9-mo-old infants exposed to foreign-language material from DVDs did not reverse the decline in phonetic perception. The AV and A exposure sessions duplicated Experiment 1's live sessions, yet no learning occurred. The results suggest that phonetic learning from complex language input relies on more than raw auditory sensory information. At this age, learning is influenced by the presence of a live person.

What does a live person provide that a DVD cannot? We suggest that specific social cues may be critical. A live human being generates interpersonal social cues that attract infant attention and motivate learning. There is evidence that communicative learning in other species, such as songbirds, is enhanced by social contact. In laboratory tests in which young zebra finches are exposed to song, visual interaction with the tutor bird is required to learn (40). Zebra finches are sufficiently influenced by social cues that they override an innate preference for conspecific song and learn from a Bengalese finch foster father who feeds them, even when adult zebra finch males can be heard nearby (41). White crown sparrows reject the songs of alien species when presented via audiotape but learn the same alien songs when they are sung by a live tutor (22). In birds, interactions can take a variety of forms. If young zebra finches are blindfolded and cannot see the tutor but can interact through pecking and grooming, learning occurs. Moreover, young birds operantly conditioned to present conspecific song to themselves by pressing a key learn the songs they hear (42, 43), suggesting that active participation and the attention it requires may be important. Attention and motivation are likely to be key elements in communicative learning, not only in birds and other animals but in humans as well (44, 45).

In the human case, the presence of a live person provides not only general social cues but also information that is referential in nature. In the live exposure sessions, the speaker's gaze often focused on pictures in the books or on the toys they were talking about, and the infant's gaze followed the speaker's gaze, which is typical for infants at this age (32, 46). Gaze following an object has been shown to be a significant predictor of receptive vocabulary (33, 34); perhaps joint visual attention to an object that is being named helps infants segment words from ongoing speech. This, in turn, would highlight the phonetic units contained in those words.

These findings suggest an interesting constraint on learning. At this early age, speech learning may occur preferentially for signals that derive from live humans rather than from other sources. Previous work suggests similar constraints on infant vocal imitation (35, 47). The combination would maximize the possibility that infant learning focuses on the appropriate signal: speech, rather than birdcalls or door slams (44, 48, 49). Similar constraints on learning have been demonstrated by young infants' tendencies to imitate goal-directed actions displayed by humans rather than by machines (50).

Our results pose questions with both theoretical and practical impact. The current results show that infants readily learn from foreign-language exposure, which raises a question about the human capacity to acquire more than one language. Because the phonetic contrasts of different languages often require different perceptual groupings (in Japanese, for example, /r/ and /l/ belong to the same category, whereas in English they are separate), bilingually raised infants must learn two different ways of classifying speech sounds. Are there limits on infants' abilities to learn the phonetic cues of different languages? Infants in the current tests readily acquired phonetic information from a language they had not previously heard, suggesting that, at least at this age, infants can learn from exposure to two distinct languages. A second question is the resilience of early phonetic learning; that is, does short-term exposure during a sensitive period for learning have lasting effects? In our tests, the ability to discriminate the Mandarin contrast was unaffected after an almost 2-wk delay. Follow-up studies on these infants are now underway to assess the long-term impact of early foreign-language exposure.

Early language learning may find a useful biological framework in Greenough and Alcantara's "experience-expectant" learning (51). Experience-expectant learning has two principal components: neural development that occurs in anticipation of the opportunity to learn and environmental information that is reliably present at that time. Infants' avid language learning in the second half-year of life, shown both in the present study and in previous studies (3, 19), could be indicative of neurological development that enables infants to neurally code the properties of language. The environment reliably provides language in a social context. Neural development on a maturational timetable and critical environmental information in a social setting may combine to provide an example of experience-expectant learning for language acquisition.

Traditional theories describe phonetic learning as an innate "modular" process in infants, one specific to speech and encapsulated in a way that isolates it from general systems (52, 53). An alternative view, buttressed by data on categorical perception tests in infants and animals, argues that infants' initial capacities are based on more general perceptual systems (54). The present data support the view that language acquisition initially draws on a broad set of perceptual, cognitive, and social abilities. A corollary argument, addressing evolutionary origins, suggests that language evolved to capitalize on preexisting general systems and then went beyond them (55, 56). The characteristics that facilitate language acquisition in children may thus have influenced the nature of language itself, ensuring that language was learnable by infants in natural settings.

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