strong incentives. The higher doses that would be needed to suppress all incentive salience are incapacitating. Still other medications, which suppress drug liking, focus on the wrong component of reward, and can at best be only partly successful. Only reversal of neural sensitization would transform the brain and mind of an addict back into the brain and mind of a nonaddict. As yet, a pharmacological cure for addiction does not exist. But the incentive-sensitization theory tells us in advance how to recognize a cure: It will reverse the physiological changes that constitute neural sensitization.

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Notes


2. For example, “Drug craving is characterized by both the desire to experience the hedonic effects of the drug...” (Berridge, Venier, and Robinson, 1993), p. 176.


ity to distinguish individual syllables on the basis of minimal differences in phonemes. In this review, we discuss the kinds of initial abilities infants bring to the task of phoneme perception, how these sensitivities are influenced by experience in a particular linguistic community, and whether events that occur during the prelinguistic period help prepare the child for the important task of language acquisition.

**MAPPING THE CHANGES IN PHONEME PERCEPTION**

Sensitive experimental techniques that were developed in the early 1970s allowed testing very young infants' speech perception abilities. These techniques revealed that infants can only discriminate minimally distinctive phonemes, but can also distinguish phonemes from all the world's languages—including phonemes not used in their language-learning environment. In contrast, research with adults, using different techniques, had led scientists to believe that adults cannot readily discriminate all phonemic distinctions that are not used in their native language. Because adults typically perform better than infants at virtually any task given to them, this counterintuitive pattern of results was most intriguing. Our work was designed to explore the age at which experience first begins to influence phonemic perception and the mechanisms that might be responsible for this change.1

To explore the counterintuitive suggestion that infants discriminate nonnative phonemes better than adults, we first compared the two groups directly. In order to do this, we needed a procedure that would be adaptable to both infants and adults. The procedure we chose is a category change procedure. In this task, the subject monitors a continuous background of syllables from one phonemic category (e.g., /ba/) and presses a button to signal when the stimuli change to a contrasting phonemic category (e.g., /da/). Correct button-presses are reinforced with the presentation of a flashing light (as feedback for older children and adults) or an electronically activated animal (as a reward for younger children). Incorrect button-presses are not reinforced, and misses are not signaled.

In the infant version of this procedure, called the conditioned head turn task, the infant sits on the parent's lap facing an experimental assistant who maintains the infant's interest by showing toys. The infant is conditioned to turn his or her head toward the sound source when he or she detects a change in the phonemic category (see Fig. 1). Correct head turns are reinforced with the illumination and activation of clapping and drumming toy animals inside a Plexiglas box. In addition, the experimental assistant claps and gives praise and encouragement. As is the case with children and adults, incorrect responses are not reinforced. In our laboratory, the criterion for successful discrimination is set at 9 out of 10 correct consecutive responses within a series of 25 trials, approximately half of which are control trials in which no change occurs.

In the first series of experiments, we compared infants and adults on their ability to discriminate two distinctions that are phonemic (i.e., can differentiate words) in Hindi but not in English and one that is phonemic in both Hindi and English. The Hindi-only contrasts were chosen to vary in their potential difficulty. The first contrast, /Ta/—/ta/, involves two phonemes that both sound like t to a native English speaker. The difference between them involves where the tongue is placed. For /Ta/, the tongue is curled back and the tip of the underside hits the roof of the mouth. This is called a retroflex consonant. For /ta/, the tip of the tongue is placed against the front teeth. This is called a dental consonant. An English speaker makes a /t/ by placing the tongue against the alveolar ridge directly behind the front teeth. This alveolar consonant is articulated at a place in between the dental and retroflex consonants.

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Fig. 1. Madeleine performing in the conditioned head turn procedure. Photo courtesy of Steven Heine.
The second contrast was a Hindi voicing contrast that also involves two phonemes that sound like t to an English speaker. In this case, the difference involves the timing and shape of the opening of the vocal cords. Hindi /t\o/ and /d\o/ involve a slightly different combination of timing and shape than is used in production of English phonemes. For linguistic and acoustic reasons, this voicing contrast is potentially easier to discriminate than the retroflex-dental contrast.

Subjects were also tested on the contrast between /ba/ and /da/, which is used in both Hindi and English. This contrast served as a control to ensure that the subjects understood (and, in the case of the infants, were willing to perform) the task.

In the first study done collaboratively with Richard Tees, John Gilbert, and Keith Humphrey, English-learning infants aged 6 to 8 months were compared with both English-speaking adults and Hindi-speaking adults. Virtually all subjects in all groups could discriminate the /ba/-/da/ contrast, and the English-learning infants and the Hindi-speaking adults could easily discriminate both Hindi contrasts. However, the English-speaking adults had difficulty discriminating the Hindi contrasts, and showed particular trouble with the difficult retroflex-dental distinction. A short training procedure (25 trials) was effective in raising the proportion of English-speaking adults who could discriminate the Hindi voicing contrast, but this amount of training did not improve adult performance on the retroflex-dental distinction.

This experiment confirmed what many researchers had expected. Testing using comparable procedures verified that infants discriminate nonnative phoneme contrasts better than adults. But we had no idea as to the age in development when the performance decrement occurs. An influential view at the time was Lenneberg's hypothesis that there is a "critical period" for language acquisition up to the onset of puberty. Extrapolating from this hypothesis led us to test children on the verge of adolescence, as well as two younger age groups. To our surprise, the results indicated that English-speaking children 12, 8, and even 4 years old perform as poorly as English-speaking adults on the Hindi contrasts not used in English. This effect was evident even though the 4-year-old children could easily discriminate the English contrast, and even though Hindi-learning children of age 4 discriminated both Hindi contrasts successfully when tested with the same procedure.

These results showing that language experience affects phoneme perception by age 4 led to additional tests of children between 6 months and 4 years old. A series of pilot tests led to a focus on the 1st year of life.

Infants between 6 and 12 months of age were tested on the difficult retroflex-dental contrast taken from Hindi, as well as on a new contrast taken from a Native Canadian language, Ntlakampx (one of the Interior Salish languages). The new contrast, glottalized velar /k\o/ versus glottalized uvular /q\o/, involves a difference in the position of the tongue in the back part of the vocal tract. English listeners hear these two sounds as "funny" /s/ sounds. We found that although English-learning infants aged 6 to 8 months can discriminate both of these contrasts with ease, infants of 10 to 12 months, like English-speaking adults, fail to discriminate the difference in either non-English contrast. The same pattern of results was replicated in a study in which the same infants were tested at 6 to 8, 8 to 10, and 10 to 12 months of age. Thus, it appeared that the change occurs between 6 and 12 months of age.

In a final manipulation, we tested a small number of 11- to 12-month-old infants who were being exposed to either Hindi or Ntlakampx in the home. Infants in each language group discriminated the contrast from their native language with ease, confirming that the change between 6 and 12 months reflects language-specific experience and is not just an age-related decrement in performance on difficult contrasts.

In a subsequent study, we tested English-learning infants using synthetically produced stimuli that varied in equal steps along a continuum from bilabial /ba/ to dental /da/ to retroflex /da/. We found that English-learning infants aged 6 to 8 months can group stimuli according to the English boundary between labial and dental stimuli, and according to the Hindi boundary between retroflex and dental, but not according to the arbitrary boundary location that does not correspond to any known phonemic category. English-learning infants aged 10 to 12 months can group only according to the bilabial-dental boundary. These results confirm that the sensitivities shown by young infants prior to language-specific tuning are not arbitrary, but rather conform to potential phonemic categories. Also, with these synthetic stimuli, we replicated our finding that language-general perception shifts to language-specific perception between 6 and 12 months of age.

More recently, Best and colleagues replicated this finding with both the Ntlakampx /k\o/-/q\o/ contrast and three contrasts from the Zulu language that are not used in English. Best found that infants 6 to 8 months old could discriminate nonnative contrasts, whereas infants 10 to 12 months old could not. These findings are of particular interest as Best used a habituation-dis习惯uation looking procedure, rather than the conditioned head turn procedure. Taken together, these replications with new phonemic contrasts and different testing procedures provide strong confirmation that listening experience brings about a change in nonnative conso-
nant perception within the 1st year of life.

**HOW TO EXPLAIN THIS PATTERN OF RESULTS?**

One possible explanation to account for these results is that phoneme sensitivities that exist in the young infant will be maintained only if those phonemes are present in the language input (a maintenance/loss view). Without such experience, the infant will lose the ability to discriminate those phonemes permanently. Originally, we thought the loss was tied to events at the level of neuronal functioning. However, a series of experiments with adults convinced us that this explanation was not adequate. Specifically, we found that adult performance varied as a function of the testing conditions. Under conditions that match the demands required in natural language use, adults fail to discriminate the nonnative contrasts. However, when memory demands are minimized (via a shortened interstimulus interval), or uncertainty is diminished (via practice or training), adults show a continued sensitivity even to the most difficult nonnative phoneme distinctions. For this reason, we began to refer to the age-related change in cross-language perception as a reorganization rather than a loss. We assumed the reorganization resulted in a restructuring of initial sensitivities to map on to those required to contrast meaning in the native language.

Recently completed research in our laboratory has shown that similarity to native language sounds is not the only factor influencing reorganization. Pegg tested infants on their ability to discriminate two variants of a single phonemic category (allophones) that occur systematically in the English language but are not used to distinguish meaning. The allophones she tested can be illustrated by the phonetic contrast between “the stalls” and “these dolls.” Both the [t] in stall and the [d] in doll sound like the English phoneme /d/; however, there are subtle differences that are discriminable to adults and that may help listeners find word boundaries. Pegg found that many English-learning in-

fants 6 to 8 months old are sensitive to these subtle differences and can distinguish the two allophones. Infants 10 to 12 months old, however, cannot. The performance of the older infants suggests that exposure to a systematic difference in speech sounds is not enough to maintain discriminability. Apparently, it is necessary that the distinction be used to contrast meaning in the native language.

**NEW DIRECTIONS**

The work we have discussed so far focused exclusively on consonant perception. An area of current interest is whether experience affects vowel perception similarly. There are several reasons why vowel perception might pattern differently. Vowels carry paralinguistic information concerning the speaker's identity, emotional tone, and pragmatic context in addition to carrying specifically phonemic information. Thus, very young infants may listen to vowels for their prosodic as well as for their phonemic information. Also, the boundaries between vowel categories are less rigid than the boundaries between consonant categories: Both adults and infants can discriminate “within-category” differences better for vowels than for consonants. Finally, discrimination of nonnative vowel contrasts is typically easier than is discrimination of nonnative consonant contrasts.

In an early study of cross-language vowel perception in infancy, Trehub reported that English-learning infants aged 5 to 17 weeks discriminated a French vowel contrast that is not used in English, thus showing the same pattern of language-general sensitivity in vowel perception as has been shown for consonant perception. In recent work, Kuhl and colleagues showed there are language-specific influences on the internal structure of
vowel categories by 6 months of age in both Swedish- and English-learning infants. This finding suggests that language-specific experience might affect vowel perception at a younger age than it affects consonant perception. However, because Kuhl's research involved testing infants' ability to generalize to other exemplars within a single vowel category rather than to discriminate across two phonemic vowel categories, it is not analogous to the studies of consonant perception.

To compare vowel and consonant perception directly, Polka and the first author tested English-learning infants and English-speaking adults on their ability to discriminate two German vowel contrasts. Each pair contrasted a high, front, rounded with a high, back, rounded German vowel in a “d-VOWEL-t” context. For example, in one pair, the vowel in “boot” (high, back, rounded) was contrasted with a German vowel produced like the vowel in “beet” but with the lips rounded (high, front, rounded). Pretesting with adults showed that although these distinctions are not phonemic in English, they are relatively easy for English-speaking adults to discriminate. All subjects were also tested on an English contrast (/dɪt/ vs. /dat/) to make sure they could perform the task.

Using two different procedures to test English-learning infants from 4 to 12 months of age, we found that the effects of experience begin earlier for vowels than for consonants, but that experiential influences continue to be seen up to 10 to 12 months of age. Infants aged 4 months performed better than infants aged 6 months on the German contrasts when tested in a habituation-dishabituation looking procedure (a procedural change necessary for testing younger infants). When tested in the conditioned head turn procedure, infants aged 6 to 8 months performed significantly better than the 10- to 12-month-old infants, but not as well as 6- to 8-month-old infants typically perform on nonnative consonant contrasts (see Fig. 2).

This study suggests that vowel perception is like consonant perception, but that experience begins to influence initial language-general capabilities at an earlier age for vowels than for consonants. However, as this is the first cross-language study of this type that has been reported using vowels, additional research is required before we can be confident about the results. Indeed, there are some reports that vowel perception may initially be organized quite differently than consonant perception, and that the effects of experience may not always be as pronounced for vowel perception as they are for consonant perception.

It is important to note that researchers have begun to investigate whether experience affects other aspects of language processing in addition to phoneme perception. Although it is beyond the scope of this article to review this burgeoning literature, it seems that infants become increasingly sensitive to many aspects of the native language, including stress patterns, rules for sequencing sounds, and cues to word boundaries. Indeed, infants may show sensitivity to the global prosody of the native language within the first few days after birth. Finally, there is evidence that babbling changes across the 1st year of life to reflect the characteristics and distribution of sounds used in the native language. An exciting question is how all these capabilities come together to prepare the child to move on to the task of word learning.

**SUMMARY**

During the 1st year of life, long before uttering his or her first words,
Resilience in Development

Emmy E. Werner

During the past decade, a number of investigators from different disciplines—child development, psychology, psychiatry, and sociology—have focused on the study of children and youths who overcame great odds. These researchers have used the term resilience to describe three kinds of phenomena: good developmental outcomes despite high-risk status, sustained competence under stress, and recovery from trauma. Under each of these conditions, behavioral scientists have focused their attention on protective factors, or mechanisms that moderate (ameliorate) a person's reaction to a stressful situation or chronic adversity so that his or her adaptation is more successful than would be the case if the protective factors were not present.

So far, only a relatively small number of studies have focused on children who were exposed to biological insults. More numerous in the current research literature are studies of resilient children who grew up in chronic poverty, were exposed to parental psychopathology, or experienced the breakup of their family or serious caregiving deficits. There has also been a grow-
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