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ABSTRACT

Frequency difference thresholds were determined for fourteen 4- to 9-month-old infants (mean age, 6 months 10 days) using a discrimination learning paradigm, following a one-up, two-down staircase procedure. The subject heard 500 msec tone bursts repeated at a rate of one per sec, with a fixed standard frequency. At various points in this pulse train, the frequency of the tone burst changed for 6 sec. If the infant turned his head 45 degrees to his right within the 4 sec response interval following the change in frequency, a visual reinforcer was activated for 2 sec. Once the infant had learned the task with a relatively large frequency change, (96 Hz), the size of the frequency change was systematically decreased on each subsequent trial until the infant failed to turn, then increased again, and so on, in order to obtain an estimate of the smallest difference in frequency that the infant could detect. Following two correct responses, the frequency difference was decreased by one step; after one incorrect response the frequency difference was increased by one step. The results showed that infants could detect 2-3% changes in frequency at 1000, 2000, and 3000 Hz, while adults detected changes on the order of 1%. This finding supports the contention that infants could be using frequency difference as a cue in speech discrimination tasks. (Author/SS)

Frequency Discrimination in Young Infants

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Frequency Discrimination in Young Infants

Abstract

Five- to nine-month-old infants were tested for frequency discrimination in a discrimination learning paradigm, following a one-up, two-down staircase procedure. The results showed that infants could detect 2-3% changes in frequency at 1000, 2000, and 3000 Hz, while adults detected changes on the order of 1%. This finding supports the contention that infants could be using frequency difference as a cue in speech discrimination tasks.

Frequency Discrimination in Young Infants

Adult observers are capable of detecting changes in the frequency of a pure tone as small as .1%. We have reason to believe that at least by the age of six months, the infant should be able to perform such a task in a comparable manner. First of all, histological and electrophysiological studies show that subcortical auditory structures necessary for frequency discrimination attain mature status at about this time. In addition, the infant of this age seems to be able to discriminate between vowel sounds in which the maximum frequency difference between corresponding formants is about .2%.

A number of attempts have been made to show that after the infant's response to an auditory signal has habitutated over repeated presentations, the response rate will increase following a change in the signal's frequency, implying frequency discrimination. These have often proven unsuccessful, however, and in those cases where discrimination has been reported, a frequency change on the order of 100% has been employed. Thus, while it can be concluded that frequency discrimination by infants is possible, it is not clear how the infant's discriminative capacity compares with the adult's.

The present study determined frequency difference thresholds for fourteen 4- to 9-month-old infants (mean age 6 mo 10 da) using a discrimination learning paradigm. All subjects were Caucasian, from middle class homes, in good health and free of physical defects. Parents were paid for participation in the study.

The technique employed is a variation of the visually reinforced speech discrimination paradigm currently being used in a number of laboratories.

[illegible] subject heard 500 msec tone bursts repeated at a rate of one per sec, with a fixed standard frequency. At various points in this pulse train, the frequency of the tone burst changed for 6 sec. Each such 6 sec period constituted a trial. If the infant turned his head 45° to his right within the 4 sec response interval following the change in frequency, the visual reinforcer, a mechanical toy enclosed in a smoked plexiglass box on a stand to the subject's right, was activated for 2 sec. Thus, the frequency change acted as a cue to the subject that reinforcement was available. Once the infant had learned the task with a relatively large frequency change, (96 Hz), the size of the frequency change was systematically decreased on each subsequent trial until the infant failed to turn, then increased again, and so on, in order to obtain an estimate of the smallest difference in frequency that the infant can detect. This process for a typical subject is shown in the first slide (SLIDE 1), where + indicates a correct response, and -, no response. Following two correct responses, the frequency difference is decreased by one step; after one incorrect response the frequency difference is increased by one step. Step size (the amount by which the frequency difference was changed) was reduced over trials from 48 Hz to a final value of 3 Hz to make each session as short as possible. We completed this procedure for standard frequencies of 1000, 2000 and 3000 Hz. Stimuli were sinusoidal in waveform and presented to the right ear at 70 dB SL (sensation level). Tone bursts had a 20 msec rise-fall time. Two 20-min sessions were usually required to train the infant and obtain the three thresholds. Five adult volunteer subjects provided thresholds under essentially the same conditions, with the mechanical toy as feedback, for purposes of comparison.

The laboratory layout is illustrated in the next slide (SLIDE 2). The infant sat on his parent's lap throughout the procedure and wore headphones which were held in place by two elastic straps designed to prevent slippage of the headphones. One experimenter sat to the subject's left and manipulated toys at the infant's midline, trying to maintain the child's attention in that direction. This practice was intended to keep the infant's false alarm rate low. Neither this experimenter nor the parent could hear the auditory signal.

The other two experimenters recorded the infant's responses from the next room, viewing the infant through a one-way window. These two observers were separated by a barrier so that each was unaware of the other's action. The first observer controlled the standard frequency of the tone burst, the size of the frequency change and the onset of each trial as well as recording head turns observed only during response intervals. The second observer, on the other hand, could record an infant response at any point in time, and did not know when a trial was occurring. Agreement between the observers was required for a head turn to count as a correct response during the response interval; (Per cent agreements between the two observers ranged from 91 to 100% for 6 observer pairs.) all head turns recorded by the second observer between response intervals were counted as false alarms. Consequently we have a count, at least, of the number of hit and false alarm responses during testing for each subject, and in general, it appears that this procedure effectively controls false alarm rate.

Thresholds, taken as the average of all reversals except the first two, were calculated for all subjects. Average thresholds for infants and adults at each of the standard frequencies are shown in the next slide

(SLIDE 3). First, note that our adult observers were detecting frequency differences of about 1%. The difference between the performance of our observers and that of adult subjects in previous frequency discrimination experiments appears to be due to differences in procedure. Since the subject in this experiment did not know when a frequency change would occur, he was placed under greater attentional demands than a subject in the usual psychophysical procedure who knows when a signal will occur. In fact, when frequency difference thresholds for these adult subjects were obtained in a situation where this uncertainty was removed, thresholds were quite close to those reported in other laboratories.

But to get to the point, infants detected changes of about 2-3% in frequency, considerably better than had previously been shown. And while the difference in threshold between infants and adults was consistent, it was actually quite small in terms of the variability often reported in the performance of adult subjects. We can conclude, then, that the 6 month old's ability to discriminate changes in frequency approaches the adult's.

More important than the absolute size of the infant threshold, however, is the fact that threshold increases with standard frequency in the same way for infants and adults. This finding argues for at least a qualitative continuity in the function of the auditory system from infancy to adulthood.

It would appear, then, that infants can indeed make relatively fine frequency discriminations. This finding confirms the functional maturity of the frequency analyzing structures of the infant auditory system and forces the conclusion that information concerning differences in frequency is available to the infant in his analysis of sounds, including the sounds of speech.

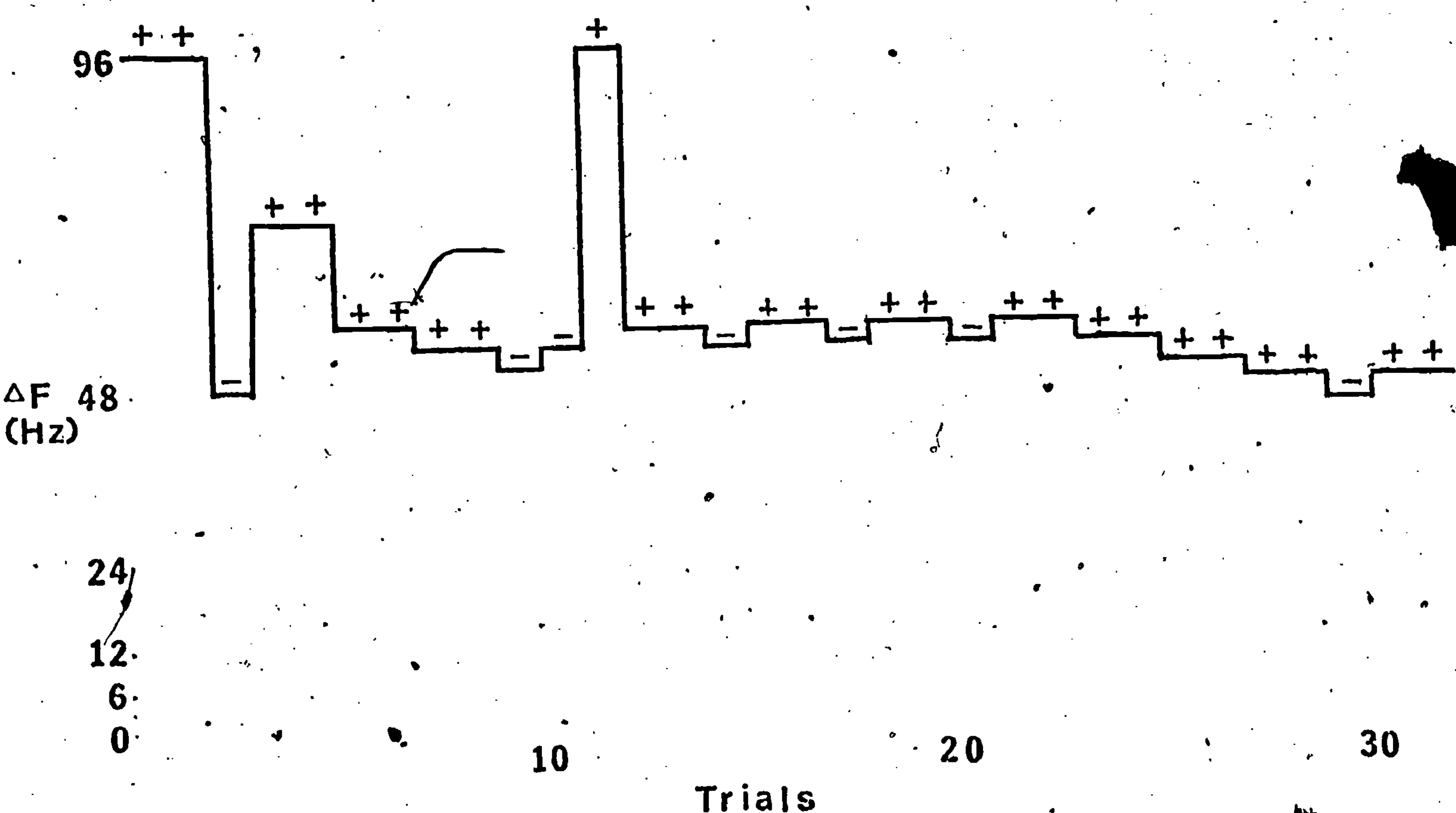

Figure 3. Typical infant response protocol. Standard frequency = 3000 Hz. Threshold in this case was 58.2 Hz.

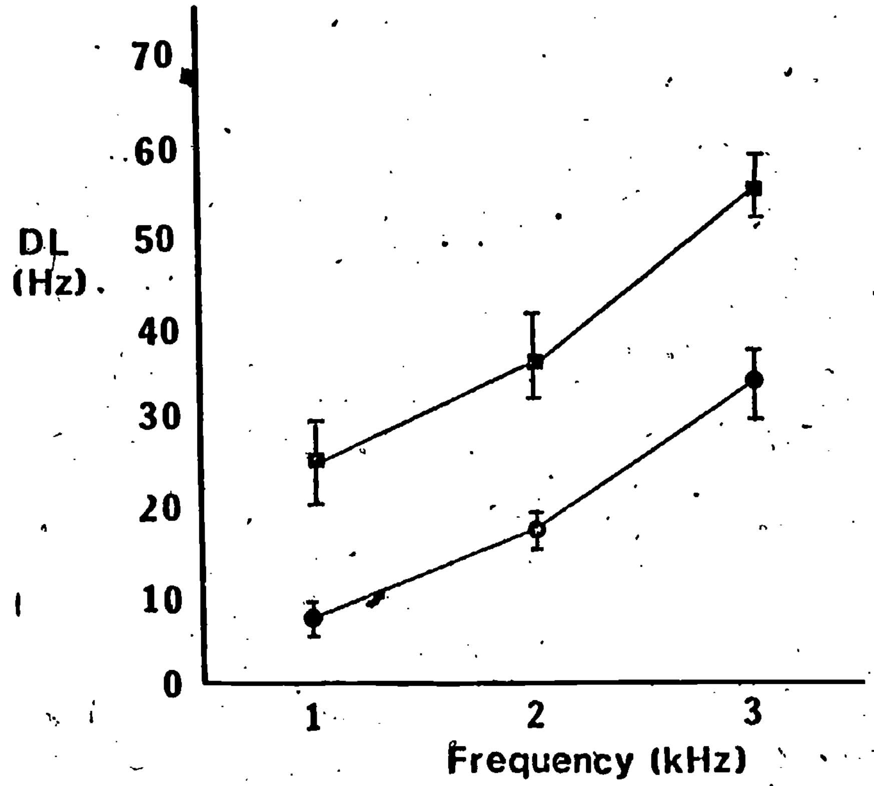

Figure 5. Average thresholds as a function of frequency for infants and adults (± 1 standard error).