Preliminary data on frequency discrimination in infancy

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An operant head-turn technique was used to measure frequency-difference thresholds for 5- to 8-month old infants and for adults. At a standard of 1000 Hz, presented at 70 dB above adult threshold, infant thresholds averaged 21.6 Hz, adult thresholds, 7.4 Hz. In a two-alternative forced choice procedure, difference thresholds of the same adults approached those reported by Wier *et al.* [J. Acoust. Soc. Am. **61**, 178–184 (1977)].

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INTRODUCTION

Various studies have explored the frequency discrimination capacities of human infants (e.g., Bridger, 1961; Leventhal and Lipsitt, 1964; Trehub, 1973; Wormith *et al.*, 1975). While some have demonstrated that infants can discriminate sounds of different frequencies, the limits of this ability have not been tested. This letter represents a preliminary report of infant frequency difference thresholds measured at a frequency of 1000 Hz.

The methodology used here is an operant head-turn technique originally developed by Moore *et al.* (1977) and modified for adaptive psychophysical methods by Aslin and Pisoni (1980). Subjects were trained to make a head turn whenever a repeated tone burst changed in frequency. This technique offers several advantages over those previously employed. For example, a threshold can be measured quickly, and adult subjects can be tested using the same paradigm.

I. METHOD

A. Subjects

Fourteen full-term infants, ranging in chronological age from 4 mo 10 days to 8 mo 1 day (mean age 6 mo 10 days), participated. Seven were males, and seven females. Thirteen additional infants did not complete the procedure, ten because they became fussy and did not return for further testing, three because they failed to reach criterion performance with 15 min of training. Their mean age was 6 mo 11 days. All of the infants were reported by their parents to be healthy and developing normally. Five adult student volunteers (two males, three females) served as a comparison group.

B. Stimuli

Stimuli were 500-msec tone bursts with a 500-msec silent interval between bursts. The rise–fall time of each burst was 20 msec. Tone bursts were delivered at 1000 Hz, 70 dB above the average adult absolute threshold measured in the same laboratory.

C. Apparatus

Sinusoids were generated by a Wavetek 136 oscillator, gated through a Coulbourn S84-04 electronic switch to a Hewlett Packard 350D attenuator and through a matching transformer to a TDH-39 earphone. The switch was operated by an electromechanical timer. The voltage to the Wavetek's VCG input was adjusted to produce the standard and comparison frequencies, using two manually set potentiometers. The potentiometers were calibrated using a Hewlett Packard 5381A frequency counter. A push button-triggered timer switched the input voltage to the comparison level on each trial. The voltage to the Wavetek's VCA input was adjusted in the same way to produce changes in amplitude. The amplitude potentiometers were calibrated using a B & K 2203 sound level meter with octave-band filter. A third timer controlled the onset and duration of the reinforcer, a mechanical toy bear. The toy was enclosed in a smoked Plexiglas box, lit from within during a reinforcement period.

Subjects listened monaurally with the right ear, with both earphones in place. Earphones were held in place with two elastic straps fashioned after those developed by Wilson *et al.* (1977).

D. Procedure

The procedures employed in this experiment were modified from those originally developed by Moore *et al.* (1977) and by Aslin and Pisoni (1980).

The experiment was carried out in two adjacent rooms with a one-way observation window in the wall between them. The infant sat on his parent's lap, at one end of a rectangular table, facing the observation window. The visual reinforcer was mounted on a small stand at the infant's eye level and placed 1.2 m from the infant along a line 45° from the infant's midline. To the infant's left sat an assistant who maintained the infant's attention at midline by manipulating silent toys on the table in front of him. Neither the parent nor the assistant could hear the auditory signal. Both parent and assistant were instructed to remain silent and to refrain from influencing the infant's head turns.

Two observers were stationed in the adjacent room at a table immediately before the observation window. One initiated trials by push button; both used push buttons to record responses. Neither could see the other's responses. The acoustic, timing, and recording system was located next to one of the observers. Neither of the observers could hear the acoustic signal.

1. Procedure

a. General procedure. Infants were trained to make a head turn whenever the standard-frequency tone burst, repeated once every second, was changed to a comparison frequency for 6 s. If a head turn occurred during the 6-s comparison interval, the infant was rewarded with the activation of the mechanical toy. Each 6-s frequency change interval constituted one trial. Observer 1 initiated a trial when the subject was in a "ready" state, quiet and attending to the silent toys. If both observers depressed their response buttons during the first 4 s of the trial, indicating a 45° head turn toward the visual reinforcer had occurred, the control system automatically activated the mechanical toy and light for 2 s. If neither or only one of the observers depressed their response buttons, the reinforcer was not activated and an error was scored. The judgments of the two observers were in agreement, on the average, on 96.4% of trials during the second-training phase and on 96.1% of trials during testing.

The training procedure for the experiment consisted of two phases. During the first phase, only change trials occurred, and the frequency change was always 96 Hz. The comparison stimulus was 2 dB more intense than the standard, and the visual reinforcer was activated during the last 2 s of each trial. Since the activation of the reinforcer was a salient visual event, the infant turned away from the assistant to look at it. Eventually, the infant anticipated the activation of the reinforcer when the frequency of the tone burst changed to the comparison level. After three consecutive anticipatory head turns, the intensity difference between the standard and comparison was eliminated. Once the infant had made three more anticipatory head turns following only the frequency change, the second training phase was begun.

During the second training phase, both change and control trials occurred, randomly interspersed. Neither observer knew whether a change would occur on a given trial during this phase. When a frequency change did occur, Δf remained at 96 Hz. The visual reinforcer was activated only if the infant turned his head during the first 4 s of a change trial. If one or both of the observers judged that a head turn had occurred on a control trial, an error was scored. The infant remained in this training phase until the performance criterion, 4 of the last 5 change trials correct and 4 of the last 5 no-change trials correct, was met.

In the testing phase only change trials occurred. An adaptive psychophysical procedure was used (Levitt, 1971; Aslin and Pisoni, 1980). Testing at each standard frequency began with a Δf of 96 Hz. Two consecutive correct responses led to a decrease in Δf and one incorrect response led to an increase. If the infant failed to respond on two consecutive trials, Δf was set at 96 Hz on the following trial. If the subject responded on this probe trial, testing was continued at the last level tested. Otherwise Δf was maintained at 96 Hz until the infant responded. If the infant failed to respond after ten trials at 96 Hz, testing was discontinued. Step size (the amount by which Δf was changed) was systematically decreased over trials from an initial value of 48 Hz, progressively halved to a final

TABLE I. Frequency difference thresholds of infants and adults at standard frequency of 1000 Hz, 70 dB *re*: adult threshold.

Infants				Adults			
	Age					Δf (Hz)	
Subjects	(mo–da)	Sex	Δf (Hz)	Subject	Sex	Head turn	2AFC
1	8–1	F	18.0	1	M	5.0	1.50
2	8–1	F	37.7	2	M	5.0	3.25
3	7–22	M	33.8	3	F	5.8	3.00
4	7–16	M	29.5	4	F	12.3	···
5	6–6	F	18.5	5	F	9.0	3.25
6	6–3	F	7.0				
7	5–27	F	57.0				
8	5–23	M	6.8				
9	5–23	F	17.0				
10	5–20	F	40.2				
11	5–20	F	9.0				
12	5–18	M	14.3				
13	4–26	M	7.3				
14	4–21	M	6.8				

value of 3 Hz. Testing was continued for 12 reversals or until an infant subject was unable to continue. The mean of all reversals except the first two was used as the threshold estimate.

Adult observers listened alone in the same laboratory. They completed the same training and testing procedures: the stimulus characteristics and response criteria employed were identical and the mechanical toy was activated as feedback that a frequency change had been correctly identified.

Four of the five adult listeners were later tested in a two-alternative forced choice (2AFC) adaptive procedure. The two intervals were 500 msec in duration, delivered 500 msec apart. Step size was 3 Hz. Each trial in this procedure began with a 500-msec warning light. The subjects also received feedback following each response.

II. RESULTS

Table I lists the difference thresholds of all subjects at 1000 Hz. Infant thresholds were quite variable, ranging from 6.8 to 57 Hz. The average infant threshold was 21.6, more than twice as large as the average adult threshold of 7.4. Note that adult thresholds in the 2AFC procedure were lower than in the head-turn procedure. The 2AFC thresholds are close to those reported by Wier *et al.* (1977) for a 1000-Hz tone.

III. DISCUSSION

Infant frequency difference thresholds appear to be higher than those of adults, at least at 1000 Hz. Several factors, including physiological immaturity and performance variables, could contribute to this age difference. However a comparison of the adult head-turn thresholds with their 2AFC thresholds makes it clear that procedural effects may be an important influence. Further methodological refinements may make it possible to estimate the relative contributions of nonsensory variables to measures of infant frequency discrimination.

Aslin, R. N., and Pisoni, D. B. (1980). "Some developmental processes in speech perception," in *Child Phonology: Perception and Production*, edited by G. Yeni-Komshian, J. F. Kavanagh, and C. A. Ferguson (Academic, New York).

Bridger, W. H. (1961). "Sensory habituation and discrimination in the human neonate," Am. J. Psychiatry **117**, 991–996.

Leventhal, A., and Lipsitt, L. P. (1964). "Adaptation, pitch discrimination and sound localization in the neonate," Child Dev. 35, 759–767.

Levitt, H. (1971). "Transformed up-down methods in psychoacoustics," J. Acoust. Soc. Am. 49, 467–477.

Moore, J. M., Wilson, W. R., and Thompson, G. (1977). "Visual reinforcement of head-turn responses in infants under 12 months of age," J. Speech Hear. Disord. 42, 328–334.

Trehub, S. E. (1973). "Infants' sensitivity to vowel and tonal contrasts," Dev. Psychol. 9, 91–96.

Wier, C. C., Jesteadt, H., and Green, D. G. (1977). "Frequency discrimination as a function of frequency and sensation level," J. Acoust. Soc. Am. 61, 178–184.

Wilson, W. R., Lee, K. H., Owen, G., and Moore, J. M. (1977). "Instrumentation for operant auditory assessment," unpublished manuscript, available from first author, Child Development and Mental Retardation Center, University of Washington, Seattle, WA 98195.

Wormith, S. J., Pankhurst, D., and Moffitt, A. R. (1975). "Frequency discrimination by young infants," Child Dev. 46, 272–275.

ERRATA

Erratum: "Shape oscillation and static deformation of drops and bubbles driven by modulated radiation stresses—Theory" [J. Acoust. Soc. Am. 67, 15–26 (1980)]

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The purpose of this erratum is to note errors of transcription in the above-article.[1] In the first paragraph of page 16, the text should read:

"... it is appropriate to expand x in terms of real ortho-normal spherical harmonic functions $\tilde{Y}_{lm}(\theta, \phi)$ which have positive integer l and integer m with $|m| \leq l$. These functions can be obtained from a linear combination[4] of the complex spherical harmonic functions Y_{lm} which are commonly used in quantum mechanics."

