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ABSTRACT

Pulsation threshold (PT) masking was used to assess frequency resolution among infants 3 and 6 months of age and adults. The masker intensity at which the pulsing probe becomes indistinguishable from a physically continuous probe is the PT. A measure of frequency resolution can be obtained by examining the effects of masker frequency on the PT. In the PT masking technique, two tone bursts were presented in alternation. As the intensity of the masker tone was increased, the probe began to sound continuously. Probe frequencies between 500 and 4,000 Hz were used. PTs were determined by randomly presenting signal trials in which a pulsating probe alternated with a pulsating masker of variable intensity or frequency; and no-signal trials, in which the probe was physically continuous and the masker remained pulsating. A blind observer judged whether a signal or no-signal trial had been presented, based on the infant's behavior. Infant responses to signals were reinforced by the activation of a mechanical toy. Preliminary results suggest that masker frequency affects 6-month-olds' and adults' PTs in much the same way. Frequency resolution becomes progressively better at higher frequencies. (Author/RH)

Pulsation Threshold Tuning Curves in 3- and 6-Month-Old Human Infants

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ABSTRACT

Frequency resolution, the ability to respond to one frequency component in a complex sound, underlies the ability to distinguish sounds. The limits of this ability, particularly during early infancy, are unclear. In this study, Pulsation Threshold (PT) masking was used to assess frequency resolution among 3- and 6-month-olds and adults.

In the PT masking technique, two tone bursts are presented in alternation. As the intensity of the "masker" tone is increased, the "probe" begins to sound continuous. The masker intensity at which the pulsing probe just becomes indistinguishable from a physically continuous probe is the PT. A measure of frequency resolution can be obtained by examining the effects of masker frequency on the PT.

Here, probe frequencies between 500-4000 Hz were used. PTs were determined by randomly presenting "signal" trials, on which a pulsating probe alternated with a pulsating masker of variable intensity or variable frequency, and "no-signal" trials, on which the probe was physically continuous and the masker remained pulsating. A blind observer judged whether a signal or no-signal trial had been presented, based on the infant's behavior. Infant responses to signals were reinforced by the activation of a mechanical toy.

Preliminary results suggest that masker frequency affects 6-month-olds' PTs in much the same way that it affects the adult's. Namely, frequency resolution becomes progressively better at higher frequencies. By contrast, while 3-month-olds' estimates of frequency resolution are similar to the 6-month-olds' and the adults' for a probe frequency of 500 Hz, frequency resolution does not improve between 500-4000 Hz. These behavioral data for 3-month-olds agree with auditory brainstem response measures taken at the same age (Folsom & Wynne, 1987).

METHOD

Subjects

To date, 12 3-month-olds, 12 6-month-olds, and 6 adults have completed testing in each of 4 experimental tasks.

Stimuli and Apparatus

The probe stimuli were 125-msec pure tone bursts with 10-msec rise/decay times and 125-msec intervals between bursts at either 500, 1000, or 4000 Hz. The masker stimuli were also 125-msec pure tone bursts with 10-msec rise/decay times and 125-msec intervals between bursts with frequencies described below. A low intensity of continuous broadband noise at 20 dB pressure spectrum level was also presented.

Infants were tested in an IAC sound-attenuated chamber. The adjoining control booth housed an Apple II-Plus microcomputer used by an observer to control the onset of the acoustic stimuli and to record all of the experimental contingencies.

Sounds were presented over a miniature earphone (Sony MDR-E242) in a small foam cushion which was placed in the infant's right ear at the concha and was secured with hypo-allergenic micropore tape. Infants were seated on the parent's lap in the center of the testing booth. The experimental set-up is shown in Figure 1.

Procedure

Infants were tested using the Observer-based Psychoacoustic Procedure (OPP) (Olsho et al., in press). An observer, blind to the stimulus type, judged whether a signal or no-signal trial occurred on the basis of the infant's behavior and recorded the judgments on-line. The only information available to the observer was the infant's behavior such as eye widening, brow raising, change in activity level, or head-turning, among others. The observer received feedback after each trial. The infant was reinforced by the activation of the mechanical toy to the infant's right whenever the observer correctly identified a signal trial. This procedure incorporates features of other infant testing techniques, including the conditioned head-turn procedure (Moore & Wilson, 1978) and the forced-choice preferential looking technique (Teller, 1979).

The definition of a signal depended on the task. The initial task was designed to determine each listener's threshold for the probe tone in the presence of the low level, broadband noise. In this probe-in-noise task a signal trial was one on which a series of 10 probe tone bursts and the continuous noise were presented. A no-signal trial was one on which only the broadband noise was presented.

For the PT tasks, a signal trial was one on which the probe and masker tone bursts alternated in the presence of the continuous broadband noise. The probe intensity was 10 dB above probe-in-noise threshold. For every 6 masker bursts there were 5 probe bursts. One probe burst was omitted after 5 probe bursts had occurred resulting in a 125-msec pause every 1375 msec. This pattern was repeated 5 times for a trial duration of 7.5 sec. No-signal trials were identical to the signal trials in every respect except that the probe tone was gated on with the onset of the first masker burst and gated off with the sixth masker burst. A 125-msec 'no-probe' interval was inserted to correspond to the omitted probe on signal trials. Like the signal trial, this pattern was repeated 5 times for a trial duration of 7.5 sec. These stimuli are illustrated in Figure 2. Thus, infants were trained to respond to a pulsating probe, and not to respond to a continuous one.

Each infant/observer pair was trained prior to threshold estimation. The mechanical toy became activated on every signal trial, regardless of whether the observer judged a signal to have occurred. The training phase continued until the observer correctly judged 4 of the last 5 signal trials and 4 of the last 5 no-signal trials.

During the testing phase of each task, one stimulus parameter (e.g., masker intensity or masker frequency) varied according to an adaptive procedure called the hybrid maximum-likelihood/PEST (Parameter Estimation by Sequential Testing) procedure (Hall, 1981). During this phase, the mechanical toy became activated only on signal trials on which the observer judged the signal to have occurred. Threshold was defined as the .70 p("yes") point on the best fitting psychometric function.

The masker was identical in frequency to the probe for the first PT task (on-frequency condition). During training, the masker intensity remained 25 dB lower than the probe. This sounds like two alternating tone bursts of equal frequency but different intensity. During the testing phase the intensity of the masker was varied to find the level at which signal trials could no longer be distinguished from no-signal trials.

In the other two tasks, masker frequency was varied (off-frequency conditions). Logically, if frequency resolution is good, then at any given level, the masker frequency can be brought quite close to the probe frequency without interfering with (i.e., masking) perception of the probe. Conversely, if frequency resolution is poor, such interference will occur at frequencies more remote from the probe. In one condition, masker frequency began above the probe and moved toward it; in the other condition, masker frequency began below the probe. The measure of frequency resolution used was the distance between these two frequencies at PT.

During training, the masker frequency was set at a value which made signal and no-signal trials easy to distinguish. Masker intensity was held constant at 10 dB above the PT in the on-frequency condition. The order of testing the two off-frequency maskers was counterbalanced across subjects in each age group and frequency condition.

RESULTS

Psychometric Functions

The psychometric function shows the proportion of correct judgments on signal trials as a function of some stimulus parameter. Figure 3 shows representative psychometric functions for each age group and probe frequency condition. The infant and adult functions differ in two respects. (1) The upper asymptote is lower for more of the infant functions than it is for the adult. (2) The lower asymptote, i.e., the false alarm rate, is generally higher for the infant functions than for the adult.

Probe-in-Noise Thresholds

As shown in Figure 4, the 3-month-olds' probe-in-noise thresholds were worse than the 6-month-olds', whose thresolds, in turn, were worse than the adults'. These age differences held up at each frequency.

Pulsation Thresholds: Age by Frequency Effects

To determine if there were different patterns of frequency resolution across age groups, Q10, a frequently used estimate of frequency resolution, was inspected. It is calculated by dividing the difference between the PTs expressed in Hz for masker frequencies above and below the probe frequency into the probe frequency. The bigger the Q10 value, the better the frequency resolution and the narrower the v-shaped curve. In accord with other behavioral data (Nozza & Wilson, 1984; Olsho, 1985) 6-month-olds and adults showed improved frequency resolution with increasing probe frequency as illustrated by narrower v-shaped curves with increasing probe frequency in Figure 4 and bigger Q10s wih increasing probe frequency in Figure 5. Three-month-olds showed a different pattern of frequency resolution. Although similar to the older infants and the adults at a relatively low frequency (500 Hz), the 3-month-olds did not show improved resolution with increasing frequency.

Pulsation Thresholds: Age Effects

A comparison between the probe-in-noise and on-frequency PTs revealed that the 3-month-olds were most susceptible to pulsation masking. At each probe frequency, masker intensity was lower than probe intensity at pulsation threshold for the 3-month-olds. By contrast, masker intensity was equal to or higher than probe intensity at pulsation threshold for the 6-month-olds and the adults.

CONCLUSIONS

- This study was the first attempt to examine frequency resolution behaviorally from infants younger than 5 months of age and was the first to use a non-simultaneous masking technique to obtain a measure of frequency resolution from infants.

- Like adults, 6-month-olds show improved frequency resolution with increasing frequency and the degree of resolution is the same as it is for adults. These data agree with those of Olsho (1985) who tested 5- to 8-month-olds with a simultaneous masking technique.

- Three-month-olds show similar frequency resolution to 6-month-olds and adults at a relatively low frequency (500 Hz). Unlike the older listeners, the 3-month-olds did not show improved resolution with increasing frequency. These data agree with auditory brainstem response measures from 3- and 4-month-olds (Folsom & Wynne, 1987).

- Both 3- and 6-month-olds show greater susceptibility to masking than adults; PTs occur at lower masker intensities for the infants than for the adults.

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Figure 1

Experimental Set-Up

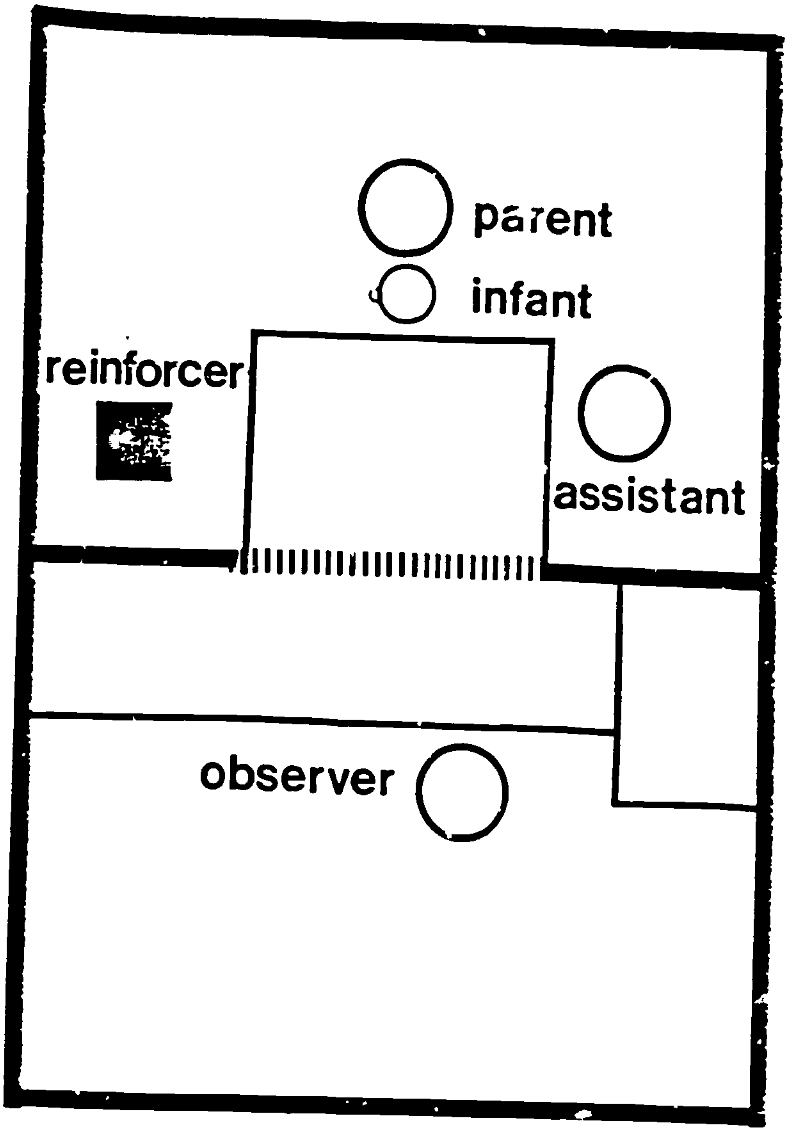


Figure 1. Laboratory layout for infant testing using the Observer-Based Psychoacoustic Procedure.

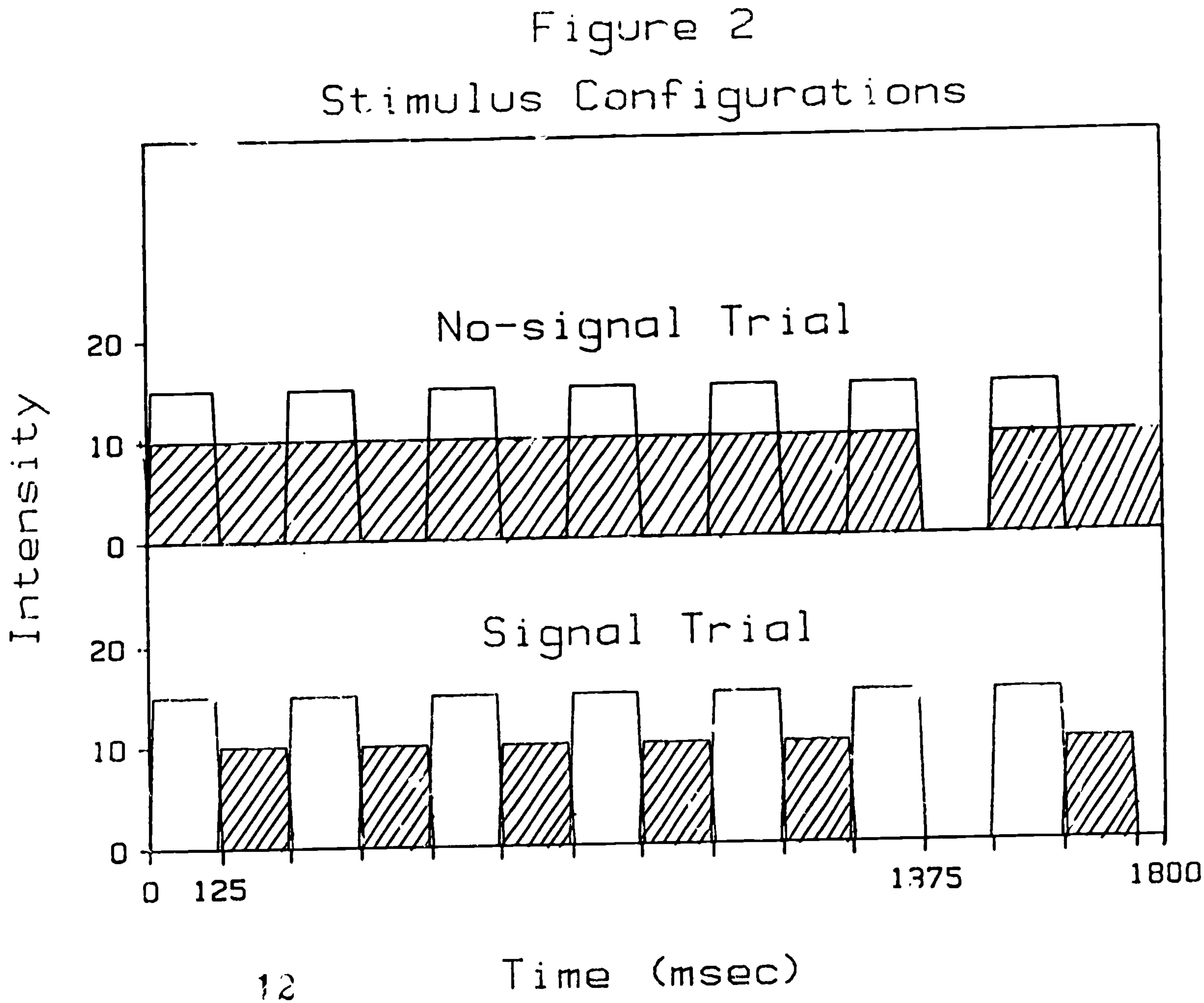
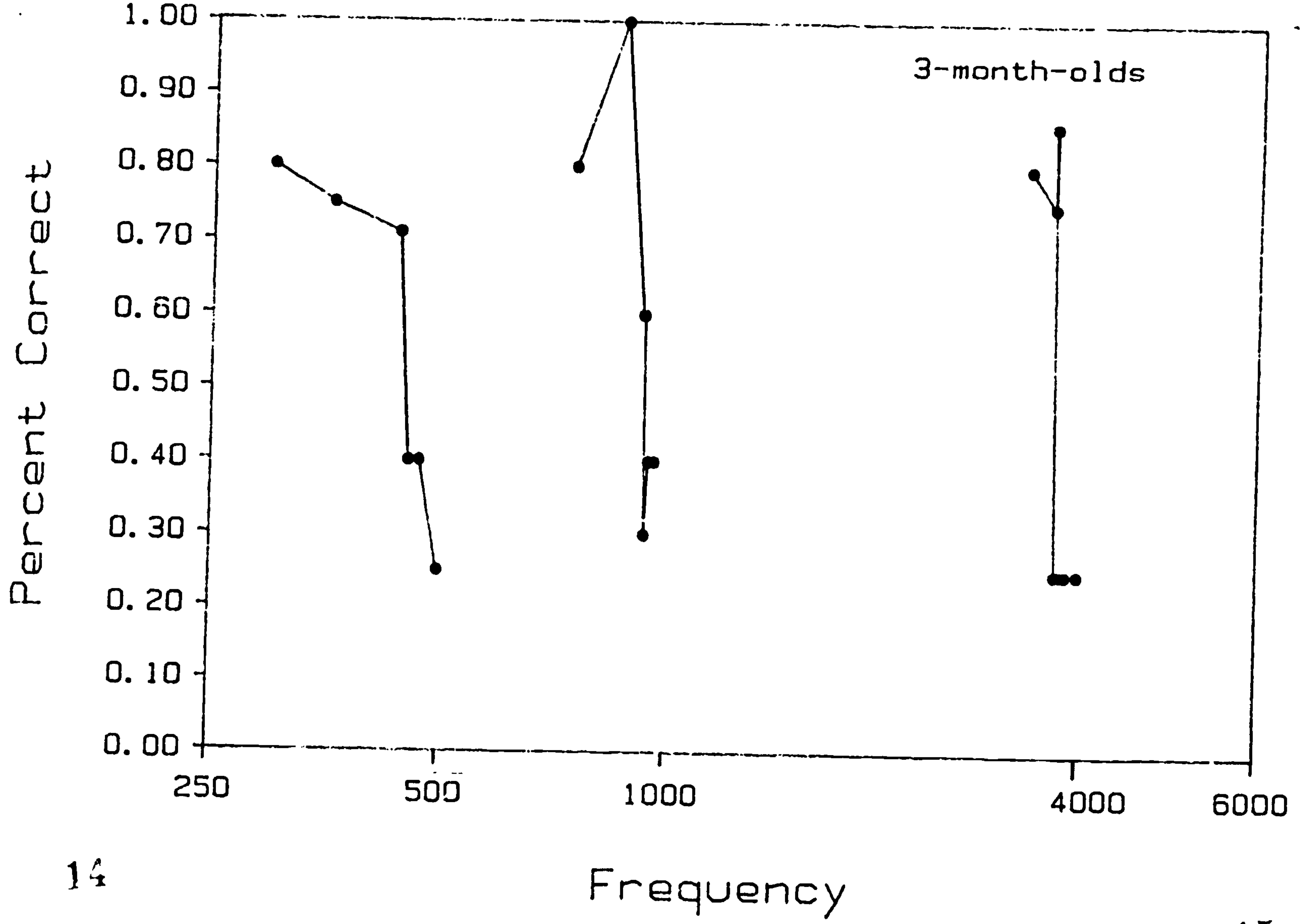


Figure 2. Stimulus Configurations for signal and no-signal trials. Probe tones are depicted with hash-marks and masker tones are plain. A low level (20 dB pressure spectrum level) of white noise was presented in addition to the two pure tones, shown.

Figure 3A
Psychometric Functions



Figures 3A, 3B & 3C. Representative psychometric functions from individual 3- and 6-month-olds and adults. Shown are examples in which masker frequency was varied to determine the pulsation threshold. For these subjects, masker frequency started below probe frequency.

Figure 3B

Psychometric Functions

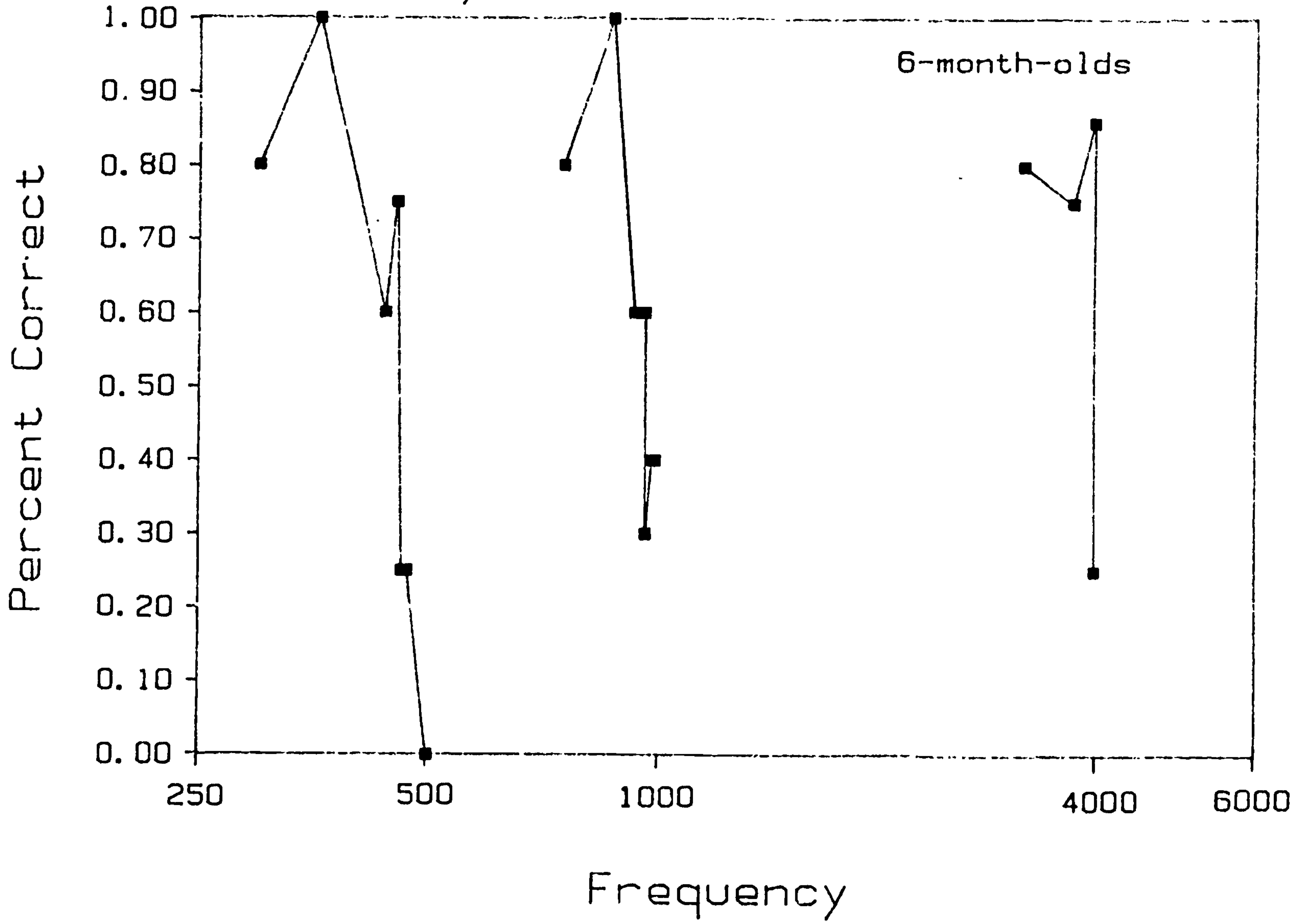
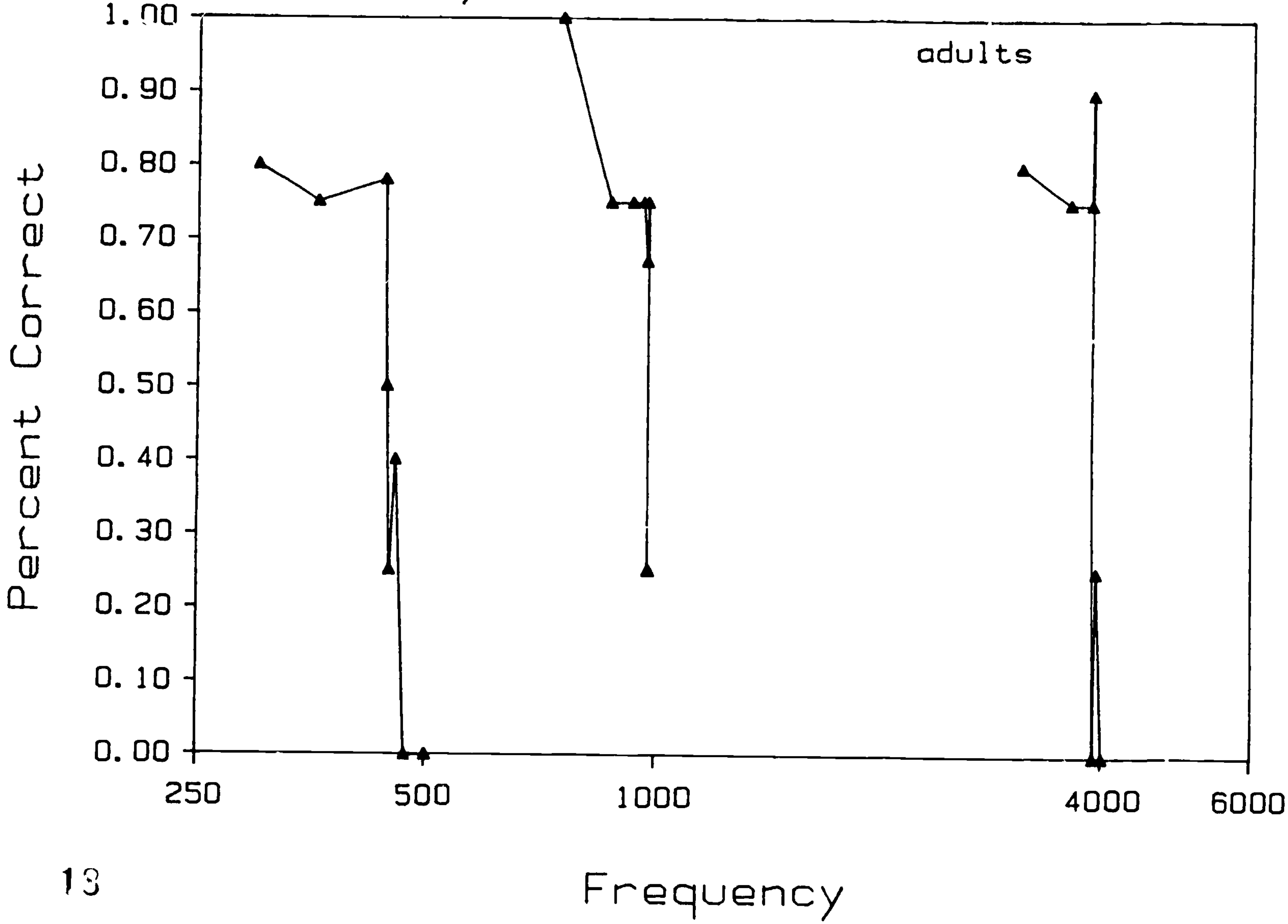


Figure 3C

Psychometric Functions



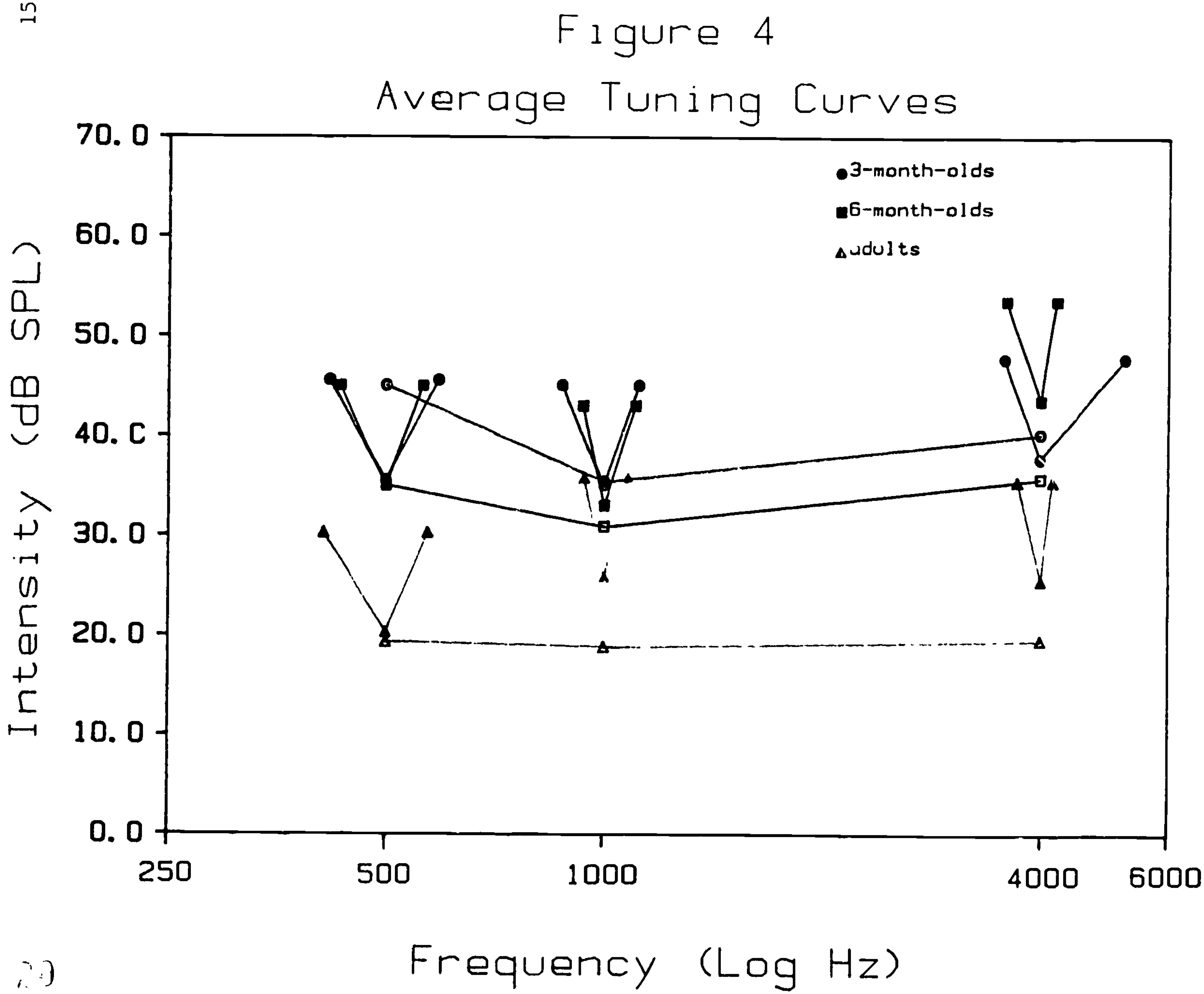


Figure 4. Masker intensity as a function of masker frequency at pulsation threshold averaged across subjects at each age (filled symbols). Opened symbols show average probe-in-noise thresholds as a function of probe frequency for each age group.

Figure 5

Individual Q10s.

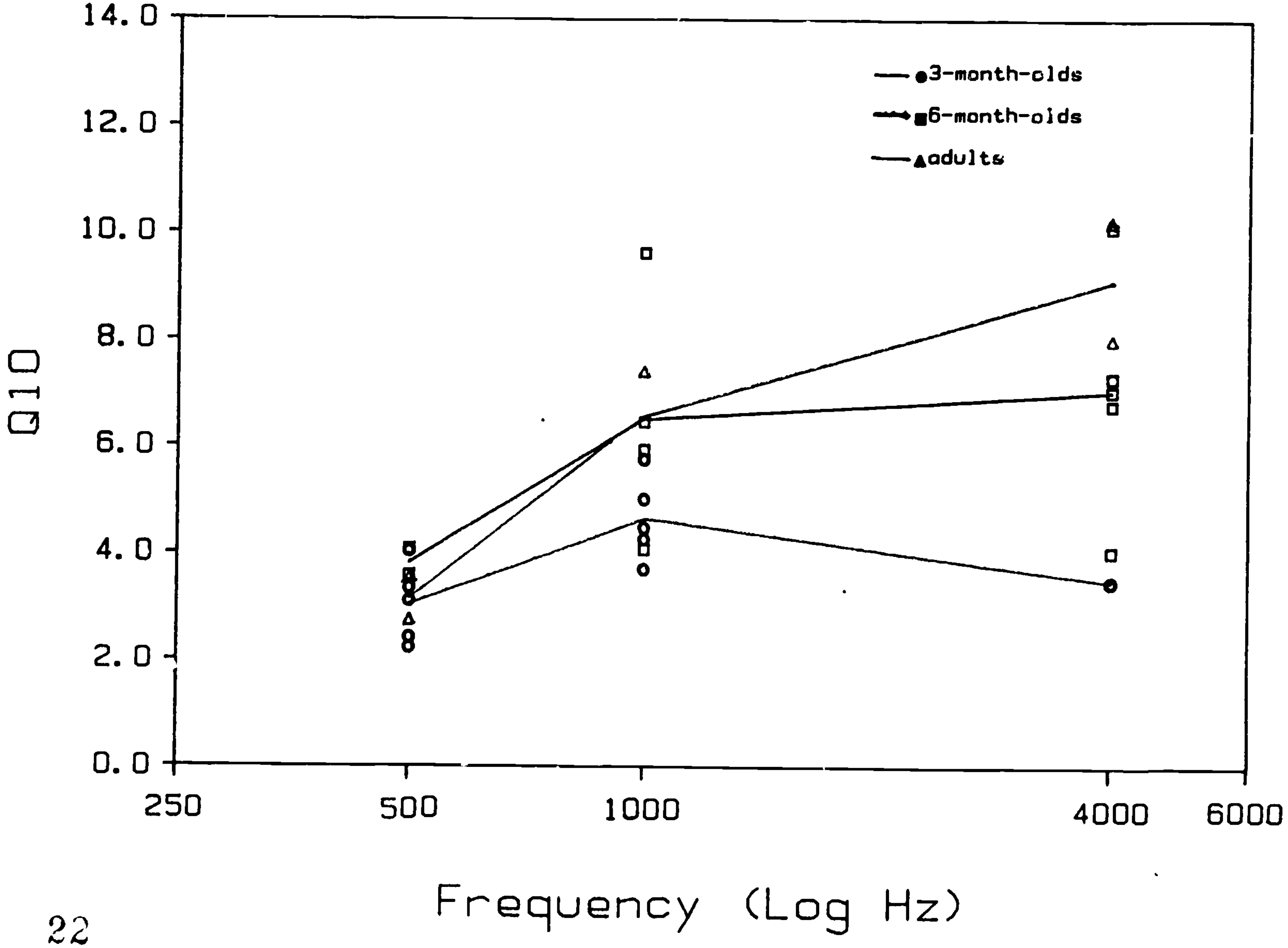


Figure 5. Individual Q10s are shown as a function of frequency for each age group (symbols). Lines connect average Q10s for each age group. The bigger the Q10, the better the frequency resolution.