Brief Tone Discrimination by Children with Histories of Early Otitis Media

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Abstract

Twelve children, ranging in age from 8.9 to 12.4 years, with histories of severe otitis media with effusion (OME) before age 3, were compared to age-matched cohorts in their ability to discriminate the frequency of tone pulses of 20-, 50-, and 200-msec duration. An adaptive procedure was used in combination with a two-alternative forced-choice paradigm to measure difference limens (DLs) for digitally generated 1000-Hz tones. The OME group exhibited larger DLs than the non-OME group at all three stimulus durations. These results provide tentative evidence of possible long-term effects of early OME on brief tone frequency discrimination.

Key Words: Auditory development, children, frequency discrimination, otitis media, sound deprivation

Abbreviations: ANOVA = analysis of variance, dB HL = decibels re hearing level, dB SL = decibels re sensation level, DF = frequency difference, DL = difference limen, OME = otitis media with effusion, PTA = pure-tone average

There is considerable evidence (Batkin et al, 1970; Webster and Webster, 1977, 1979, 1980; Clements and Kelly, 1978; Clopton, 1980; Feng and Rogowski, 1980) that depriving young animals of normal sound stimulation may result in abnormalities in the neural development of the central auditory pathways. Whether comparable effects may occur in humans has been a source of scientific debate for many years (Hanson and Ulvestad, 1979; Ventry, 1980; Paradise, 1981; Moore, 1985; Antebay et al, 1986; Finitzo et al, 1990). In particular, the question of whether sound deprivation associated with early otitis media with effusion (OME) may produce long-term problems associated with language or higher order auditory processing skills has been the focus of considerable research. While some of the studies have found evidence that OME may effect development of language or auditory processing skills (Lewis, 1976; Zinkus and Gottlieb, 1980; Brandes and Ehinger, 1981; Sak and Ruben, 1981; Jerger et al, 1983; Feagans et al, 1990; Friel-Patti and Finitzo, 1990; Gravel and Wallace, 1992; Hall and Grose, 1993; Brown, 1994; Hall et al, 1995); other investigations have not found such effects (Allen and Robinson, 1984; Fischler et al, 1985; Black et al, 1988; Rach et al, 1988; Wright et al, 1988; Teele et al, 1990; Roberts et al, 1991; Harsten et al, 1993).

While of immense clinical importance, the use of complex language and/or higher level auditory processing functions as dependent variables has added complications to studies in this area. It may be appropriate to study more basic aspects of the effects of early sound deprivation on discrimination of the individual physical parameters of sounds, such as rate, duration, and frequency, etc., that are believed to form the psychophysical substrate for normal speech perception. The present report describes findings from a retrospective investigation that obtained evidence that some children with histories of
early OME may be impaired in their ability to discriminate the frequency of short-duration tone pulses.

**METHOD**

**Subjects**

Twenty-four children were tested in the present study. The OME group (eight males, four females) ranged in age from 8.9 to 12.4 years (mean: 10.5) while the non-OME group (six males, six females) ranged from 8.9 to 11.9 years (mean: 10.5). All children in the OME group had been medically diagnosed as having had chronic middle ear disease with effusion prior to their third birthday. Medical records indicated that all 12 children had had two or more bilateral myringotomies with tubes. No child was included in the non-OME group who, according to parental report, had had episodes of OME that required medical treatment. All children were from middle-class Caucasian family backgrounds with English as the primary spoken language.

Children in both groups had pure-tone audiometric thresholds of 15 dB HL or better bilaterally at all octave frequencies from 500 to 8000 Hz. The OME group had a mean pure-tone average (PTA) threshold (for frequencies of 500, 1000, and 2000 Hz) of 10.7 dB HL (SD: 4.4) at the right ear and 11.5 dB HL (SD: 3.9) for the left ear. The respective mean PTAs for the non-OME group were 11.3 (SD: 3.2) and 9.9 (SD: 4.7) dB HL. Tympanometry indicated that all subjects had normal middle ear pressure and compliance (peaks between -100 and +50 mmH2O) in both ears. No child was included in the study who had a history of major medical or behavioral problems or had received remedial educational services.

**Tone Generation Procedures**

Digitally generated 1000-Hz pure-tone stimuli, with linear rise/fall times of 5 msec (0–100% of full amplitude) and steady-state (plateau) durations of 190, 40, and 10 msec, were presented in quiet to the test ear (ear with better PTA threshold at 500, 1000, and 2000 Hz) at 50 dB SL relative to each of the three standard stimuli. Stimuli were generated using a 80486-based microcomputer with a Data Translation DT2823 data acquisition card serving as the analog signal input/output interface. All signals were generated at a 20-kHz sampling rate. After conversion to analog form, the tones were amplified by a Crown D75 amplifier and presented to the subject through a KOSS earphone. Subjects were tested in a sound-treated audiometric test booth.

**Psychophysical Test Procedure**

The subject was seated inside the test booth in front of a color computer monitor. The test protocol consisted of a two-alternative, two-interval forced-choice paradigm developed by Hall and Wood (1984). In each trial, a monitor display was presented that consisted of a 300-msec warning light, followed by two 600-msec observation intervals marked by the occurrence of two different colored square graphics ("red" followed by "green"). The two intervals were separated by a 600-msec pause. Standard and comparison stimuli were presented in each interval. The standard and comparison tones were the same duration, and the comparison tones occurred 200 msec following the offset of the standard tones. In one interval (randomly determined), the two tones were of equal frequency; in the other interval, the comparison tone was higher in frequency. The subject was required to verbally indicate which interval contained the "different" tones. The experimenter then entered the response at the computer keyboard. Feedback was provided by briefly presenting the appropriate red or green square graphic on the subject’s monitor.

An adaptive procedure (Levitt, 1971) was used in which the frequency difference (DF) between the standard and comparison tones was increased following an incorrect response or a correct response followed by an incorrect response (+,–), and decreased after two consecutive correct responses (+,+) . This procedure estimates the 70.7 percent threshold level. For the first four reversals, the DF was changed by a factor of 2.0. After four reversals, the change factor was reduced to 1.25. A run was terminated after 13 reversals, and the difference limen (DL) was taken as the average of the last nine reversals. In each test, the initial starting DF for the 200-msec duration tones was 25 Hz. For tones of 50- and 20-msec duration, the starting DF was 37 and 50 Hz, respectively.

Prior to testing, all children received a preliminary training session. The first stage of training consisted of presenting a series of trials involving 200-msec tones with a DF of 300 Hz. After the children accurately responded to five consecutive trials with these longer tones, they were further trained until they exhibited...
five consecutive correct responses respectively to trials containing 50-msec tones with a DF of 300 Hz and then to trials with 20-msec tones and a DF of 1000 Hz. The second phase of training required the child to discriminate progressively smaller frequency differences with 200-msec tones. Using an initial DF of 25 Hz and a frequency change factor of 2.0, this procedure followed the psychophysical step procedure described in the previous paragraph until eight reversals were obtained. Following training, the formal testing was given. Each test duration was tested twice, and the order of the six subtests was determined using Latin square logic. The total testing time, including training, for each child averaged 60 minutes. A brief rest break was presented at the session midpoint.

RESULTS

Table 1 shows the means and standard deviations of the frequency DL obtained by the two subject groups at each tone duration, while Figure 1 shows performances of individual subjects in each group. Considerable variability in performance was seen with the OME children. Eight of the 12 children in this group exhibited frequency DL with both 20- and 200-msec duration tones that fell more than two standard deviations beyond the mean of the control group. At 50 msec, only 5 of 12 children exceeded this limit.

DISCUSSION

The present finding that some children with histories of early otitis media may be impaired in discriminating the frequency of short duration tones may have important implications for the effects of this common childhood disease on normal language development. Frequency discrimination is an analytic function that is critical for normal speech understanding (DiCarlo, 1962; Gengel, 1973; Ritsma et al, 1980; Marshall, 1981; Lyregaard, 1982; Dreschler and Plomp, 1985). In addition to allowing perception of vocal inflections and the emotional properties of ongoing speech, good frequency analysis abilities are necessary for discrimination of various short-duration components of speech, such as discriminating among vowels with closely adjacent formant frequencies and among spectrally similar consonants. Researchers (Liberman et al, 1967; Stevens and Klatt, 1974; Strange et al, 1976) have documented the contributions of such short-duration events as consonant-vowel and vowel-consonant transitions, noise bursts, stop-release aspirations, etc., to the intelligibility of speech. It may well be that the ability of the auditory nervous system to perform a fine-tuned, short-duration spectral analysis on these types of sounds is a crucial component in speech intelligibility.

The two-alternative forced-choice paradigm used in the present research was selected because of its successful use by Hall et al, (Hall and Fernandes, 1983; Tyler et al, 1983; Hall and Wood, 1984) in investigations of brief tone discrimination in young adults with cochlear hearing loss. As with other forced-choice paradigms, the task requires subjects to attend, discriminate, and briefly “remember” the perceived differences until allowed to elicit a response. Therefore, it is not possible to determine whether the poorer performances by the present OME subjects were due to sensory, motivational, or some form of subtle cognitive deficit (e.g., attentional, short-term memory).
REFERENCES


