Psychoacoustic Development in Humans and the Effects of Otitis Media on Psychoacoustic Development

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Abstract: Chronic otitis media in early childhood has often been related to subsequent difficulties in speech and language development. Our interest has been in the sequelae of the transitory hearing losses associated with otitis media with effusion (OME) on the development of auditory functions after the return of normal hearing sensitivity in quiet. In parallel to this, we have also been interested in chronicling the development of various psychoacoustic functions in children with no history of hearing loss. This review will describe these two lines of investigation and will highlight current trends in this area.

Psychoacoustic measures of auditory development in children with normal hearing and fluctuating conductive hearing losses reveal several general trends. First, processing efficiency is usually reduced in young children. One manifestation of this is that they require higher signal-to-noise ratios (SNRS) to reliably detect the presence of a signal in a masker. Nevertheless, measures that are derived from these masked thresholds often indicate mature auditory function. For example, measures of frequency selectivity that are derived from notched-noise masking paradigms can be adult-like even in children as young as 4 years of age. The finding that young children require higher SNRS, yet can exhibit derived measures on a par with adults can also be seen in measures of binaural processing using the masking level difference (MLD). Children as young as 5 years of age exhibit MLDs of adult-like magnitude for broad-band maskers, although the raw masked thresholds show a strong age effect. This maturity of binaural function extends also to sensitivity to off-midline stimuli. Children, like adults, show approximately the same reduction in MLD magnitude as the signal/masker phase is drawn up to 180 degrees off midline. For narrow-band maskers, however, young children have particular difficulty extracting the tonal signals, a difficulty which is not simply a reflection of the perceptual similarities between the signal and the masker.

A second manifestation of processing inefficiency in young children is evident in the temporal domain. Measures of temporal modulation transfer functions (TMTFs) reveal that overall sensitivity to amplitude modulation generally improves with age, although the shape of the function is relatively constant with age (i.e., TMTF time constants are relatively age-invariant). We interpret this as showing that the encoding of the temporal envelope in the auditory periphery is probably mature by even 4 years of age, although the efficiency with which the modulation information is processed develops well beyond this age. That is, the mechanism for encoding temporal fluctuations may be intact years before the skills for processing temporal fluctuations are mature. This interpretation is supported by studies on more complex across-frequency processing of temporal fluctuations, including monaural and dichotic comodulation masking release (CMR) and the detection of signals in multiple modulation patterns. Measures of CMR appear to be adult-like by early childhood, confirming that the mechanism for encoding temporal fluctuations is largely intact in young children and that their difficulty in extracting signals from narrow-band maskers does not reflect a reduced ability to encode the fluctuating envelope. When multiple modulation patterns are present, children and adults both exhibit the same pattern of performance: signal detection is less disrupted when a second modulation pattern is completely interwoven with the first modulation pattern than when the second pattern is only partially interwoven with the first pattern. However, the pattern of CMR results from children and adults differ when the temporal synchrony between the onsets of the various comodulated bands of noise making up the masker are varied. Children appear to be less tolerant of asynchronies than are adults. Our interest in the perceptual performance of children under conditions of temporal asynchrony extends also to studies of non-simultaneous masking, particularly backward masking, where the performance of children appears to be more variable than adults.

In terms of psychoacoustic measures of auditory development in children with fluctuating conductive hearing losses, one general trend that has emerged is that deficits in function due to early transitory hearing loss do not
appear to be permanent; rather, the duration of abnormal performance appears to be strongly associated with the specific function being measured. This trend has emerged from our major emphasis on the effects of early chronic otitis media with effusion (OME) on auditory development. For many years it has been speculated that OME may have negative effects on the development of speech, language, and hearing. Our focus has been on the detection of signals in noise backgrounds. Our usual approach has been to measure performance just before a child receives tympanostomy tubes, and then to repeat testing at specific intervals (often over several years) following the return of a normal audiogram. Our investigations have indicated that OME does not generally result in impairment for a simple task of detecting a pure tone in a narrowband noise masker. However, conceptually more complex tasks often are associated with abnormal performance even in the presence of a normal audiogram. Abnormal performance may persist for months or for years, and the duration of abnormal performance appears to be strongly associated with the specific auditory function being measured. For example, a simple CMR task is often associated with degraded performance soon after the normal audiogram is restored, but performance is usually in the normal range by approximately six months. In contrast, a more complex task where more than one modulation pattern is present simultaneously appears to be associated with a longer period of recovery. Likewise, performance on the MLD task is often associated with gradual improvement that can take place over a duration of several years. One interpretation of these findings is that auditory function is most efficient when the central auditory system is able to develop consistent strategies for analyzing peripheral information that is relatively constant given a constant physical input. When a child has OME, a constant physical stimulus may result in different patterns of neural information, depending upon the current state of the disease. While the chronic OME condition persists, the establishment of optimally efficient strategies of auditory analysis may be precluded. Once the OME condition has resolved, the auditory system can begin operating on a more reliable relation between physical input and the auditory representation of the input. This stable relation may allow an optimization of auditory analysis, a process that may take longer for relatively complex analyses.

ACKNOWLEDGMENTS

The work described in this review has been supported by the NIH NIDCD.