Commentary on "Development of Frequency Perception in Infants and Children" by K.D. Fenwick and B.A. Morrongiello

Commentaires au sujet de "Élaboration d'une perception des fréquences chez les nouveaux-nés et les enfants" par K. D. Fenwick et B. A. Morrongiello

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Fenwick and Morrongiello's thorough review of developmental research on frequency perception in infants and young children examined methodologies typically used in research settings. Many methodological problems specific to audiometric testing of young children and infants were discussed. The authors also reviewed developmental trends exhibited in auditory functioning. The focus of this commentary will be on how these testing methods and research findings relate to and differ from clinical paediatric audiology.

Because infants cannot be tested using conventional audiometric techniques, the clinical audiologist must use testing procedures that rely heavily on examiner observations and judgements. Visually reinforced audiometry (VRA) is most commonly used for testing infants or developmentally delayed children (Stelmachowicz, Larson, Johnson, & Moeller, 1985). VRA is essentially the same as the conditioned head-turn technique. When using VRA, two-examiner testing is recommended (Stelmachwicz et al., 1985). In two-examiner testing, one examiner operates the audiometer, while the other sits in the test booth with the child to serve as a distracter between the stimulus presentations, to reinforce for correct responses, and to judge whether or not the child responds to sound. Headphones, which Fenwick and Morrongiello recommended be worn to mask the test signal, typically are not used for this purpose, possibly because they prevent the examiner from hearing the signal while trying to establish the conditioned response. Headphones also are used to allow the examiner outside the test booth to communicate with the examiner inside the booth. By using the headphones as a communication system, examiners can compare judgements as to whether or not the child responded to the test stimulus, thus improving test reliability. Unfortunately, even though headphones used as a communication system enhance the testing procedure, they do not prevent parents or examiners from giving the child non-auditory cues. Perhaps if masking headphones with a talkover option were used by the examiners and parent, non-auditory cues would be reduced, while communication is maintained between the examiners.

Fenwick and Morrongiello also reported on developmental trends in hearing sensitivity, specifically, in pure tone thresholds, masked thresholds, and critical bandwidths. Although test stimuli, subject criterion, and procedural differences make cross study comparisons difficult, results indicate that neonates and very young infants are more sensitive to lower than to higher frequency stimuli, with sensitivity improving as a function of age. Although the physiological basis for these results has not been clearly identified, other findings support the idea that the auditory system is still developing after birth. For example, developmental changes in the external ear canal resonance (Kruger,1988; Feigin, Kopun, Stelmachowicz, & Gorga, 1989) have an effect on the sound pressure level reaching the eardrum. This effect is dependent on the peak resonance of the ear canal, which decreases from approximately 7000 Hz at birth (Kruger, 1988) to approximately 2000 Hz at 60 months (Feigin, Kopun, Stelmachowicz, & Gorga, 1989). Clinically, however, these developmental trends may not be measurable due to the variability in measurement procedures resulting from the particular stimulus delivery system used.

Typically, the stimulus delivery system used clinically incorporates the sound field, but supra-aural headphones or insert earphones can also be used. VRA thresholds measured in the sound field will be affected by the accuracy of the sound field calibration and by the noise floor of the test booth (Berger, Wald, Morrill, & Royster). Ambient noise levels of up to 62 dB SPL at 8000 Hz are considered acceptable for sound treated audiometric test suites (OSHA, 1983). The authors recommended the use of headphones in threshold testing in order to obtain ear specific data. Unfortunately, conventional supra-aural headphones are problematic because of the poor fit they provide for an infant, the low frequency leakage that occurs, the problem with test-retest reliability of headphone measures, and the resistance often encountered when attempting to place them on the head of a very young child (Skinner, 1988). An alternative to using these headphones is the ER-3A insert earphone. The insert earphone offers greater potential for obtaining monaural information because it is less cumbersome, leakage is reduced due to a better fit, control over placement is greater, and a child may more readily wear the insert earphone. Perhaps if measurement variability is reduced, subtle developmental changes will be able to be measured.

Once a more reliable/accurate testing system is available the developmental trends in hearing sensitivity may become more important. Of interest is how these developmental trends are affected by a hearing impairment. Early intervention is an important part of the rehabilitation process (Ross & Seewald, 1988). This intervention includes selecting an appropriate amplification system. The effect or interaction of these developmental changes on a hearing impairment is worth investigation because it may have implications for hearing aid fittings and for the monitoring of a child's hearing over time. If developmental psychologists can measure age-related changes in the lower boundary of the auditory area (i.e., thresholds), perhaps there are age-related changes in the upper boundary of the auditory area (i.e., loudness discomfort levels). If loudness discomfort levels (LDLs) could be measured reliably in young children or infants, audiologists could use this information to help set the upper limit of hearing aids in young hearing impaired children. Unfortunately, the youngest age at which LDLs have been reported reliably is five (MacPherson, Elfenbein, Schum, & Bentler, 1989).

Fenwick and Morrongiello's review illustrates that although much has been learned about infant frequency perception, a great deal more needs to be known. The authors point out that it is difficult to assess frequency perception in young infants and young children. With both researchers and clinicians working together the potential to answer some of these questions is great. D. L. C. Z.

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Fenwick and Morrongiello's article is a stimulating review of methods and recent findings from behavioural studies of frequency specific auditory development in humans. The description of techniques and suggestions for improving certain aspects of infant testing and observation may be useful to the clinical audiologist. The review of recent research raises several important theoretical and clinical issues that also illustrate the potential difficulties of test interpretation for a sensory system that matures differentially along various physiological dimensions.

For the clinician, the overview of behavioural techniques now used in research laboratories is valuable. The review makes clear that, with the careful selection of a testing procedure, sufficient testing time, and ample personnel, reliable evaluations of auditory function can be obtained from most developmentally normal infants older than four months and perhaps even younger. Unfortunately, many audiology clinics lack the flexible or programmable computer equipment needed to institute these specialized testing procedures. The limited amount of testing time resulting from heavy patient loads also may preclude the use of many of these techniques. Many of the research methodologies outlined by Fenwick and Morrongiello may not be practical for the audiologist in a hospital setting who is often asked to assess the integrity of auditory function in an infant that may be developmentally delayed or neurologically impaired. Poor performance of an infant or youngster in either a reflexive or conditioned response task may not reflect impaired auditory function but motor or sensory-motor dysfunction. As indicated by the authors, signal detection analysis techniques can be used to separate response tendencies from actual sensitivity. Signal detection analysis may also be useful for separating hearing sensitivity from other dysfunctional systems in the developmentally delayed or neurologically impaired patient. Unfortunately, most clinical audiologists lack the requisite theoretical and practical background necessary to apply these techniques.

Beyond practical issues of clinical implementation of research methods, this article also raises interesting theoretical issues. For example, patterns of frequency specific auditory development obtained in behavioural and electrophysiological studies are inconsistent. Based on a thorough review, Fenwick and Morrongiello conclude that threshold differences between infants and adults are larger for lower frequency than for higher frequency stimulation. Developmen-tal changes in masking and critical bands demonstrate larger adult/infant differences as well as a more prolonged period of threshold change for low frequency sound. In contrast, results from electrophysiological studies of auditory brainstem maturation using the auditory brainstem response (ABR) have shown that peak latencies approach adult values earlier for responses produced by lower rather than by higher frequency stimuli (Teas et al., 1982). ABR tuning curves obtained from infants also develop adult-like characteristics earlier for lower than for higher frequency stimulation (Folsom & Wynne, 1986).

Several factors may contribute to this discrepancy. To begin with, the physiological locus of development evaluated in behavioural and electrophysiological studies may be different. The behavioural findings reported by Fenwick and Morrongiello were obtained primarily from infants older than five to six months. For example, Trehub et al. (1988) found continued improvement in low frequency sensitivity until 10 years of age. By contrast, the largest changes in the ossicles, the cochlea, and in the brainstem auditory pathway of humans occur prior to 40 weeks conceptual age, or normal term birth. The ossicles of the middle ear attain human dimensions by about 30 to 36 weeks conceptual age (Anson, 1984). Most aspects of anatomical and functional development in the human cochlea are completed by 30 to 32 weeks of age (Pujol, 1985), although some minor changes in frequency selectivity may persist at three months of post-term age (Folsom & Wynne, 1986; 1987). The largest changes in ABR estimates of auditory brainstem maturation also occur before term birth. Much smaller and slower developmental changes do continue postnatally until about three to five years of age. However, by three years of age, most characteristics of the ABR are adult-like (Teas et al., 1982; Eggermont, 1986; Eggermont & Salamy, 1988).

The presence of marked differences in behavioural tests of sensitivity between adults and children older than three years suggests the probability that the primary locus of these changes is not in the cochlea or the auditory brainstem. Prolonged maturation of behavioural auditory function may reflect ongoing developmental changes at other locations in the auditory pathway. For example, the resonant frequency of the external auditory canal is initially higher in young infants than in adults but decreases to the mature adult resonant frequency of 2.7 kHz by about two years of age (Kruger & Ruben, 1987). This shift in external ear canal resonant frequency might influence the pattern of frequency specific sensitivity obtained in behavioural studies. In addition, cortical maturation continues long after brainstem development is complete. Therefore, developmental changes in auditory cortical function also may contribute to the prolonged maturation patterns found in behavioural studies.

Finally, the differing results in electrophysiological and behavioural studies of auditory development might be due in part to methodological factors. As noted by Fenwick and Morrongiello, auditory testing for infants typically relies on reflexive unconditioned responses or operantly conditioned responses, while adult responses are voluntary. It may not be appropriate to compare auditory thresholds for voluntary responses from older infants or adults with involuntary or conditioned responses from younger infants. Even within the developmental populations, stimuli of equal physical intensity but different frequency may not have equal potential for producing a conditioned or unconditioned response. Indeed, some frequency specific differences noted in behavioural investigations could be related to the response output rather than the sensory input portion of the auditory function.

Electrophysiological studies of frequency specific development are not immune to methodological criticism. Particularly in infant populations, relatively high stimulus presentation levels are necessary to obtain a robust ABR. When stimulus presentations levels exceed 40 to 50 dB above threshold, place specific activation of the cochlea may be compromised significantly. For a low ABR generated by a low frequency stimulus, the site of generation may be shifted toward regions of higher frequency representation closer to the base of the cochlea (Klein & Teas, 1978). Unless this upward spread of activation is avoided, low frequency responses may actually be dominated by activity from higher frequency regions of the cochlea. Thus, observed patterns of development found in electrophysiological studies, as in behavioural studies, may be affected by the techniques used to measure auditory maturation.

Fenwick and Morrongiello provides a useful and provocative background of current methods and results in behavioural auditory research. Implementation of their suggested changes to clinical protocols, although not practical in all cases, may improve the reliability of infant hearing assessment. A comparison of developmental patterns obtained from behavioural and electrophysiological auditory studies suggest that interdisciplinary investigations might be beneficial. Studies that combine measures of anatomical development, measures of sensory maturation unaffected by behavioural response paradigms such as the ABR, and behavioural responses presumably requiring auditory cortical function may yield a more complete and accurate evaluation of auditory development.
C.W.P.

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