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A Sound Foundation Through Early Amplification

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Aided cortical auditory evoked potentials: bridging the gap between early hearing aid fitting and behavioral assessment

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Abstract

As a result of newborn hearing screening, hearing aids are typically prescribed and fitted by 2-3 months of age. However, the assessment data used when prescribing hearing aids in this age group is limited in quality and quantity. There is an urgent need to supplement existing practices, by developing procedures that provide information about the appropriateness of amplification, at an earlier stage of the care pathway. Studies are underway to assess the use of aided sound field obligatory cortical auditory evoked potentials (CAEPs) in infants. The detection of an aided CAEP has the potential to provide reassurance that sounds are being physiologically detected by the auditory system and motivate parents to persevere with hearing aids; not a trivial matter in infants who might not immediately demonstrate benefit. An absent CAEP response will alert the clinician to the need to review the existing prescription and consider alternative management options. By addressing this urgent need, the current project has the real potential to improve clinical management of children with hearing loss at an earlier stage in the care pathway.

Introduction

Permanent childhood hearing impairment (PCHI) is the most common childhood sensory deficit with a prevalence of around 1-2 per 1000 births (Fortnum et al., 2001). It is a potentially devastating long-term condition because of its impact on communication skills (Gregory et al., 1995), learning and education (Stacey et al., 2006), behavior (Hind & Davis, 2000), mental health (Hindley et al., 1994), employment opportunities (Punch et al., 2005), family dynamics (Gregory et al., 1995) and quality of life (Hind & Davis, 2000). In England, for example, currently more than 70% of children with hearing loss do not meet the government education attainment target at 16 years of age (Action on Hearing Loss, 2011). Effective intervention by six months of age can reduce the negative impact of PCHI on speech and language learning (Yoshinago-Itano et al., 1998, Moeller et al., 2007a,b).

The value of early identification of PCHI has long been recognized by our research group (e.g., Ewing & Ewing, 1944). From the 1960s, a behavioral test (the Health Visitor Distraction Test) was introduced to screen the hearing of all 7-9 month old infants. However, the typical age of identification of PCHI was approximately 2 years and the median age of hearing aid fitting was delayed by a further 6 months (Fortnum & Davis, 1997). As a result, a persuasive case was made for the introduction in the United Kingdom of the world's first national universal newborn hearing screening program (Davis et al., 1997). The screening program was evaluated by our team who endorsed implementation of the auditory brainstem response (ABR) screen in England from 2006 (Bamford et al., 2005). As a result of this national screening program, the median age for prescribing and fitting hearing aids to infants is currently 80 days (Wood et al., 2015).

New challenges

The success of newborn hearing screening has resulted in new challenges. Behavioral methods of hearing assessment (e.g., head turning in response to a sound) cannot be used reliably until a developmental age of 7-9 months (Widen, 1993). Therefore, when prescribing hearing aids to infants, clinicians rely on objective measurements. The most commonly used measure is the frequency-specific ABR. The ABR is a well-established technique but it can be problematic for a variety of reasons:

- Behavioral thresholds often deviate from predicted ABR thresholds by 10 dB, and occasionally by 20 dB (Stapells, 2011).
- It might not be possible to detect a response when there is a severe hearing impairment, yet a hearing aid could still be beneficial (Stelmachowicz, 2008).
- Middle ear disease can complicate response detection (Stelmachowicz, 2008).
- A response is absent in some clinical populations (e.g., auditory neuropathy spectrum disorder; Roush et al., 2011).
- It assesses hearing only up to the brainstem and can miss disorders at a higher level in the brain (Ozdamar et al., 1982).

A way forward

Although the observations of parents and professionals are important (Bagatto et al., 2011), the range of observable behavior in infants is limited (Bess & Humes, 2003). Therefore, there is an urgent need to identify new procedures that can confirm the audibility of speech and the appropriateness of hearing aid prescriptions in infants.

Behavioral methods of hearing assessment (e.g., tracking eye movements in response to sound) are used in research settings in infants, but they have not yet been shown to be reliable when assessing individual infants in the clinic. However, case studies have reported the potential use of obligatory cortical auditory evoked potentials (CAEPs) to confirm that stimuli have been successfully received by the auditory cortex in children (Rapin & Graziani, 1967; Gravel et al., 1989).

In adults, the CAEP consists of a series of peaks and troughs (P1-N1-P2) that occur within about 300 ms after stimulus onset. In infants, the morphology is often dominated by a single positive wave around 200 ms (see Figure 1), although there is some variability in reported CAEP morphology across studies.

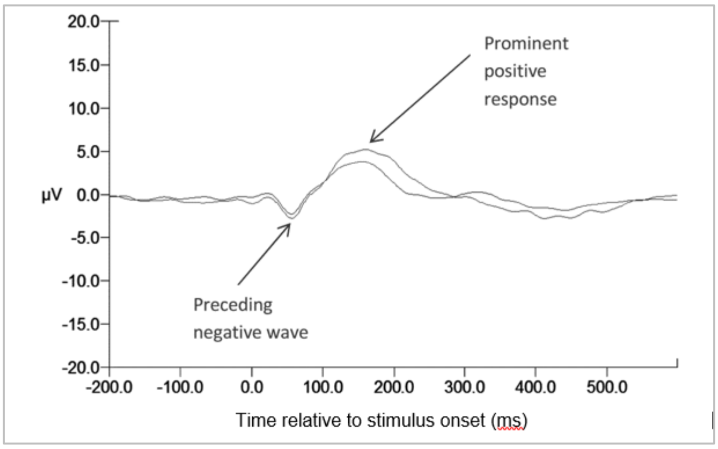

Figure 1. CAEP obtained from a group of 60 normal hearing infants using the HEARLab system. This shows two sub-averages of around 75 sweeps in response to the stimulus /g/ (21 ms) presented at 65 dB SPL from a loudspeaker at 0° azimuth.

There is interest in using CAEPs to assess the audibility of speech and to evaluate hearing instrument effectiveness in infants (Dillon, 2005; Purdy et al., 2005). In a review, Billings et al. (2012) concluded that aided CAEPs can be clinically useful when determining if stimuli are physiologically detected. In summary, CAEPs have potential to personalize treatment and improve quality of life for infants with hearing loss and their families.

Two small-scale studies have investigated the ability to detect CAEPs in children who use hearing aids (Chang et al., 2012; Van Dun et al., 2012). Chang et al. (2012) tested 18 infants with hearing loss, with and without hearing aids. However, many of the participants were older (mean 7.4 months, range 3-15) than our target clinical population of 3-7 months of age. Surprisingly, it was not possible to detect a response in 30-40% of participants when stimuli were estimated to be audible. The relatively high failure rate might have been due to (i) the non-optimal recording conditions because the researchers were relatively inexperienced at measuring CAEPs (Dillon, personal communication), (ii) audibility of the CAEP stimuli being inaccurately estimated from behavioral measures obtained using different stimuli and a variety of clinicians, and (iii) lack of a retest when the initial recording conditions were poor (e.g., due to the participant being restless). Van Dun et al. (2012) tested 25 infants with hearing loss, some while wearing their hearing aids. Once again, participants were older (mean 19 months, range 8-30) than our target clinical population. The inability to detect a CAEP when the stimuli were audible was 22-28%. Again, (i) the CAEP recordings were obtained by relatively inexperienced personnel (acknowledged by the authors) , and (ii) there was no retest in cases where the CAEP could not be detected. Although these two studies show some promise, they share a number of limitations and indicate the need for further research.

The feasibility of recording CAEPs in a clinical setting has not been reported. Practitioners who are considering implementation of a new procedure wish to know the duration of the test procedure and how much testing can be completed within a single appointment (Janssen et al., 2010). Also, the acceptability of the aided CAEP procedure to parents/caregivers is unknown. In summary, (i) only a few studies have been published on this important topic, and (ii) what work has been done is limited in scope and has potential limitations.

CAEP recordings from infants with normal hearing

We recorded CAEPs in the soundfield in approximately 100 babies, age 5-39 weeks, who passed their newborn hearing screen and for whom there was no family concern about hearing impairment. Data were collected using the HearLab Cortical Auditory Potential Analyser (Frye Electronic Inc). This system is based on a PC and consists of software that runs under the Microsoft Windows environment and a set of specialized hardware components. The stimuli on the HEARLab system (labeled /m/, /g/ and /t/) were extracted from running speech, truncated from their full durations (to between 20-30 ms), and spectrally re-shaped so as to have their dominant energy peaks at 500, 1500, and 3000-4000 Hz. The purpose of these stimuli were to represent speech with dominant energy in the low, mid and high frequencies, respectively. The stimuli were presented from a single loudspeaker at 0^0 azimuth at a level of 65 dB SPL (when measured in isolation using a sound level meter with an impulse setting, this is approximately equal to the long-term rms level of the continuous speech from which the stimuli were extracted). We recorded around 150 artifact-free epochs, with an inter-stimulus interval of 1125 msec, for each of the three stimuli.

Our preliminary findings, yet to be submitted to a peer-reviewed journal, show that the test was successfully completed in 95% of infants. Test time was typically 30 minutes (range, 17-89 minutes). All infants showed a response to at least one stimulus and most showed a response to at least 2 stimuli. Parents were interviewed and reported positive experiences of the test procedure. These preliminary findings suggest that infant CAEPs are clinically feasible, acceptable to families, and useful for indicating a physiological response to a range of sounds.

Next steps: infants with hearing loss

We have now embarked on a study involving infants with hearing loss who wear hearing aids. The initial stages of the project involve (1) determining appropriate test stimuli to use for aided testing, and (2) optimizing automated CAEP detection methods. The next stage will be to define the performance of aided CAEP. We will perform aided CAEP testing between 3-7 months of age. We will use the same test stimuli to determine minimum response levels at around 9 months of age using visual reinforcement audiometry (the gold standard measure of audibility). This will allow us to determine the proportion of infants with a detectable CAEP when the stimuli are audible. We will record information relevant to clinical feasibility including test time and completion rates. Two approaches will be used to assess caregiver acceptability. First, all caregivers will be asked to fill in a short online questionnaire adapted from the parent rating scale that was validated in our preliminary study on normal-hearing infants. Second, semi-structured interviews will be used to obtain information about the caregivers' experiences of the test procedure.

Conclusion

Studies are currently underway to assess the clinical performance of aided CAEP in infants with hearing loss. Aided CAEPs have the potential to supplement existing clinical procedures and provide an opportunity to obtain aided information before it is possible to obtain reliable information from behavioral assessment procedures. The detection of a CAEP response will provide reassurance that auditory stimuli can be physiologically detected and this, in turn, might encourage parents to persevere with the hearing aids. The aided CAEP procedure has the potential to improve clinical practice by providing important hearing aid management information at an earlier stage in the care pathway of infants with hearing loss.

References

Action on Hearing Loss (2011). Hearing matters: Taking action on hearing loss in the 21st century. *Action on Hearing Loss* (formerly RNID), London.

Bagatto, M.P., Moodie, S. T., Malandrino, A. C., Richert, F.M., Clench, D. A., & Scollie, S. D. (2011). The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP). Trends in Amplification, 15(1), 57–76.

Bamford, J., Ankjell, H., Crockett, R., Marteau, T., McCracken, W., Parker, D., Tattersall, H., Taylor, R., Uus, K., Young, A. (2005). Evaluation of the newborn hearing screening programme in England: Studies, results and recommendations. Report to DoH and National Screening Committee, 1-242.

Bess, F. H., Humes, L. E. (2003). Audiology: The Fundamentals. 3rd ed. Philadelphia: Lippincott Williams and Wilkins.

Billings, C. J., Papesh, M. A., Penman, T. M., Baltzell, L. S., & Gallun, F. J. (2012). Clinical use of aided cortical auditory evoked potentials as a measure of physiological detection or physiological discrimination. *International Journal of Otolaryngology*, *2012*, 365752.

Chang, H.-W., Dillon, H., Carter, L., van Dun, B., & Young, S.-T. (2012). The relationship between cortical auditory evoked potential (CAEP) detection and estimated audibility in infants with sensorineural hearing loss. *International Journal of Audiology*, *51*(9), 663–670.

Davis, A., Bamford, J., Wilson, I., Ramkalawan, T., Forshaw, M., & Wright, S. (1997). A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technology Assessment (Winchester, England)*, *1*(10), i–iv, 1-176.

Dillon, H. (2005). So Baby; how does it sound? Cortical assessment of infants with hearing aids? *The Hearing Journal*, 58, 10-17.

Ewing, E. R., Ewing, A.W.G. (1944). The ascertainment of deafness in infancy and early childhood. *Journal of Laryngology and Otology*, 59, 309-333.

Fortnum, F., Davis, A.C. (1997). Epidemiology of permanent childhood hearing impairment in Trent Region, 1985-1993. *British Journal of Audiology*, 31, 409-446.

Fortnum, H., Summerfield, Q., Marshall, D., Davis, A., Bamford, J. (2001). Prevalence of permanent childhood hearing impairment in the United Kingdom and implications for universal neonatal hearing screening: questionnaire based ascertainment study. *British Medical Journal*, 323, 536–9.

Gravel, J., Kurtzberg, D., Stapells, D. R., Vaughan, H. G., Wallace, I. F. (1989). Case studies. *Seminars in Hearing*, 10, 272-287.

Gregory, S. (1995). Deaf children and their families. Cambridge: Cambridge University Press.

Hind, S., Davis, A. (2000). Outcomes for children with permanent hearing impairment. In R. C. Seewald & J. C. Bamford (Eds). *A Sound Foundation Through Early Amplification 1998*. Stäfa, Switzerland: Phonak AG (pp 199-212).

Hindley, P. A., Hill, P. D., McGuigan, S., Kitson, N. (1994). Psychiatric disorder in deaf and hearing impaired children and young people: a prevalence study. *Journal of the Child Psychology and Psychiatry*, 35, 917-934.

Janssen, R. M., Usher, L., Stapells, D. R. (2010). The British Columbia's children's hospital tone-evoked auditory brainstem response protocol: how long do infants sleep and how much information can be obtained in one appointment? *Ear and Hearing*, 31, 722-724.

Moeller, M. P., Hoover, B., Putman, C., Arbataitis, K., Bohnenkamp, G, Peterson, B., Wood, S.L., Lewis, D. E., Pittman, A. L., Stelmachowicz, P.G. (2007a). Vocalisations of infants with hearing loss compared to infants with normal hearing – Part I: Phonetic development. *Ear and Hearing*, 28, 605-627.

Moeller, M. P., Hoover, B., Putman, C., Arbataitis, K., Bohnenkamp, G., Peterson, B., Estee, S., Lewis, D. E., Pittman, A. L., Stelmachowicz, P. G. (2007b). Vocalisations of infants with hearing loss compared to infants with normal hearing – Part II: Transition to words. *Ear and Hearing*, 28, 628-642.

Ozdamar, O., Kraus, N., Curry, F. (1982). Auditory brainstem and middle latency responses in a patient with cortical deafness. *Electroencephalography and Clinical Neurophysiology*, 53, 224-230.

Punch, R., Creed, P. A., Hyde, M. (2005). Predicting career development in hard-of-hearing adolescents in Australia. *Journal of Deaf Studies and Deaf Education*, 10, 146-60.

Purdy, S. C., Katsch, R., Dillon, H., Storey, L., Sharma, M., Agung, K. (2005). Aided cortical auditory evoked potentials for hearing instrument evaluation in infants. In R. C. Seewald & J. C. Bamford (Eds). *A Sound Foundation Through Early Amplification 2004*. Stäfa, Switzerland: Phonak AG (pp 115-127).

Rapin, I., Graziani, L. J. (1969). Auditory-evoked responses to normal, brain damaged and deaf infants. *Neurology*, 17, 881-894.

Roush, P., Frymark, T., Venediktov, R., Wang, B. (2011). Audiologic management of auditory neuropathy spectrum disorder in children: a systematic review of the literature. *American Journal of Audiology*, 20, 159-170.

Stacey, P. C., Fortnum, H. M., Barton, G. R., Summerfield, A. Q. (2006). Hearing-impaired children in the United Kingdom, I: Auditory performance, communication skills, educational achievements, quality of life, and cochlear implantation. *Ear and Hearing*, 27, 161-186.

Stapells, D. R. (2011). Frequency-specific threshold assessment in young infants using the Comprehensive handbook of pediatric audiology (pp.409-448). San Diego: Plural Publishing, Inc.

Stelmachowicz, P., Hoover, B.M., Lewis, D.E. (2007). Progress means new challenges: Current issues in paediatric amplification. In R. C. Seewald & J. M. Bamford (Eds). *A Sound Foundation Through Early Amplification 2007*. Stäfa, Switzerland: Phonak AG (pp 161-172).

Van Dun, B., Carter, L., Dillon, H. (2012). Sensitivity of cortical auditory evoked potential detection for hearing-impaired infants in response to short speech sounds. *Audiology Research*, 2, 65-76.

Widen, J. (1993). Adding objectivity to infant behavioural audiometry. *Ear and Hearing*, 14, 49-57.

Wood, S. A., Sutton, G. J., & Davis, A. C. (2015). Performance and characteristics of the Newborn Hearing Screening Programme in England: The first seven years. *International Journal of Audiology*, *54*(6), 353.

Yoshinago-Itano, C., Sedley, A.L., Coulter, D.K., Mehl, A. (1998). Language of early and later-diagnosed children with hearing loss. Pediatrics, 102, 1161-1171.

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