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The use of speech stimuli to elicit aided cortical auditory evoked potentials in teenagers with hearing impairment: performance characteristics, subject considerations and clinical relevance

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Introduction

Aided cortical auditory evoked potential (CAEP) measurements with speech stimuli may provide information about the appropriateness of hearing aid fittings when reliable behavioural information is not available. This type of testing has provoked considerable interest, particularly in the identification of babies and children that may be suitable for cochlear implantation (Sharma, 2006). HEARLab™ is the first commercially available clinical system designed specifically to measure aided CAEPs to speech stimuli. An important advantage of the system is the automated statistical procedure, which calculates the probability of a cortical response being present, thereby removing errors due to tester uncertainty, and the time needed to interpret results.

The validation of this automated CAEP measurement tool is still in its early stages, and at the time of writing, this is thought to be the first study to analyse the aided CAEP of hearing-impaired teenagers for speech stimuli presented in the sound field using HEARLab.

Unaided and aided CAEP results for /m, /t/ and /g/ were compared against the behavioural thresholds of teenagers for the same speech sounds to investigate the performance characteristics of HEARLab for this age group. Additional factors such as the effect of noise and rejected data, subject considerations and clinical relevance are also discussed.

Aims

The aims of the study were:

- Calculate the sensitivity and specificity of HEARLab in the aided and unaided condition
- Investigate the relationship between residual noise levels and accept/reject data against presence/absence of response
- Compare the average residual noise levels in teenagers against adults and babies in CAEPs obtained

Methods

Participants

Twelve subjects (7 male and 5 female) aged 12-14 years old from a specialist school for the deaf.

Hearing impairment ranged from moderate to profound.

Nine subjects wore hearing aids bilaterally, two had unilateral hearing aids and one wore a hearing aid plus C.I. (the C.I. was removed for testing).

All subjects showed no otological abnormality on otoscopy, and tympanometry was within normal limits.

Procedures

All measurements were made in an acoustically treated room with soundfield equalisation using the protocol within the HEARLab system.

Participants were seated on a comfortable reclining chair and snap-on electrodes (< 5 kOhms) were attached to the vertex (positive), right mastoid (negative) and forehead (ground).

Each speech stimulus was presented at 55, 65 and 75 dB SPL and minimal behavioural detection levels were recorded, with and without hearing aids, prior to cortical measurement.

The room lights were dimmed and subjects watched a sub-titled DVD, with sound disabled.

Speech stimuli (/m/, /t/, /g/) of 30, 30 and 20 ms duration respectively were presented from a single loudspeaker at 0° azimuth. For both the unaided and aided condition, three runs were carried out per subject at a level of 55, 65 or 75 dB SPL. Within each run, the stimuli were presented in blocks of 25 (automatically changing from /m/ to /t/ and then /g/) until a minimum of 150 epochs for each stimulus were obtained per condition.

The starting level and the order of testing (aided or unaided) were balanced across participants. All noise levels during testing were within the 'green' category on the traffic light system on HEARLab, indicating low noise levels.

All hearing aids were run through a Kamplex FP35 test box and gain levels were recorded prior to testing.

A test session lasted around 90 minutes.

Results

Tables 1 and 2 show the sensitivity of HEARLab, for ranges of sensation levels (SL), in the unaided and aided condition. The sensitivity was calculated as # positive cortical detections /# positive behavioural responses. SL was calculated in the aided and unaided condition using an audibility calculator (Dillon 2010, personal communication) and personal hearing aid gain data for each participant. A cortical response is considered present when its p-value is smaller than 0.05 at the end of the recording.

Type	SL (dB)	#detections	# behavioural Responses	Sensitivity (%)
Aided	>10	56	73	77
Aided	0–10	12	30	40
Unaided	>10	7	11	64
Unaided	0–10	7	14	50

Table 1. Sensitivity for the unaided and aided condition

Type	SL (dB)	#detections	# behavioural responses	Sensitivity (%)
/m/	>10	18	28	64
/m/	0–10	4	6	66
/g/	>10	21	24	88
/g/	0–10	4	10	40
/t/	>10	17	21	80
/t/	0–10	4	14	28

Table 2. Sensitivity for each speech stimuli in the aided condition

Specificity was calculated as # absent corticals / # absent behavioural responses = 83/88 = 94% (two-sided 0.95 confidence interval 88%-98%)

The average noise levels (2.04, 2.07 uV) and accept/reject ratios (0.08, 0.07) in those cortical responses present and absent respectively, were compared and no significant difference ($p > 0.05$) between the two groups were found

The residual noise levels obtained for each child per condition and after averaging of 100 epochs are shown in Figure 1.

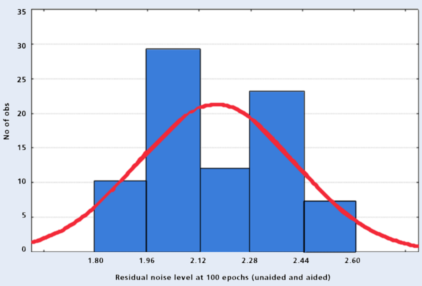

Figure 1. Residual noise levels (uV) obtained for 100 averaged epochs

Discussion

The results show that HEARLab is more sensitive for sensation levels > 10 dB.

A previous study with HEARLab on babies aged 8-30 months (Van Dun et al, 2010a), demonstrated that the probability of CAEP presence was 77% for sensation levels > 10 dB and 56% at sensation levels $0 \le SL \le 10$ dB, when comparing with visual reinforcement orientation audiometry (VROA) thresholds using /m/, /t/, and /g/ sounds. The present study shows similar results, with 75% sensitivity for the unaided and aided condition at >10 dB SL

Similar patterns of results are demonstrated in the sensitivity data for /t/ and /g/ stimuli, but with slightly lower sensitivity for the /m/ stimulus.

Lower sensitivity was also measured in the unaided condition.

The specificity of the study is 94% (two-sided 0.95 CI 88% - 98%), which shows the false positive rate of the statistical detector of HEARLab is not significantly different from 5%.

25% of audible stimuli did not evoke a CAEP in this study, about the same proportion as in babies (Van Dun et al 2010a). The presence or absence of a response did not depend on residual noise levels or accept/reject data. Previous studies have shown absent corticals at sensation levels of above 10 dB in adults for tone-burst stimuli (Van Dun et al. 2010b, Lightfoot and Kennedy 2006, Tsui et al. 2002). Perhaps other factors are involved such as speech and language ability, and level of hearing loss need to be investigated further in a larger study group.

The audibility calculator is an approximation of sensation level (due to variation in HTL data etc.) and introduces uncertainty to the sensitivity of HEARLab where some of the SLs calculated to be above 10 dB would actually be below 10 dB and vice versa.

The noise levels that were obtained in this age group for 100 epochs are shown in Figure 1 and range from 1.8 – 2.6 uV. This noise range is in the middle of that obtained in comparable studies of HEARLab in adults (0.6 - 2.2 uV) and babies (2.4 - 4.6 uV) (Van Dun, et al. 2010a,b), with a lean towards the adult noise range. Data obtained for this age group could be used in the HEARLab software, to use the traffic light system (which alerts the clinician to high, low and medium noise levels) more accurately.

Clinical implications

First, consider the situation where a cortical response is present ($p < 0.05$) in response to a sound at conversational level. This result provides some confidence that the infant is perceiving that sound at the level tested. The level of confidence is determined by the p-value of the detection.

Second, consider the case where no cortical response is present ($p > 0.05$). If the true sensation level of the sound were to be > 10 dB SL, the results indicate that the most likely outcome is that a cortical response would have been observed. If the sound truly is inaudible, then the statistical detection criterion adopted will ensure no response is detected 95% of the time. If the true sensation level were to be within the range 0 to 10 dB SL, then the probability of a significant response is intermediate.

When, in actual use, the true sensation level is unknown, the lack of a cortical response indicates a likelihood, but by no means a certainty, that the sensation level is 10 dB or less. The clinician can use this likelihood to supplement other information the clinician has about the subject.

Conclusions

It is preferable to use a SL >10 dB criterion when using the HEARLab software for CAEP analysis as the probability of obtaining a response at lower sensation levels is small. This is an important factor to take into account, when assessing children and adults with severe-profound impairment, where the dynamic range of the hearing instrument is small and low to medium stimulus levels are likely to be within and/or close to this range.

This is a preliminary study and more analyses need to be done with a larger participant group, including the effect of p-values, speech discrimination and 3 frequency average on the likelihood of a present or absent CAEP response.

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References

Lightfoot G, Kennedy V. Cortical electric response audiometry hearing threshold estimation: Accuracy, speed and the effects of stimulus presentation features. Ear and Hearing 2006: 443-456

Sharma A, Dorman MF. Central auditory development in children with cochlear implants: clinical implications. Adv Otorhinolaryngol. 2006;64: 66-88.

Tsui B, Wong LLN, Wong ECM . Accuracy of cortical evoked response audiometry in the identification of non-organic hearing loss. International Journal of Audiology 2002; 41: 330-333.

Van Dun B, Carter L, Dillon H. Clinical Report: HEARLab infant study. 2010a (in preparation)

Van Dun B, Carter L, Dillon H. Clinical Report: HEARLab adult study. 2010b (in preparation)

Further Information

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