Individual cochlear delays measured with tone-burst-evoked otoacoustic emissions

A new method to resolve the OAE onset ambiguity in the time domain

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Abstract

Methods to estimate cochlear delay in humans have been traditionally based on either phase-derived group delays from otoacoustic emissions (OAEs), or auditory brainstem responses (ABR). These methods demonstrate large variability in cochlear delay estimates and are derived from across subject averages. This work aims to assess the individual variability in cochlear delay.

Tone-burst evoked otoacoustic emissions (TBOAEs) are used in this study to estimate cochlear delay. The OAE is analysed by separating the non-linear components of cochlear origin, and the linear reflection in the time domain. The observed latencies as a function of frequency are qualitatively similar across subjects. For the individual subjects, the delay for each tone-burst frequency is reproducible, defining OAE latency as the time between the onset of the stimulus and the peak of the first OAE burst. Results were obtained in agreement with previous studies. However, care must be taken when comparing the results of previous studies. This is due to an ambiguity in the time domain regarding the true onset point of the OAE, and hence the derived cochlear travelling wave latency. The inter-subject variability explains the discrepancy observed in other studies, e.g. using different stimulus paradigms. The relatively small within-subject variability suggests that the present method is a good approach for estimating cochlear delay. Comparing these results with estimates based on ABR, the assumption that OAE delay is twice the basilar membrane delay (as implied by the theory of coherent reflection) does not hold for frequencies below 2 kHz. The membrane delay (as implied by the theory of coherent reflection) does not hold for frequencies below 2 kHz. However, for frequencies below 2 kHz the model proposed by the CRF theory does not seem to hold.

The present method is based on temporal separation of the linear reflections occurring in the ear canal and the non-linear reflections occurring in the cochlea. This separation was made individually for the 9 normal hearing test subjects.

• Stage 1: OAE onset ambiguity
  - Stimulus: 2 clicks 55/65 dB peSPL (peak equivalent SPL)

• Stage 2: OAE recordings
  - Stimulus: Tone-bursts at 9 frequencies [500Hz - 8kHz] and 66 dB peSPL

Results

Latency for test subject 8

Repeatability for test subject 10

Intersubject variability

Discussion

• Throughout this study, some problems were faced regarding the correct attribution of the OAE burst. The points of disparity seen in the repeatability test can be accounted for from the relative noise floor. This noise might be due to internal noise, the OAE recordings are indeed sensitive to the subject's movements.

• Gorga et al. (1988) obtained a measure of the BM delay (\(\tau_{BM}\)) from Gorga et al.

Conclusion

• The method developed in this study presents a good alternative to other paradigms to estimating the cochlear delay. This method has the advantage that only time domain information is used and the post processing is kept simple.

• The good repeatability shows that the results obtained are not dependent on probe fitting.

• Future work - Using an online noise floor estimate to ensure same noise floor for all recordings

References