#145 A FAST METHOD FOR PSYCHOPHYSICAL ESTIMATION OF NONLINEAR COCHLEAR PROCESSING USING SCHROEDER PHASE HARMONIC COMPLEXES

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Introduction

- Schroeder phase harmonic complexes (Schroeder, 1970) consist of sinusoids with identical amplitudes but with phases adjusted to minimise the waveform crest factor.
- Their ability to mask probe tones changes depending on their "scalar factor" (e.g. complexes with scalar factors of -1 and +1 are temporally-reversed), due to interactions between the complex and the phase response of the basilar membrane (Summers & Leek, 1998).
- When the cochlea is more linear (e.g. in sensorineural hearing loss or at very high and low stimulus levels) the difference between the maximum and minimum masked thresholds across the range of scalar factors is reduced (Summers & Leek, 1998). This is called the "phase effect".
- Schroeder phase masking functions (threshold vs scalar factor):
  - are more sensitive than pure-tone audiometry in detecting changes in cochlear nonlinearity as a result of cochlear implant surgery (Gifford et al., 2008); and
  - are typically measured using three-alternative forced-choice (3 AFC) methods which take ≈45 minutes/curve.
- We have developed a fast method of measuring the same function in 8 to 10 minutes using a Békésy tracking procedure.

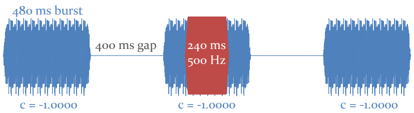
AIMS:

1. ***to determine whether our new fast method produces results equivalent with the conventional 3AFC method;***
2. ***to establish its test-retest reliability;***
3. ***to use it to measure Schroeder phase masking functions in normal hearing and hearing impaired participants.***

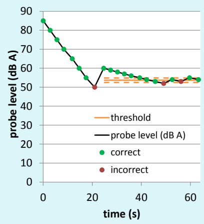
Conventional vs fast method

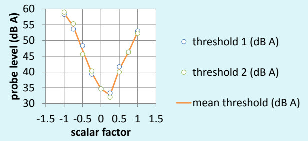
Conventional 3AFC method

Subject chooses which of the 3 maskers contains the probe tone



Adaptive algorithm alters probe level. Around 25 presentations required to obtain threshold at each scalar factor.

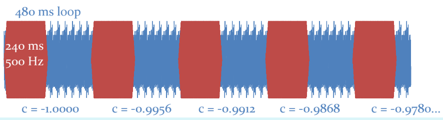




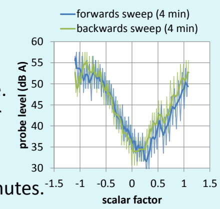
Final threshold is the average of two trials. Total time to record the final curve is around 45 minutes.

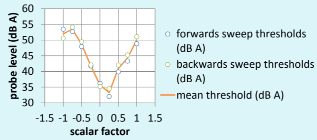
Fast sweep method

Subject holds a key while they can detect the probe in the presence of the slowly changing continuous masker



Probe level changes at 2 dB/s according to subjects response. The masker scalar factor is slowly swept from -1 to +1 over 4 to 5 minutes.





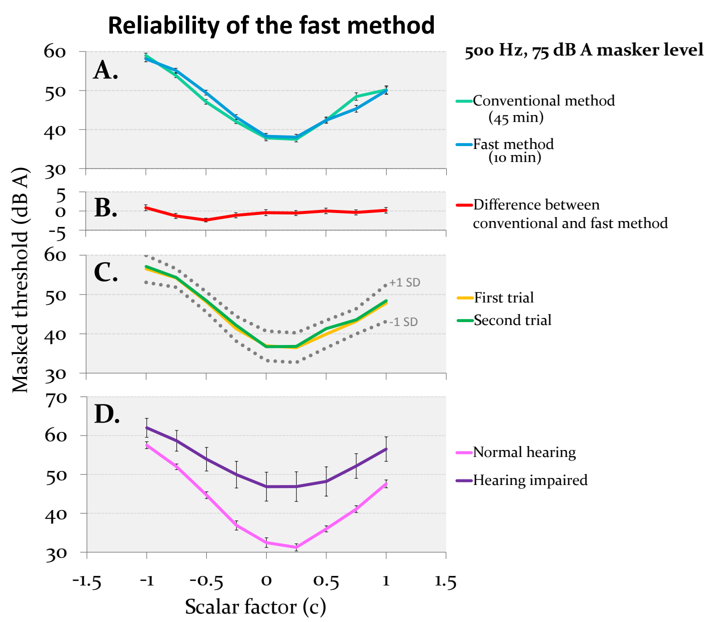
Final threshold is the average of the two sweeps. Total time to record the final curve is 8 to 10 minutes.

Methods & Materials

44 normal hearing and 15 hearing impaired participants were tested in sound treated booths at the University of Canterbury and the International Islamic University Malaysia. All stimuli were presented monaurally through Sennheiser 280 Pro headphones via external USB sound cards.
3 experiments were conducted:

1. **Agreement between the 3AFC and fast methods:** Schroeder phase masking functions were measured at 500 Hz (75 dB A masker level) among normal hearing participants using the conventional and fast methods to find the level of agreement between the two methods.
2. **Test-retest reliability of the fast method:** The fast method was repeated twice within the same session at 500 Hz (75 dB A masker level) in normal hearing participants.
3. **Measuring size of phase effect using the fast method:** The fast method was performed at 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz at a low (45 dB A) and medium (75 dB A) masker levels, in normal hearing and hearing impaired participants.

Results



A. Both the 3AFC and fast methods show similar patterns for masking functions, despite the differences in the time taken to complete the test (n=26 normal hearing participants).

B. The mean difference of the masked thresholds for both methods ranged between -2.4 dB at c=-0.5 to 0.9 dB at c=-1 (n=26 normal hearing participants).

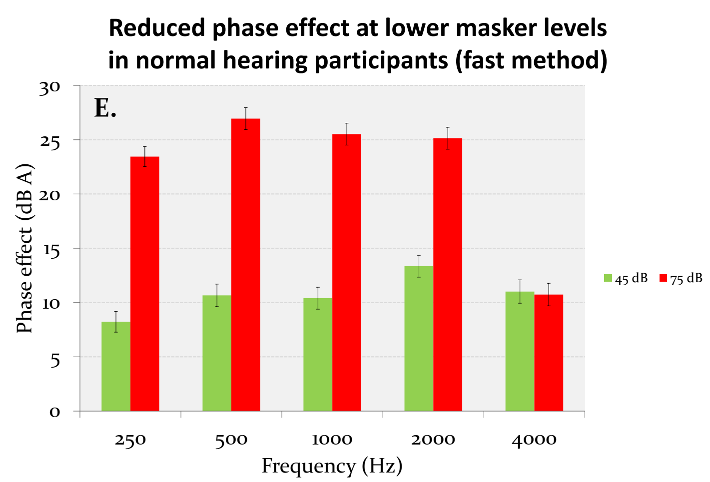
C. High repeatability was observed for the fast method, with results for the second trial falling within 1 SD of those from the first (n=16 normal hearing participants). The interclass correlation coefficient was 0.759, which was within acceptable values (Cicchetti & Sparrow, 1990).

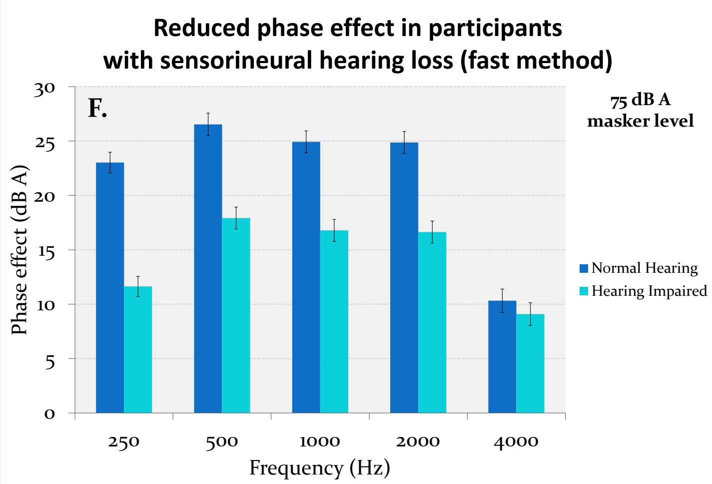
D. As with the conventional 3AFC method, the fast method measured flatter Schroeder phase masking functions from hearing-impaired participants (mean 500 Hz threshold = 34±12.3 dB HL; n=13) than it did from normal hearing participants (mean 500 Hz threshold = 9±3.6 dB HL; n=16). See Panel F for data for other frequencies.

E. Phase effects in normal hearing subjects were significantly reduced for the low intensity masker (45 dB A) than the medium intensity masker (75 dB A) at all measured frequencies except for 4 kHz ($p<0.05$).

F. Phase effects were significantly reduced in the sensorineural hearing loss participants than in normal hearing participants at all frequencies except for 4 kHz ($p<0.05$).

Error bars = standard error





Conclusions

- The fast method of measuring Schroeder phase masking functions is repeatable and produces results equivalent to the conventional method – both important aspects of the reliability of a new test (Chinn, 1990).
- Consistent with previous literature, the phase effect was reduced in conditions where cochlear nonlinearity is reduced (Ruggero et al., 1997), namely:
    - at low masker intensities (Recio & Rhode, 2000; Summers & Leek, 1998).
    - in participants with sensorineural hearing loss (Gifford, et al., 2008; Oxenham & Dau, 2004; Recio & Rhode, 2000; Summers & Leek, 1998).
- The lack of a significant difference in results between conditions at 4 kHz was most likely due to participants confusing masker edge pitch distortion with the probe (Kohlrausch, Houtsma & Evans, 1992).
- The new fast method of measuring Schroeder phase masking functions is effective and efficient, at least for frequencies up to 2 kHz.
- The almost 80% reduction in testing time compared to the conventional 3AFC method should facilitate future research investigating the phase curvature and nonlinearity of the cochlea using this technique, and allow it to move from the laboratory to the clinic.

References

Cicchetti, D. V., & Sparrow, S. S. (1990). Assessment of adaptive behavior in young children. In J. J. Johnson & J. Goldman (Eds.), *Developmental assessment in clinical child psychology: A handbook* New York: Pergamon Press.

Chinn, S. (1990). The assessment of methods of measurement. *Statistics in Medicine, 9*, 351-362.

Glifford, R. H., Dorman, M. F., Spahr, A. J., & Bacon, S. P. (2007). Auditory function and speech understanding in listeners who qualify for EAS surgery. *Ear and Hearing, 28*(2), 114-118.

Kohlrausch, A., Houtsma, A. J., & Evans, E. F. (1992). Pitch related to spectral edges of broadband signals [and discussion]. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 336(1278), 375-382.

Oxenham, A. J., & Dau, T. (2004). Masker phase effects in normal-hearing and hearing-impaired listeners: Evidence for peripheral compression at low signal frequencies. *The Journal of the Acoustical Society of America, 116*(4), 2248. doi: 10.1121/1.1786852

Recio, A., & Rhode, W. S. (2000). Basilar membrane responses to broadband stimuli. *J. Acoust. Soc. Am. , 108*(5), 2281-2298.

Ruggero, M. A., Rich, N. C., Recio, A., Narayan, S. S., & Robles, L. (1997). Basilar-membrane responses to tones at the base of the chinchilla cochlea. *J Acoust Soc Am. , 101*(4), 2151-2163

Summers, V., & Leek, M. R. (1998). Masking of tones and speech by Schroeder-phase harmonic complexes in normally hearing and hearing-impaired listeners. *Hearing Research, 118*, 139-150.

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