Frequency Specific Objective Audiometry
With Multi Frequency Amplitude Modulation Following Responses (MF-AMFR)

Multi Frequency AMFR

Amplitude Modulation Following Responses are steady-state evoked responses to continuous amplitude modulated tones. They have been shown to offer a means for a reasonably accurate and frequency-specific prediction of hearing thresholds from 0 up to 120 dBHL. The Multi Frequency AMFR (MF-AMFR) technique according to John et al. (Audiology, 1998) aims at reducing testing time by testing up to 4 octave frequencies per ear simultaneously, assuming independence of cochlear activation patterns.

Clinical application of the MF-AMFR technique awaits standardization of recording parameters and test protocol. The MASTER system specifies hardware and software but little outcome results has been reported from independent sources.

In this study normative data from normal-hearing subjects were collected with the MASTER technique with two different electrode configurations. Furthermore, preliminary data from hearing impaired subjects were collected with a third recording configuration to improve the signal-to-noise ratio.

Normal hearing subjects
Method

The MASTER software runs on a PC with a standard data acquisition card connected to an audiometer. Stimuli were presented by insert phones (Eartone 3A, configuration I) or headphones (TDH 39, configuration II). Eight octave frequencies (4 per ear) were presented, each with 100% AM and 20% FM. Modulation frequencies were 82, 90, 98 and 106 Hz in the left, and 86, 94, 102 and 110 Hz in the right ear. Electrodes were applied as follows:

	Configuration I	Configuration II
+	high forehead	vertex
-	neck	neck
ground	right clavicle	forehead

A Grass CP511 preamplifier was used with a gain of 10000. The signal was bandpass filtered (10-300Hz, -6dB/oct) and sampled at 1 kHz with 1024 samples per epoch. A rejection level of 50 uV was used. 48 sweeps of 16,38 sec were averaged. The amplitude of the spectrum at each modulation frequency was tested against the signal in 120 neighboring bins in an F-test (α=0.05).

Procedure

The AMFR threshold was established in descending steps of 5 dB starting at 50 dB. Each level was tested for about 12 minutes (48 sweeps). Total testing time was 2 hours on average.

Subjects were instructed to relax; some slept for part of the procedure. Nine normal hearing subjects were tested with electrode configuration I, and 10 with configuration II. Fifteen were male, 4 were female.

Results

No AMFR could be detected up to the a-priori maximum stimulus level of 50 dB in 1 to 5% of the measurements In half of the cases this was for a 500 Hz carrier.

The differences between the behavioral and the MF-AMFR threshold are shown in Figure 1. An analyses of variance (GLM) was performed with Configuration and Ear as independent factors; Frequency was a repeated factor. Thresholds were better predicted for frequencies above 500 Hz, and better predicted with configuration II, especially in the case of 500 Hz carriers in the right ear. Across configurations, the mean difference was 16.4 dB with a standard deviation that ranged from 6.6 dB for 2000 Hz to 11.2 dB for 500 Hz.

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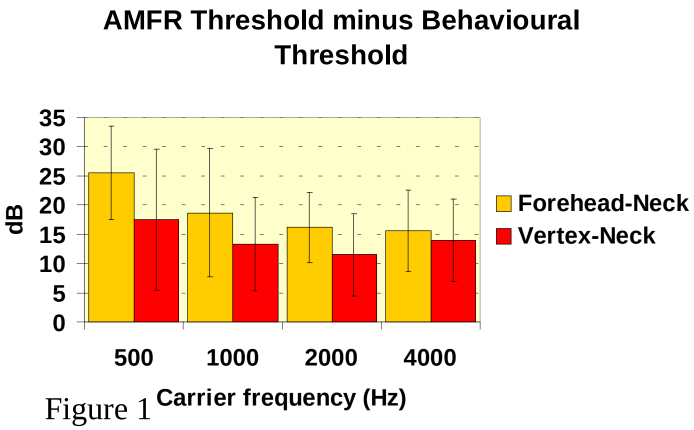

Figure 1

Only results from the 1000 Hz carrier frequency are shown in Figure 2. As can be seen, thresholds were much better predicted for the group tested with the Cz-Inion configuration. John et al. showed the response amplitude to be unaffected by the number of carrier frequencies (1 to 4) at moderate stimulus intensities. This suggests that electrode configuration is an important factor in the improvement shown in figure 2.

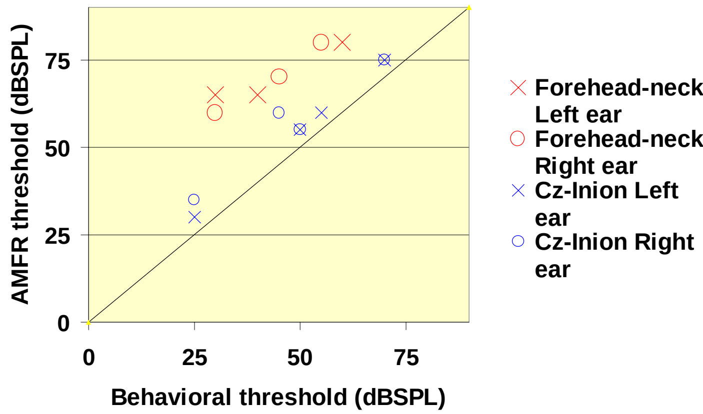

Figure 2

Threshold estimation using the response growth function

In 10 subjects thresholds were estimated from a linear fit of the response growth function. This was not possible in 8% of the measurements due to missing values. The mean regression thresholds exceeded the behavioral thresholds by 12, 4, 2 and 4 dB (500 - 4000 Hz) with standard deviations of 8, 11, 7 and 9 dB. To increase efficiency, thresholds were also estimated after 16 instead of 48 sweeps. This did not affect the mean sensitivity of the estimation; standard deviations increased slightly to 8, 12, 11 and 9 dB. However, now in 12% of the measurements insufficient data points were available for threshold estimation.

Hearing impaired subjects (single frequency AMFR)

Seven hearing impaired subjects were tested using two different electrode configurations. All subjects had sensorineural flat symmetrical hearing losses. Three subjects were tested with 48 sweeps per measurement using the forehead-neck electrode configuration (configuration I). Four carrier frequencies were presented simultaneously to each ear. Another 4 subjects were tested for only 16 sweeps using a Cz-Inion configuration with a ground at Pz. Two carrier frequencies were presented, one to each ear.

Conclusions

- In relaxed normal hearing subjects thresholds were overestimated by 16 to 26 dB using the forehead-neck electrode configuration and by 11 to 18 dB using the vertex-neck configuration; the standard deviation varied between 6 to 12 dB
- The number of absent responses was reduced with the vertex-neck configuration
- Threshold estimation based on the response growth function showed a trade-off between sensitivity and efficiency.
- Preliminary results from hearing impaired subjects suggest that a high sensitivity can be obtained with an electrode configuration with the positive electrode at Cz.

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