THE PRESCRIPTION OF HEARING AIDS FEATURES FROM THE AUDITORY STEADY STATE RESPONSES

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ABSTRACT
The advent of universal hearing screening programs has ensured early detection of hearing impairment at birth. This involves the fitting of hearing-aids at the earliest stage possible. It is important to have hearing aid fitting protocols specifically designed for very young infants. These protocols will be dependent upon electrophysiologic methods, as behavioural audiometry is not viable until 5-6 months of age and in some cases of infants or young children with developmental delay, not possible at all.
Non-linear circuits found in digital or wide-dynamic range compression (WDRC) hearing-aids have incorporated new fitting strategies that provide information about the loudness growth function over the range of intensities amplified. The adjustment of non-linear hearing-aids involves the concept of loudness growth normalization, where hearing-aid features would be adjusted for a particular hearing loss in order to normalize the perception of loudness. From this kind of loudness judgment it is possible to derive electroacoustic characteristics of hearing-aids such as average gain, maximum output, compression ratio and onset level.
In this presentation we propose a method to estimate the loudness growth function from the amplitude- intensity function of the Auditory Steady-State Responses (ASSR). This procedure enables determination of some basic properties of hearing aids. A hearing aid evaluation is discussed as an example of a sensorineural impairment. This procedure based directly on the ASSR could deliver an initial adjustment of the hearing-aid until other behavioural responses can be obtained.

INTRODUCTION
The advent of universal hearing screening programs has ensured early detection of hearing impairment at birth. This involves the fitting of hearing-aids at the earliest stage possible. Early hearing-aid fitting in infants contributes to acquisition and development of oral language. For this reason, it is important to have hearing aid fitting protocols specifically designed for very young infants. These protocols will be dependent upon electrophysiologic methods, as behavioural audiometry is not viable until 5-6 months of age, and in some cases of infants or young children with developmental delay, not possible at all.

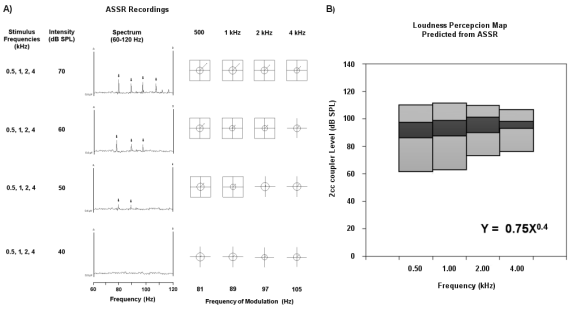
In infants and in the adult population, hearing-aid fitting consists of three stages: the assessment of hearing sensitivity, the selection of adjustment parameters to restore the hearing perception and the verification of the prescribed gain for each patient. Assessing hearing implies the establishment of hearing thresholds, maximum comfort and discomfort levels at different frequencies for each ear independently. The prescription of adjustment parameters requires the establishment of the gain, in such a way that the speech spectrum is amplified within the dynamic hearing range of the patient. Finally, the verification of amplification allows us to check that the objectives set in the prescription of adjustment parameters have been achieved (Zenker & Barajas, 1999).

For certain difficult-to-test populations, hearing thresholds can only be obtained through electrophysiological measures that do not require any voluntary response from the individual. Moreover, electrophysiological tests can assist those involved in the adaptation of hearing-aids, since these tests can measure auditory function objectively. The Auditory Steady-State Responses (ASSRs) constitute a procedure that provides a quick and objective way to establish electrophysiological hearing thresholds at different frequencies. The ASSRs have several advantages in their application in hearing-aid fitting. First, they provide assessment of hearing thresholds at different frequencies. Secondly, from these measurements it is possible to infer the adjustment parameters of hearing-aid devices. Thirdly, the acoustic characteristics of the ASSR's stimuli allow us to verify that the hearing-aid is functioning and the subject perceives and discriminates sounds at a brain level (Picton et al. 2002).

In a recent contribution of our group (Zenker et al. 2008)), an attempt was made to prove whether it is possible to establish a relationship between subjective loudness growth derived from the Contour Test and the physiological responses obtained from the ASSR. Zenker et al. (2006) proposed an ASSR prescription method based on the amplitude of the physiological response based on the Amplitude Projection Procedure developed by Kiesslling for the Auditory Brainstem Responses (Kiessling 1983). Dynamic range, gain, compression and MPO of the hearing-aid were established from the level-amplitude function of the ASSRs.

In figure 1 an example case is shown were the ASSRs were obtained in a 27-month-old infant diagnosed with bilateral moderate sensorineural hearing impairment. ASSR thresholds were 50 dB SPL for 0.5Hz and 1.0 kHz; 60 dB SPL for 2 kHz and 70 dB SPL for 4 kHz. (Converted to dB HL, the thresholds were 55, 50, 63 and 75 dB for 0.5, 1.0, 2.0, and 4.0 kHz, respectively).

Figure 1: (a) ASSR amplitude spectra recorded at levels ranging from 70 to 40 dB HL for the four carrier frequencies presented to each ear. Arrows indicate a significant response. (b) Predicted Loudness Perception Map for the same subject.



Dynamic Range

Figure 2 shows the amplitude projection from which the dynamic range is obtained. In this figure, the previously established amplitude-level function from a group of normal hearing subjects (continuous line) is presented with the amplitude-level function obtained from a group of hearing-impaired children (dashed-line). In the same figure, the dynamic range of speech (40 to 80 dB) for the 500 Hz is projected upward from the abscissa to the normal amplitude-intensity function. Then, horizontally it is projected to the function obtained from the hearing-impaired individual and, finally, projected vertically upward to yield the output dynamic range. Hence, the equivalent dynamic range for this child with a moderate hearing loss is 27 dB (84 -57 dB) for a 40 dB input range.

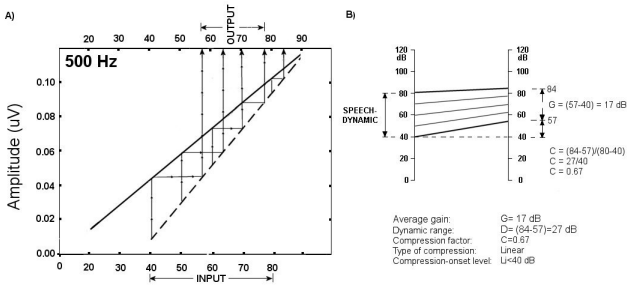
Gain and Compression Factor

The difference between the initial point of the output dynamic range (in this case 57 dB) and the initial point of the input dynamic range (40 dB) define the gain (57 -40= 17 dB) of the hearing-aid. The width of the output dynamic range is determined from the output range (in this case 57 to 84 dB, or 27 dB). The need for compression is determined by the ratio of the output dynamic range (27 dB) to the input dynamic range (40 dB, that is, 27/40= 0.67.

Maximum Power Output

From the ASSRs obtained for this patient the MPO can be derived from the loudness sensation levels estimated from the amplitude – level function. The MPO of the hearing-aid is determined from the formula: MPO = [Loud – B0 – (B2*Amplitude)]/B1. The MPO must be fitted to the category of uncomfortably loud, that is, Contour Test Category 7. The amplitude data used in the formula are those obtained at the highest test level (80 dB SPL) for this patient. The MPO settings for this patient are 103, 110, 123 and 121 dB SPL for 0.5, 1.0, 2.0 and 4.0 kHz, respectively.

Figure 2: (a) The Amplitude Projection Procedure (APP). Solid line indicates the amplitude-level function for normal hearing subjects and dashed line indicates the amplitude-level function for infants-children with sensory hearing loss. The input speech dynamic range of 40-80 dB is projected upwards on the normal curve. Then, the projection from the curve for ears with hearing loss yields the output dynamic range for this patient. (b) The gain requirement is estimated as the difference between hearing loss (57 dB) and the lower limit of the LTASS (40 dB), or 57-40= 17 dB. The compression factor (C) is given by the ratio of the dynamic range (84-57= 27 dB) of the patient to the normal speech dynamic range (80-40= 40 dB), C=0.67



The treatment of those with hearing loss involves the selection and fitting of amplification devices. In difficult-to-test individuals, such as young infants, subjective and objective measures such as functional gain and real-ear probe measurements, are not always possible. For those subjects who do not provide reliable responses to behavioural audiometry, the appropriate selection and fitting of hearing-aids requires the establishment of accurate hearing thresholds by other means. ASSR can be used in the characterization of hearing loss in order to estimate the auditory threshold. The hearing aids adjusting procedure described in this study provides estimates of loudness sensation derived from the amplitude-level function of the ASSR. This procedure provides frequency specific information about features of hearing-aids, such as average gain, compression factor, onset level and output limitation. This procedure based directly on the ASSR amplitudes could deliver an initial adjustment of the hearing-aid until other behavioural responses can be obtained.

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