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Using a DSP Instrument Fitting Protocol for Pediatric Cases

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While it is clear that many benefits of digital signal processing (DSP) seem particularly applicable to the needs of children[1], many clinicians may not be comfortable with programming the instruments properly or verifying the fittings on children. This may be due to the limited ability of very young children to express their preferences. The lack of a fitting protocol with appropriate recommendations may be another reason for such unease.

A fitting and verification protocol for fitting SENSO DSP instruments on children, based on the 1995 position statement of the working group on Amplification for Infants and Children with Hearing Loss[2], was initiated by Widex Hearing Aid Co. In the fall of 1997, the House Ear Institute CARE Center was asked to evaluate this protocol with 10-20 children to determine its clinical practicality.

This report summarizes experiences with this protocol and briefly reviews the results of its implementation. This article also shares findings on the efficacy of a digital hearing instrument in a pediatric population.

Candidates ~ Instruments

Subjects were 14 children, ages 19 months to 17 years old, seen between September 1997 and March 1998. The families of these children chose the digital hearing instruments from among a variety of appropriate options presented to them as part of a routine clinical procedure.

The children were seen 1-3 times during the 30-day trial period following the fitting. They were also requested to return for follow-up at three and six months.

During the time of this study, the SENSO was available in three BTE and one ITE/ITC model that offered three channels and a choice of six cross-over frequencies. These hearing instruments allowed fitting hearing losses up to 90 dBHL. Today, the instruments are also available in two power models suitable for severe-to-profound hearing losses.

Programming the Instruments

These hearing instruments can be programmed by determining the in-situ (hearing instrument positioned in the ear) *behavioral thresholds (or Sensogram)* at three frequency bands (low, mid and high), or by pre-programming the hearing instruments directly using audiometric thresholds (or their estimate, e.g., ABR tone pip thresholds) at three frequencies. The in-situ threshold measures can be determined with any child who is able to give reliable behavioral responses and take into account the effects of residual ear canal volume and venting which alter the SPLs in the child's ear.

The measurements can be obtained in children as young as 6-8 months using the Visual Reinforcement Audiometry (VRA) technique.[3] Stimuli are presented via the hand-held programmer through the hearing instruments, and the child is trained to turn to a light/toy when he/she hears the stimulus (Fig. 1). Older children (e.g., 2-5 year olds) can be trained to give a conditioned play response. As with VRA, conditioned play can be done using the stimuli from the programmer and a peg or block toy that interests the child. For children over five years old, standard audiometry with hand raising is appropriate. After the behavioral thresholds are determined, a feedback test is conducted with the hearing instruments in the child's ears to minimize the occurrence of feedback.

If the instruments are pre-programmed using audiometric threshold data, the feedback test must be performed with a finger over the earhook so that feedback values will be "0". These values can be adjusted if necessary once the instruments are in place on the child's ears.

▶ *Results:* Behavioral thresholds were obtained for all 14 children. However, pre-programming the hearing instruments was also found to be a viable option for older children since, in all cases, their behavioral threshold values were within 5-10 dB of their audiometric thresholds. It is tempting to generalize this observation for children under five years of age instead of determining their behavioral thresholds; young children fatigue easily and may be unable or unwilling to respond reliably to sound field test stimuli if they have already performed the same tasks during that same appointment. However, because the size of the ear canal in children younger than five years old is significantly different from those of older children and adults[4], the adult RECDs included in the formulation of the behavioral threshold values may not apply, and these values for young children may not be as consistent with audiometric thresholds. More data are necessary to establish this relationship in children under five.

Electroacoustic Measurements

The instrument uses a special signal processing technique that identifies a stationary signal as "noise" and reduces its gain after the stimulus is "on" for approximately 10 seconds. Because of this property, the choice and the duration of the stimulus could affect the measured frequency gain response curve of the hearing instrument. In performing the Electroacoustic measurements using the Frye 6500 system, a 5-second composite noise stimulus was presented at 50, 60 and 70 dB SPL input levels. A 30-second pause was introduced between each stimulus level in order to achieve full gain recovery.

▶ *Results:* We were able to examine the frequency response of the digital instrument and its gain change as input levels changed.

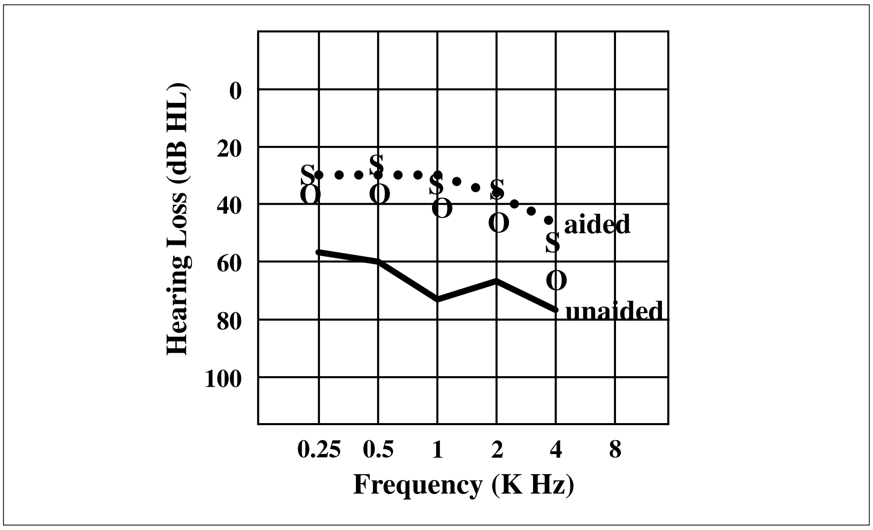

Figure 1. Average sound field thresholds with and without the digital hearing instruments (N=14). The aided thresholds between the children's previous instruments (O) and those of the DSP instruments (S) are also indicated (N=7).

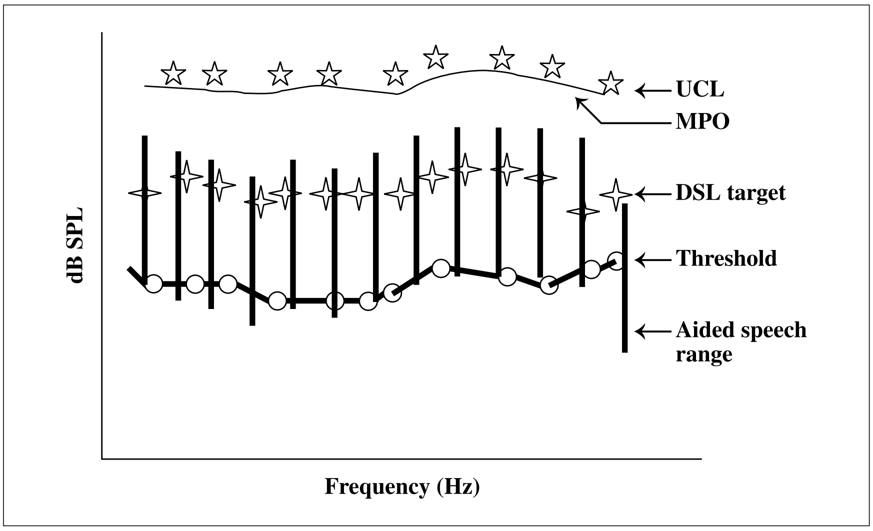

Figure 2. Idealized graphical output of the Audioscan RM500 SPEECHMAP/DSL program when used for the digital aid. The bottom of each bar should be above the threshold curve to be acceptable. One should not be overly concerned with matching the middle of the »thick bars« to the DSL targets.

Aided Sound-field Thresholds

The same behavioral techniques were used to estimate the aided thresholds. Initially, narrow bands of noise were used as stimuli. Subsequent comparisons with warble-tone stimuli revealed no significant differences in aided thresholds between the two stimuli. Both stimuli were used inter-changeably in our aided threshold measurements. In determining the aided threshold, an ascending approach was followed. Stimulus duration was about 2 seconds so that the maximum gain of the hearing instrument could be determined. Speech awareness or speech reception thresholds also were obtained on all children.

▶ *Results:* Fig. 1 summarizes the average unaided sound field (SF) thresholds for the better ear and the average aided SF thresholds. On an individual level, the aided SF thresholds were within the range of conversational speech for 11 of the 14 children. Of the remaining three children, all had essentially equal or better functional gain with the digital instrument compared to their previous instruments. For seven of the 14 children with whom we compared the aided digital instrument thresholds to those of the previous instruments, an advantage of 5-10 dB was seen across frequencies.

Real-Ear Measurements

The same considerations for determining electroacoustic output should be applied when using real-ear measurement (REM) systems to verify output. The stimulus used in most real-ear systems, because of its stationary nature, may be interpreted as "noise" by the hearing instrument, resulting in erroneous measurement.

We elected to perform REMs using the Speech Map/DSL program of an Audioscan RM500 because of the brevity of the stimulus. The Speech Map program allows for actual real-ear and simulated real-ear (S-REM) measurements. In the S-REM mode, individual measurement of real-ear to coupler difference (RECD) was determined with insert earphones to predict the real-ear responses from coupler measures. Alternatively, average RECDs are available for use.

Once the audiometric thresholds, RECD and UCL values are entered, the program generates an SPL-O-Gram with the patient's residual dynamic range (thresholds and UCLs) and a target output. The target is based on the recommendation of the Desired Sensational Level (DSL) fitting formula proposed by Seewald[5]. This target takes into account the degree of hearing loss, as well as the age-related changes in ear canal acoustics seen in children.

Because the SENSO's loudness algorithm is based on slow-acting compression[6,7] and the DSL algorithm does not calculate for the effect of attack and release time on its gain recommendation, clinicians are not advised to match the output of the instrument to any real-ear targets. Rather, the goal of REMs is to ensure that most of the amplified speech spectrum is within the patient's dynamic range (Fig. 3, i.e., above threshold for the "average" stimulus, but not exceeding the predicted UCLs for the MPO stimulus).

▶ *Results:* Real-ear measures were able to be performed on seven of the 14 children. The remaining children either would not accept the probe-tube in their ear canals, could not sit still for the measurement or there was feedback with the probe-tube in the child's ear. Results of REMs on the seven children were consistent with the expected results. That is, using the normal speech stimulus, most of the amplified speech spectrum was above threshold but below the UCL. In two of seven cases, the initial program yielded REMs that indicated outputs significantly below the desired degree of audibility. The gain values (HTLs) for the appropriate filter band were adjusted to reach audibility.

Speech Perception Tests

Speech tests were selected based upon the age of the children. For two children who were under 2.5 years old, the Ling 6 Sound test[8] was administered in sound field using VRA, and the threshold for detection of each sound was recorded. For one child, the test was administered in a face-to-face, auditory-only condition using the conditioned play technique. Two of the children who were 2.5-5 years old were asked to repeat each Ling sound again in the face-to-face, auditory-only condition. Identification/detection of these sounds at normal conversational level is consistent with the ability to perceive most of the components of conversational speech.

The Word Intelligibility by Picture Identification (WIPI) test[9] was administered to one four-year-old child. The WIPI is a six-alternative, forced-choice, picture-pointing test that requires identification of words differing by one or more phonemes. Two children ages four to seven were given the Phonetically Balanced Kindergarten (PBK)[10] monosyllabic word lists, and the NU-6[11] monosyllabic word lists were administered to four children eight years and older.

The Hearing in Noise Test for Children (HINT-C)[12] was also used with six children who were six years and older. Each list consists of 10 sentences and can be scored for sentence-correct or words correct in each condition. Recorded HINT sentences were delivered in quiet and in noise at either 40 or 50 dB HL, and at one or more signal-to-noise (SNR) ratios from -10dB to +10dB depending on the clinician's estimates of the child's ability to perform on the test. Because the children differed greatly in their degrees of hearing loss, ages and levels of maturity, it was not practical or possible to test all the available SNR conditions for comparison purposes.

▶ *Results:* Speech perception tests were conducted on 12 of the 14 children. Two children were not tested because they were from another country and did not speak English. Of the five children in the youngest group with whom the Ling 6 Sound test was performed, all detection levels were within the range of conversational speech. Better scores were obtained in quiet with the digital instrument compared to the previous instruments (44% vs. 28% and 96% vs. 90%) for two children. Two children with whom we were able to perform the HINT-C test also showed better performance with the digital instrument than their previous instrument (35% vs. 30% and 60% vs. 20%). For those children with whom we were unable to compare scores, the digital instrument scores were considered to be satisfactory relative to their hearing loss (Fig. 3).

Survey Instruments

Several patient/parent report scales were recommended as part of the protocol to determine subjective benefit.

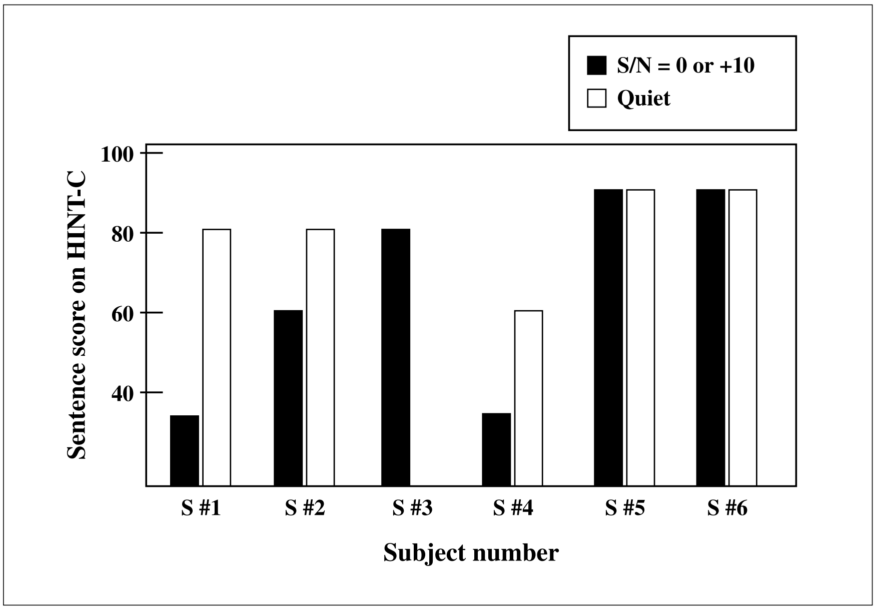

Figure 3. Sentence scores in quiet and in noise (SNR=0 or +10) on the HINT-C for six of the 14 children fit with the digital aids.

For children younger than five years old, the Meaningful Auditory Integration Scale[13] (MAIS) and the Meaningful Use of Speech Scale[14] (MUSS) were used to elicit parental feedback. The Listening Inventory For Education[15] (LIFE) and the Screening Instrument for Targeting Education Risks[16] (SIFTER) were recommended for use with school age children.

The LIFE determines the amount of difficulty a child has in various school listening situations and gathers the teacher's evaluation of the efficacy of the amplification. The SIFTER, which was given to the families of school-age children, is a teacher report scale that seeks to identify children who need educational intervention.

▶ *Results:* We found the greatest benefit of the MAIS and the MUSS to be that they provided us the opportunity to sit down with the parents and stimulate discussions on the kinds of behaviors they observed in their children in various situations. In many cases the conversations wandered from the specific information that we requested to providing more useful information than we might have obtained with direct questioning. Of the nine SIFTER forms that were given to our school age children, only one completed form was returned. Several factors may have contributed to this low return rate, including the fact that our children were distributed over a wide geographical area and consequently we did not have a direct relationship with most of the teachers.

Whereas the families of the younger children kept all their follow-up appointments, the same was not true for the older children. Most of these patients did well and tended to cancel appointments unless there was a problem. This does not, however, obviate the need for close monitoring of the child's performance with the hearing instruments. Clinicians and patients alike could benefit from practical survey tools that could be sensitive to the needs of both the younger (infants and toddlers) and older (teens) pediatric populations.

Observations

▶ The considerations involved in fitting a digital hearing instrument to a pediatric population are no different from those of an analog hearing aid (pre-selection, actual selection and fitting, verification, and validation).

▶ The actual fitting process for digital hearing instruments should be the same for children as it is for adults, as long as the clinician accounts for age-related differences in behavior and maturity (e.g., use of VRA).

▶ The traditional verification measures (coupler measures, real-ear measures, SF aided thresholds, etc.) may need to be adapted for some digital hearing instruments. This is because the processing algorithms in some digital aids may impose special requirements on the measurement procedures. Conventional measurement systems can be used to reliably verify the output of a digital hearing instrument when special attention is paid to the necessary stimulus characteristics such as duration, inter-stimulus interval, and spectrum.

▶ Although 11 of the 14 children purchased these digital hearing instruments during the study period and all (including their parents) expressed satisfaction with the performance of the instruments, we do not have a complete set of data on all of these children to support this observation. Factors such as time, family cooperation and reliability in keeping appointments interfered with the CARE clinicians' ability to complete all elements of the protocol in fitting each patient. Although subjective questionnaires are expected to be extremely beneficial tools for validating the performance of hearing instruments for all ages, this assumption was valid only for the very young children among our subjects because we were able to work directly and immediately with the reporting parents. Our experience may be important for researchers and manufacturers: a fitting protocol must not only be complete and useful, it must also be efficient and practical for clinical use.

The SENSO's fitting and verification protocol covers multiple issues related to fitting the instruments on children. It allows for flexibility appropriate to various age groups and individual needs, and addresses issues of analysis of hearing instrument function/performance specific to the devices.

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