ADVANCED CLINICAL AUDIOMETRY: MEASURING RESIDUAL AUDITORY CAPACITY USING A STANDARD AUDIOMETER UNDER COMPUTER CONTROL.

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This paper describes a clinical audiometer-based computer controlled Psychoacoustic Test System (PATS). Experimental psychoacoustic test procedures offer the possibility to improve the measurement of residual auditory capacity for diagnostic and rehabilitative purposes. Experimental procedures of interest include measures of frequency resolution and loudness growth, as well as more advanced measures of speech intelligibility and of hearing threshold. Unfortunately, within Clinical Audiological settings, equipment and time constraints have frustrated attempts to introduce such procedures. One reason is that these measurements often require equipment which is not available in a clinical setting, and indeed is generally considered to be unsuitable for such settings. Moreover, these experimental procedures typically require more time than is available in a clinical setting. To address these concerns, we have implemented an approach using a general-purpose, widely-available, audiometer, controlled by a PC. With special-purpose software, this configuration permits us to perform psychoacoustic test procedures which could not otherwise be performed in a clinical setting.

At present the following tests are implemented on the Psychoacoustic Test System: 1) an Adaptive Speech Reception Threshold (SRT), 2) the modified Distinctive Features Differences Test (DFD[m]), 3) a high-resolution, Swept Frequency Audiogram (SFA), 4) measures of Dynamic Range, including, Threshold, Loudness Discomfort Level (LDL), and Growth of Loudness, and 5) a Psychophysical Tuning Curve (PTC) procedure. These procedures have undergone evaluation in our laboratory and have recently been installed in a clinical setting for further evaluation. We anticipate that combinations of these measures should provide additional audiological information which is of relevance to the fitting of personal amplification devices.

1. Psychoacoustic Test System (PATS)

The psychoacoustic test system requires a 386 PC with a D/A board, anti-alias filters, and a GSI-16 audiometer. All of the stimuli are stored digitally and are played-back by the PC's D/A board. After passing through the anti-alias filter the test signal goes to the Tape input of the GSI Audiometer. As well, all of the test stimuli are calibrated in dB Hearing Threshold Level (ANSI S3.6-1969) for presentation via TDH earphones or ER3 insert earphones.

The computer program controls all aspects of each test procedure, including presentation of stimuli via remote control of the GSI audiometer, data collection and scoring. In order to simplify use of the PATS program, a graphical interface with drop down menus and dialogue boxes was instituted (see Figure 1). Each client is assigned a numeric code and the clinician can enter personal data (i.e., name and address), as well as audiometric threshold data. The program automatically generates the data file name for each test procedure based upon the client code. The PATS program includes a routine to initialize and calibrate the GSI audiometer. As well, the clinician can specify the test ear and level (dB HTL) of both the test stimuli and noise. The PATS program has a facility to view all test results for a particular client.

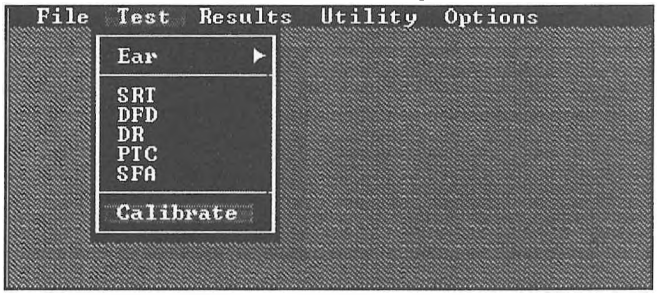

Figure 1. Main PATS screen showing test menu items.

2. Adaptive Speech Reception Threshold (SRT) Test

The adaptive SRT test procedure is a modified version of the automated SRT and was described by Cheesman (1992). This adaptive procedure provides an efficient, accurate, and reliable estimate of a listener's SRT in quiet or noise. During each trial, one of six spondees is presented. The client indicates which word they heard by selecting one of the six corresponding response alternatives displayed on a video monitor. The adaptive procedure follows the Levitt (1971) rule to converge on the 70% point of the underlying psychoacoustic function. Clinical trials to date have focused on improving the efficiency by reducing the number of trials required for convergence while maintaining accuracy and reliability.

3. Modified Distinctive Features Differences Test (DFD[m])

The DFD[m] is a test of speech intelligibility. The test consists of 21 nonsense syllable stimuli. All consonants are presented in the same context (A_IL). The target is the middle consonant of the VCVC word. The test stimuli were produced by four talkers (2 male and 2 female). During each trial one of the 84 stimuli is presented. The client indicates which word they heard by selecting one of the 21 corresponding response alternatives displayed on a video monitor (see Figure 2). The DFD[m] test is scored for percentage of identification errors and the errors are analyzed for type of confusion made (i.e., percentage of voicing, manner, and place confusions). The DFD[m] test of speech intelligibility provides more detailed analysis of speech perception than traditional speech tests, which typically only provide percentage correct. Clinical research to date has focused on the

sensitivity of the DFD[m] to differences between hearing aid electroacoustic circuits and acclimatization to amplification for individual subjects, as well as, normative data (Cheesman, Lawrence and Appleyard, 1992).

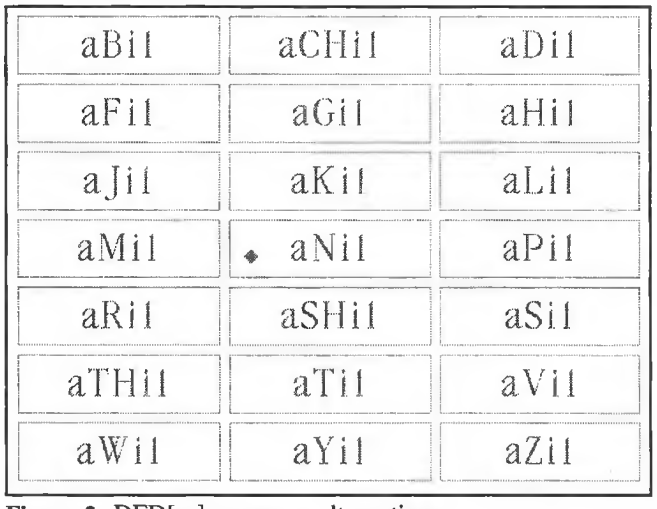

Figure 2. DFD[m] response alternatives.

4. Dynamic Range

The auditory dynamic area is measured using a categorical rating scale for loudness and is based upon a report by Allen, Hall and Jeng (1990). First, the pure tone threshold and loudness discomfort level are measured. Then, a pure tone stimulus is presented at 30 levels between the threshold and LDL in a random sequence. After each presentation of a pure tone pulse at a sound pressure level the client is required to indicate the category which corresponds to the perceived loudness of the sound. The categories range from; nothing, very soft, soft but OK, comfortable, loud but OK, very loud, to uncomfortably loud. Previous clinical trials have focused on the reliability of the threshold and LDL procedures (Gagné, Seewald, Zelisko, Hudson, 1991; Gagné et. al., 1991). Clinical trials will determine the reliability of the loudness scaling procedure, and relate the loudness measures to satisfaction with various types of amplification (i.e., linear vs compression).

5. Swept Frequency Audiogram (SFA)

The SFA uses the Bekésy tracking procedure to measure auditory threshold across frequency with greater detail than can be obtained when threshold is only measured at the 8 standard audiometric frequencies. The SFA procedure measures sensitivity to pure tone pulses (presented 2 per second). Frequency is swept logarithmically at a rate of two minutes per octave. Intensity is adjusted at a rate of 2 dB per second. The procedure is based upon a report by West and Evans (1990). Threshold can be measured across 6 octave bands centred at; 250, 500, 1000, 2000, 4000, 8000 Hz. Normative data have been collected on a group of normal hearing subjects.

6. Psychophysical Tuning Curve (PTC)

The PTC procedure is based upon reports by Patterson (1976) and Glasberg and Moore (1990). An adaptive procedure (70% rule) is used to measure thresholds for pure tones (500, 1000, 3000 Hz) in notched guassian noise. The lower and upper limit of the notch width varies from 0 to 0.5 (0,0; .2,.2; .3,.3; .5,.5; .3,.5; .5,.3 lower and upper respectively). Normative data are being collected on a group of normal hearing listeners.

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