Procedure for Defining the Auditory Area of Hearing Impaired Adolescents with Severe/Profound Hearing Loss I: Detection Thresholds

Procédure de définition du champ auditif des adolescents malentendants atteints de pertes auditives séveres a profondes I : seuils de détection

Jean-Pierre Gagné, Richard C. Seewald, Debra L.C. Zelisko, and Susan P. Hudson
Hearing Health Care Research Unit
Department of Communicative Disorders
The University of Western Ontario

Keywords: auditory area, detection thresholds, psychophysical procedures, hearing aid selection

Abstract

The measurement of detection thresholds (DTs) constitutes an important component of defining the auditory area of a hearing aid candidate. In the present investigation, DTs obtained with a modified Pascoe procedure were compared to those obtained with a conventional audiometric procedure at 500 and 2000 Hz. The modified Pascoe procedure consisted of an ascending method of limits embedded into a one observation interval forced-choice loudness rating paradigm. DTs were obtained from 10 adolescents with severe/profound sensorineural hearing loss on three different occasions. A stimulus delivery/real-ear measurement system that made it possible to record the Sound Pressure Level (dB SPL) of the signals in the occluded external ear canal of the subject was used to measure the threshold levels obtained with both psychophysical procedures. Results revealed that the within session and across session intra-subject variability observed with the modified Pascoe procedure was sufficiently small to recommend the implementation of this psychophysical procedure clinically.

Résumé

La mesure des seuils de détection (SD) représente un élément important de la définition du champ auditif de l'éventuel porteur d'un appareil auditif. Au cours de la présente étude, les seuils de détection obtenus à l'aide de la procédure Pascoe modifiée ont été comparés à ceux qui ont été obtenus à l'aide d'une procédure audiométrique conventionnelle à 500 et 2000 Hz. La procédure Pascoe modifiée consiste en une méthode des limites ascendantes combinée à un paradigme de jugement de sonie par procédure de choix forcé dans un seul intervalle de temps. Les seuils de détection ont été obtenus en trois occasions de 10 adolescents atteints d'une surdité neurosensorielle sévère à profonde. Un système d'envoi de stimulus et de mesures in vivo qui a permis d'enregistrer le niveau de pression sonore (dB SPL) des signaux dans le conduit auditif externe occlus du sujet a été utilisé pour mesurer les seuils obtenus en suivant les deux procédures psychophysiques. Les résultats ont révélé que la variabilité intra-sujet pendant la séance et entre les séances observée à l'aide de la procédure Pascoe modifiée a été assez limitée pour recommander la mise en application clinique de cette procédure psychophysique.

An accurate description of an individual's auditory area constitutes an important pre-requisite for the selection and fitting of an appropriate amplification system. According to Skinner (1988, p.119) the auditory area is defined as: "...the range of intensities between the threshold and the uncomfortable listening level (UCL) over the frequency range that can be heard." Aspects of the auditory area that are particularly relevant for amplification include: (1) Detection Thresholds (DTs), (2) Most Comfortable Listening Levels (MCLLs), and (3) Loudness Discomfort Levels (LDLs). These landmarks of the auditory area may be used to select the frequency response, gain, and the maximum acoustic output of the amplification system(s) for a hearing impaired individual.

Several variables may have an influence on the validity of the audiometric data used to select an amplification system. These may include: (1) the psychophysical procedure, (2) the acoustical characteristics of the signal, (3) the individual's response criteria, (4) the capabilities of the individual to perform the task, (5) the clinician's proficiency, (6) the instructions, (7) the status of the listener's hearing, and (8) the listener's motivation and alertness (Skinner, 1988). Thus, the accuracy of the hearing aid fitting will depend largely on the reliability and validity of the audiometric data that are used to select the amplification system. Presently there is no standardized procedure to measure various components of the auditory area for the purpose of selecting amplification. Psychophysical procedures most often used to measure the various components of the auditory area include: (1) ascending method of limits (e.g., ASHA, 1978; Berger, Harrison, Monack, & Ferren, 1980; Burns & Hinchcliffe, 1957; Carhart & Jerger, 1959; Skinner & Miller, 1983; Tyler & Wood, 1980); (2) descending methods of limits (e.g., Burns & Hinchcliffe, 1957; Cox, 1981); (3) method of adjust-

ments (e.g., Burns & Hinchcliffe, 1957; Byrne & Dillon, 1981; Dirks & Kamm, 1976; Harris & Smith, 1979; High & Glorig, 1962; Pelmear & Hughes, 1974: Stephens, Blegvad, & Krogh, 1977; Tyler & Wood, 1980); (4) up-down adaptive psychophysical procedures (e.g., Levitt, 1971; Taylor & Creelman, 1967); and (5) loudness judgements (e.g., Pascoe, 1978, 1986, 1988; Pascoe, Miller, Skinner, Albee, Freiert, & Hack, 1980). A review of the psychophysical procedures that have been used to measure each individual component of the auditory area is provided by Hawkins (1980) and Skinner (1988).

Several psychophysical procedures have been used to measure DTs in children and adults. The most prevalent procedure consists of an ascending method of limits described by Carhart and Jerger (1959) and later proposed as: Guidelines For Manual Pure-Tone Threshold Audiometry (ASHA, 1978). In this procedure, an ascending method of limits is used to present pure-tone stimuli in 5 dB increments, with the initial level of the tone presented at 10-dB below the anticipated threshold. Once a response has been obtained the level of the stimulus is decreased by 10 dB, and the ascending procedure is resumed (in 5 dB increments) until a response is elicited. Detection threshold is defined as: "the lowest level at which responses occur in at least half of a series of ascending trials with a minimum of three responses required at a single level." (ASHA, 1978, p. 298). The across session variability (i.e., standard deviations) in DTs obtained with the aforementioned ascending method of limits typically range from 2.5 - 5.0 dB, at audiometric frequencies below 4000 Hz (see Jerger, 1962; Tyler & Wood, 1980). Given the deviations allowed in the standard for the calibration of audiometers (ANSI- S3.6, 1969), intra-subject variability of less than 10 dB is deemed acceptable for the purpose of diagnostic audiology (Green, 1978; Harris, 1978).

The ascending method of limits procedure typically used to measure threshold in clinical audiometry is an unforced-choice procedure (i.e., the subject is simply asked to respond if, and when, a stimulus is detected). This approach may lead to some uncertainty and apprehension on behalf of the listener, which in turn may result in producing a high level of false-positive or false-negative responses. There have been reports that forced-choice procedures, in which a nonauditory signal is used to cue the presentation of the test sound, would yield more reliable results (Skinner, 1988, p. 125).

There have been few attempts to develop a systematic approach to measure all aspects of the auditory area with the same psychophysical procedure. Pascoe (1978, 1986, 1988) described a procedure which consists of an ascending method of limits embedded into a single observation interval forced-choice loudness rating psychophysical procedure that can be used to measure all aspects of the auditory area. In this procedure a listener was given a 10-point loudness rating scale that ranged from 0 (i.e., "nothing") to 9 (i.e., "too loud"). Specific points of the loudness rating scale were used to operationally define an individual's DTs, MCLLs, and LDLs, at various audiometric frequencies. The procedure developed by Pascoe is appealing for several reasons: (1) the stimuli are described in terms that are easily understood by naive listeners, (2) the response task is simple and can be completed by most listeners, (3) the procedure can be easily implemented in most clinical settings, (4) the same procedure can be used to obtain all the components of the auditory area that may be required for the selection of an amplification system (i.e., DTs, MCLLs, LDLs), and (5) the procedure is time-efficient. Pascoe (1986) reported that the auditory area of an adult can be completely defined, for both ears, in approximately 30 minutes. To our knowledge there are no published reports on the intra-subject variability associated with DTs obtained with the psychophysical procedure described by Pascoe (1978, 1986, 1988). However, Pascoe (1986, p. 102) reported: "In general, we have found that by using a forced-choice method, by avoiding variations in the sequence direction, and by reducing steps to 2 dB, threshold repetition can be extremely reliable."

The present report summarizes one of two preliminary experiments designed to investigate the use of a modified Pascoe procedure to measure the DTs and LDLs in hearing impaired adolescents. The ultimate goal of the research program is to develop a single psychophysical procedure to measure the auditory area in children. However, it should be noted that hearing impaired adolescents rather than children were recruited as subjects for the investigation. This was done in an attempt to clearly delineate issues related to the test procedure from other subject related variables that may also have an effect on the variability of a specific audiometric procedure such as: (1) the subject's internal response criteria, (2) the subject's ability to perform the task, and (3) the subject's motivation and alertness. Future investigations concerning the applicability of the present procedure to measure aspects of the auditory area among younger hearing impaired children would be based on the findings of the present study as well as the results of the companion investigation (Gagné, Seewald, Zelisko, & Hudson, 1991).

The three specific purposes of the present investigation were to: (1) assess the within session intra-subject variability of the modified Pascoe procedure, (2) investigate the across session intra-subject variability of a modified Pascoe procedure, and (3) assess the criterion validity of the modified Pascoe procedure. Throughout, DTs obtained with a modified Pascoe procedure were compared to those obtained with a psychophysical procedure recognized as the conventional clinical psychophysical procedure to measure DTs (i.e., the ascending method of limits described by ASHA, 1978).

Method

Subjects

Ten students from a provincial school for hearing impaired children participated in the investigation. The subjects ranged from 12-19 years of age. Only students with no known language/learning difficulties other than those associated with hearing impairment were admitted into the study. All subjects displayed tympanometric results that were within normal limits. All had a bilateral sensorineural hearing loss greater than 65 dB HL in the better ear. Only one ear was tested per subject. The mean audiometric hearing threshold levels (of the test ear) for the group of subjects are shown by the open triangles in Figure 1. Those hearing threshold levels were obtained with calibrated TDH-50 earphones (ANSI S3.6, 1969) using a conventional psychophysical procedure (ASHA, 1978).

Instrumentation

All measurements were made in an audiometric test suite. Test stimuli were generated from a Grason Stadler audiometer (GSI-10), and consisted of pulsed pure tones with a 50% duty-cycle of 400 msec. The stimulus delivery/real-ear measurement system used in the present investigation is illustrated in Figure 2. The system was similar to the one described by Zelisko et al., (1990). Specifically, the output transducer consisted of a high output button-type hearing aid receiver (Danavox, Model N68). The transducer was attached to a standard customized earmold designed specifically for the investigation. Each earmold was equipped with a 1.4 mm parallel (probe-tube) vent. A Fonix 6500 hearing aid analyzer was used to measure the level of the signals (in dB SPL) generated in the occluded ear canal of individual subjects. The tip of the probe-tube was positioned to extend at an insertion depth of approximately 30 mm from the intertragal notch. Silicon putty was used to secure the probe-tube to the earmold. The probe-tube remained attached to the earmold throughout the course of the investigation (i.e., all six test sessions). The real-ear electroacoustic analyzer was calibrated daily. The same signal delivery/real-ear measurement system was used to measure the DTs obtained with both psychophysical procedures under investigation.

Figure 1. Test-ear mean (with error bars representing ±1 standard deviation) detection thresholds of the 10 hearing impaired subjects. (Note: only one subject had a detection threshold within the linear range of the earphone at 6000 Hz).

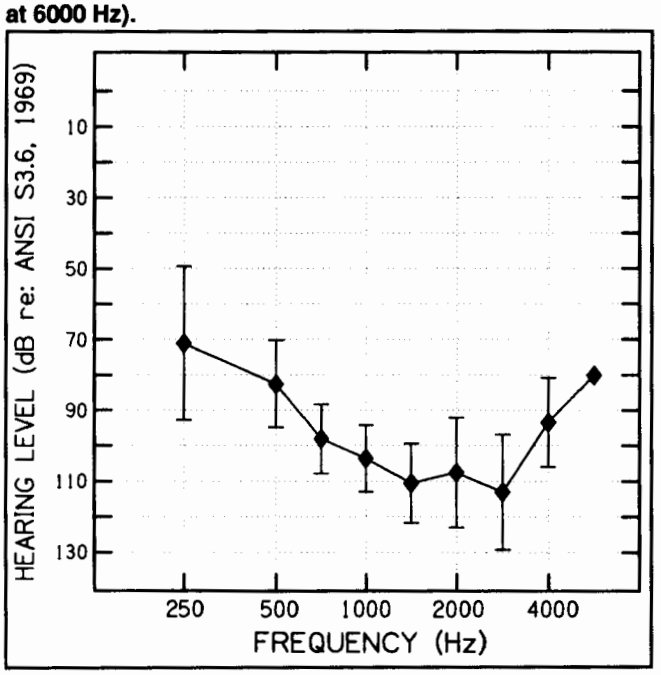
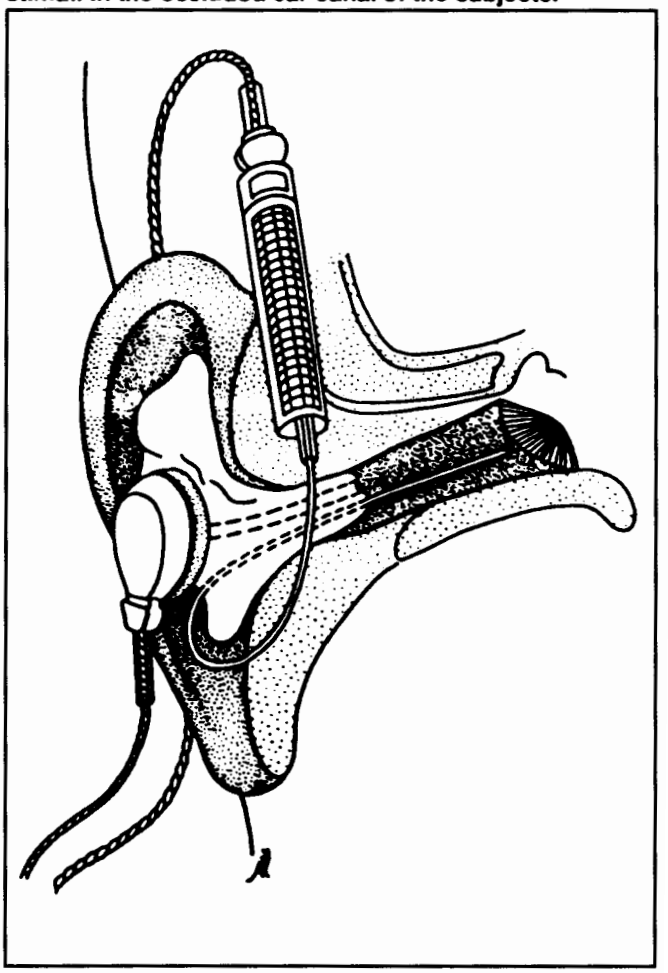


Figure 2. Illustration of stimulus delivery/real-ear measurement system used to present and record the test stimuli in the occluded ear canal of the subjects.



Experimental Design

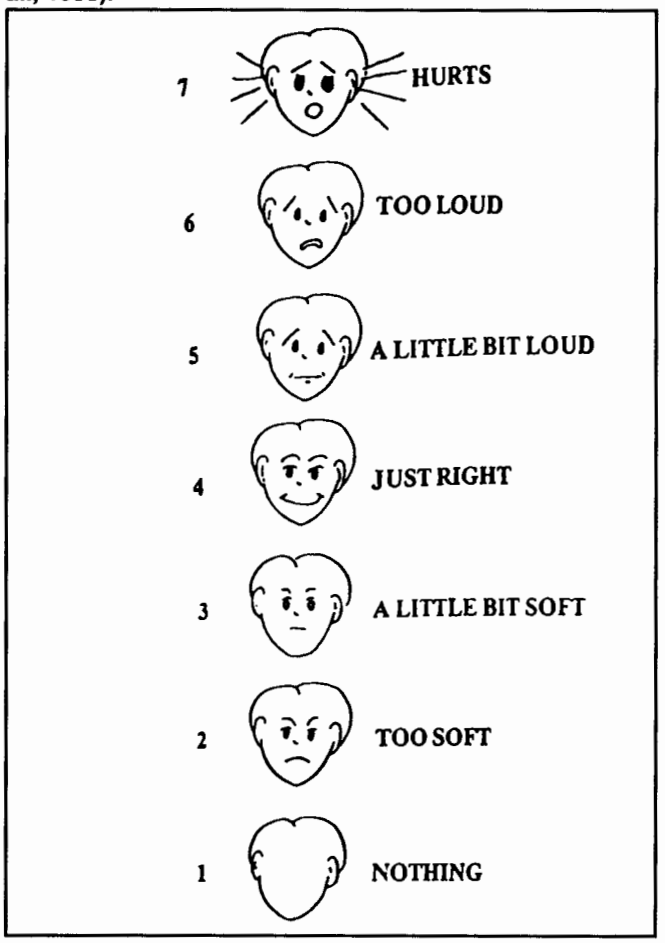
Each subject participated in a total of six test sessions over a period of eight weeks. The modified Pascoe procedure was used to measure thresholds for three test sessions. A conventional audiometric test procedure was used to measure thresholds for three other test sessions. During each session thresholds were measured at 500 and 2000 Hz. The order of presentation of the test procedure and test frequency was counter-balanced across all six sessions.

The conventional audiometric test procedure consisted of a modified ascending method of limits (ASHA, 1978), with two exceptions. First, the level of the stimulus was varied in 2-dB steps. Second, the starting level of each ascending block of trials was 3 - 6 dB below the DT level estimated from audiometric results obtained during the subject selection phase of the investigation (or the DT obtained on previous blocks of trials). The exact starting level was selected randomly. DT was operationally defined as: the lowest level at which a response occurred in at least one-half of a series of ascending trials with a minimum of three responses required at the same level. During each test session five blocks of trials were completed at each test frequency. The DT obtained was recorded after each block of trials. At each test frequency, the conventional audiometric DT value recorded for a given test session consisted of the mean of the DTs obtained for each of the five blocks of trials completed with this psychophysical procedure.

The modified Pascoe procedure consisted of an ascending method of limits incorporated into a one observation interval forced-choice paradigm. As with the conventional procedure, the starting level of the ascending run was selected randomly and the initial trial was presented 3 - 6 dB below the subjects DT level. Stimuli were presented in 2 dB increments. A cueing light was used to signal the presentation of each trial. Following each trial the subject was asked to report the loudness of the stimulus based on the 7-point rating scale shown in Figure 3. The rating scale consisted of a modification of the loudness rating scale used in a previous investigation of LDLs among hearing impaired children (see Kawell, Kopun, & Stelmachowicz, 1988). Each point of the rating scale consisted of a numerical value, a pictorial display, and a written description of loudness.

A block of trials was terminated once the subject reported a loudness rating of 2 or more (that is, a rating other than the loudness category 1-nothing). The lowest intensity level at which this response was obtained was recorded as the DT for that block of trials. During each test session eight blocks of trials were completed at each test frequency. The DT level obtained during each block of trials was recorded. At each frequency, the DT value recorded for a given test session consisted of the mean of the DTs obtained during the last five, of the eight blocks of trials, completed with this psychophysical procedure.

Figure 3. Rating scale used by the subjects to report the loudness of each test stimulus (modified from Kawell et al., 1988).



Results and Discussion

Within Session Intra-Subject Variability

Results obtained during each test session were analyzed to compare the mean within session intra-subject variability observed with each of the two psychophysical procedures under investigation. For each test frequency, the within session intra-subject variability for the conventional audiometric procedure consisted of the standard deviation of the five DTs obtained with that psychophysical procedure during one test session. The within session intra-subject variability for the modified Pascoe procedure consisted of the standard deviation of the last five (of the eight) DTs obtained with that psychophysical procedure during a given test session. The

mean within session intra-subject variability reported for each test session (and each frequency) consisted of the average of the standard deviations computed for the 10 subjects (see Figure 4). A two-way ANOVA for repeated measures revealed that there were no significant effects for test frequencies (F = 2.073, df = 1,2; p=.287) or for psychophysical procedure (F = 14.451, df = 1,2; p=.063). Also, there were no significant interactions between test frequency and psychophysical procedure (F = 14.451, df = 1,2; p=.063). In summary, results indicated that the within session intra-subject variability observed with the modified Pascoe procedure was comparable to the within session intra-subject variability observed with the conventional audiometric procedure at both test frequencies.

Across Session Intra-Subject Variability

The across session intra-subject variability was examined for the two psychophysical procedures under investigation. For each subject, the across session intra-subject variability consisted of the standard deviation of the three mean DTs (i.e., one for each test session) obtained with each psychophysical procedure. The across session intra-subject variability (at 500 and 2000 Hz) obtained with each psychophysical procedure, for individual subjects are shown in Figure 5. The *mean* across session intra-subject variability observed at 500 Hz was 2.52 dB for the conventional audiometric procedure and 3.49 dB for the modified Pascoe procedure. The mean across session intra-subject variability observed at 2000 Hz was 1.64 dB for the conventional audiometric procedure and 1.83 dB for the modified Pascoe procedure. A two-way ANOVA for the repeated measures indicated that there was no significant effect for test frequency (F = 2.498, df = 1,9; p=.148) and no significant interactions between test frequency and psychophysical procedure (F = 1.613, df = 1,9; p=.236). However, analysis revealed that there was a significant effect for psychophysical procedure (F = 11.306, df = 1,9; p=.008). The latter result is most likely attributable to the intra-subject variability of one subject (TM) who displayed an across session variability of 7.88 dB at 500 Hz when the modified Pascoe procedure was used to measure DTs during the first test session. It should be noted that the mean across session intra-subject variability observed with the modified Pascoe procedure was within the range of the across session intra-subject variability (i.e., 2.5 - 5.0 dB) typically reported for adults tested with a conventional audiometric procedure (Jerger, 1962; Tyler & Wood, 1980). Moreover, the across session intra-subject variability observed in the modified Pascoe procedure was less than the intra-subject variability deemed to be acceptable for the purpose of diagnostic audiology (Green, 1978; Harris, 1978).

Figure 4. Mean within session intra-subject variability displayed as a function of test session and two test frequencies. Each data point represents the mean of the within session standard deviation obtained from each of the subjects during a given test session. Square symbols depict results obtained with the conventional audiometric procedure and triangular symbols depict results obtained with the modified Pascoe procedure.

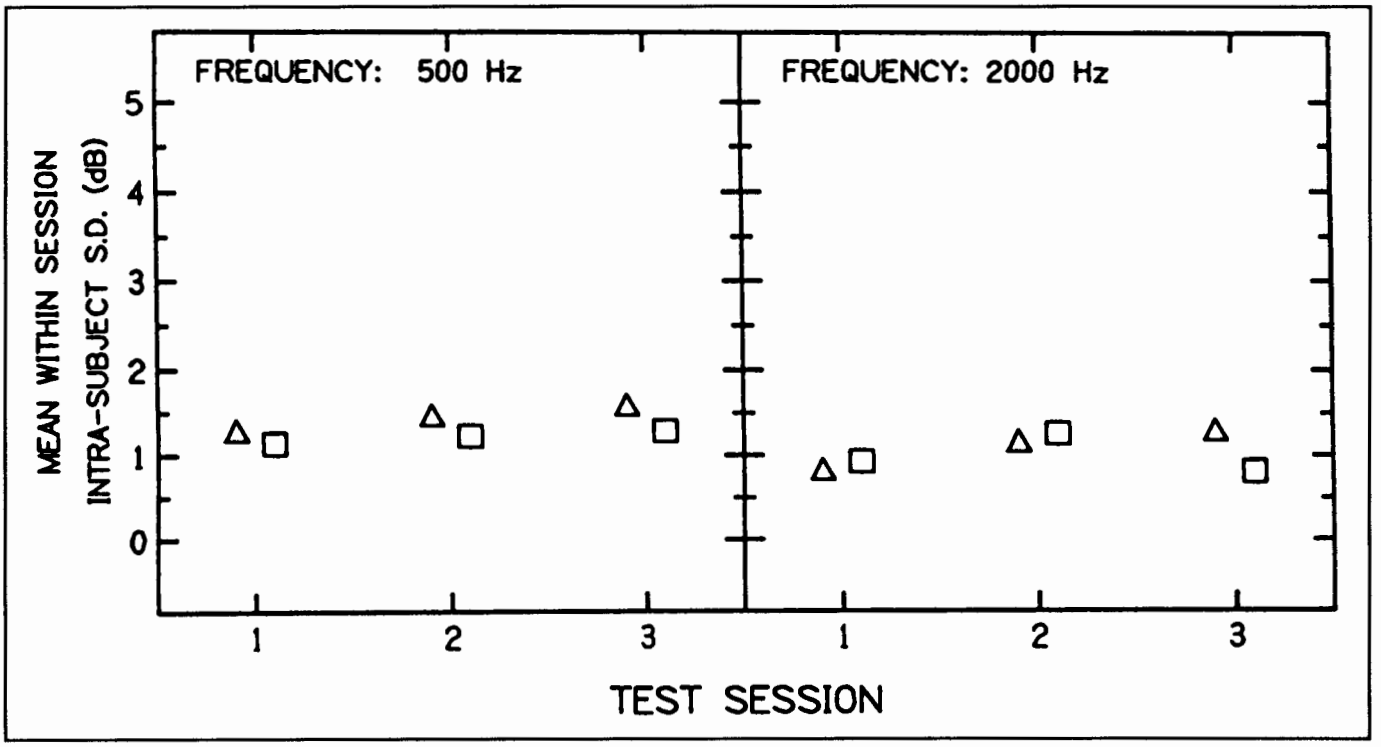
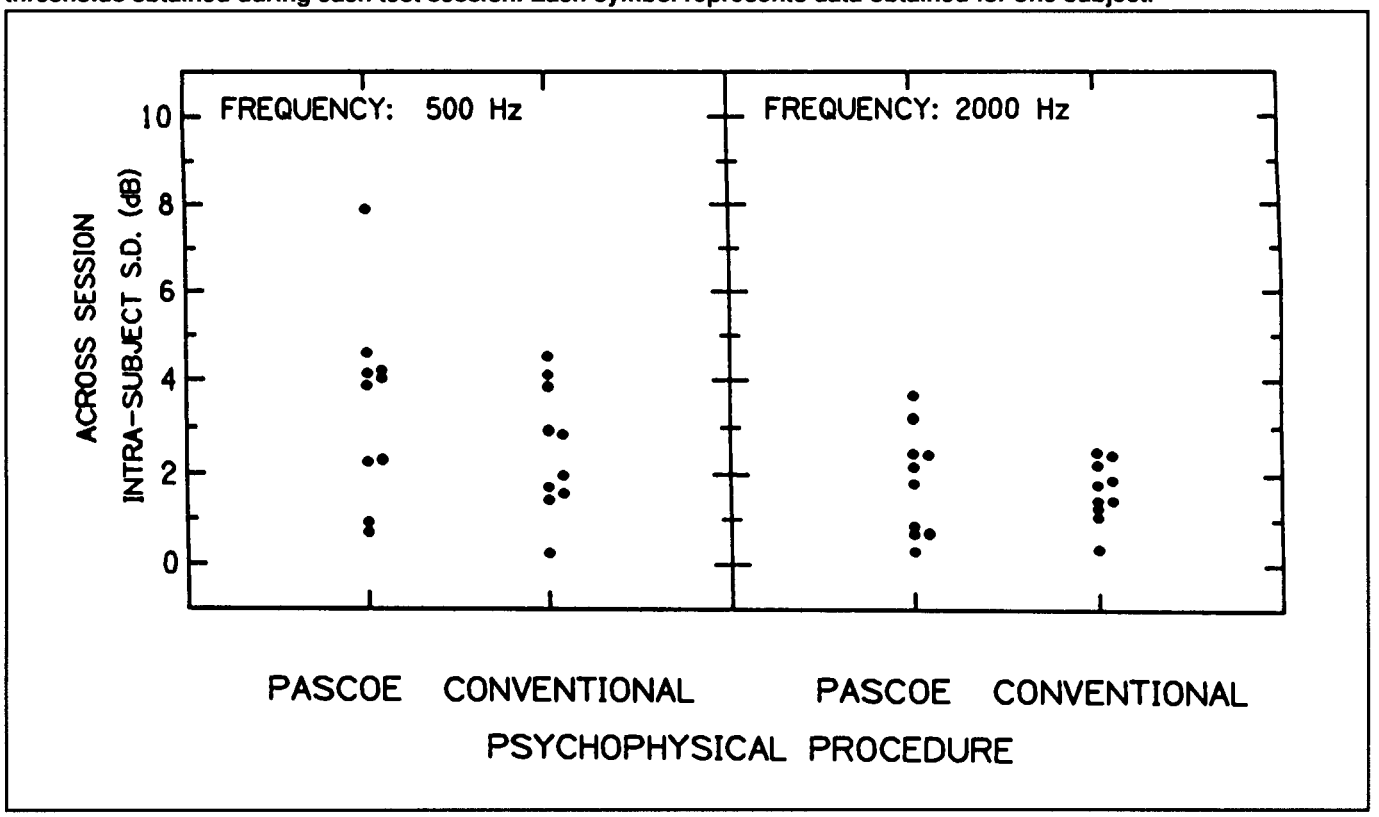


Figure 5. The across session intra-subject variability observed with each psychophysical procedure at the two test frequencies. The across session intra-subject variability consists of the standard deviation of the mean detection thresholds obtained during each test session. Each symbol represents data obtained for one subject.



Criterion Validity of the Modified Pascoe Procedure

Pearson product moment correlations were computed to investigate the relationship between the DTs obtained with the two psychophysical procedures. For each subject, the average of the three mean DTs (one for each test session) obtained with the modified Pascoe procedure (i.e., three test sessions) was correlated with the average of the three mean DTs obtained with the conventional audiometric procedure (i.e., three test sessions). The Pearson product moment correlation coefficient obtained at 500 Hz was .983. The Pearson product moment correlation coefficient obtained at 2000 Hz was .980. At both test frequencies the correlation between the DTs obtained with the modified Pascoe procedure and the DTs obtained with the conventional audiometric procedure was significantly greater than zero (p). Also, at both frequencies, the error of variance (i.e., r^2) was less than 5%. These results are considered to indicate high criterion validity (Cronbach, 1970).

To further investigate the criterion validity of the modified Pascoe procedure, a difference score was calculated for each subject at each test frequency. Each difference score was computed by subtracting the average of the three mean DTs obtained with the conventional audiometric procedure from the average of the three DTs obtained with the modified Pascoe procedure (see Table 1). This type of analysis was deemed appropriate because at present the recognized procedure to measure DTs clinically (i.e., the gold standard) consists of the established ascending method of limits outlined in the Guidelines For Manual Pure-Tone Audiometry (ASHA, 1978). The mean difference score observed at 500 Hz was -.72 dB and the mean difference score observed at 2000 Hz was 1.15 dB. At both test frequencies, the mean difference score was smaller than the within and the across session intra-subject variability observed with both psychophysical procedures under investigation. These findings indicate that, at least within the range of hearing threshold levels displayed by the subjects who took part in the investigation (i.e., severe/profound hearing loss), the two psychophysical procedures yield similar absolute DT levels.

Conclusion

Present results revealed that hearing impaired adolescents could perform the task required to measure DTs with the modified Pascoe procedure. None of the subjects who partic-

Table 1. Mean detection thresholds (dB SPL) across three sessions at 500 and 2000 Hz for each subject.

	500 Hz			200 Hz		
Subject	Pascoe	Conventional	Diff. Scores	Pascoe	Conventional	Diff. Scores
SD	76.7	79.4	-2.7	92.7	95.0	-2.3
DK	126.6	128.6	-2.0	137.4	141.0	-3.6
RL	98.1	95.2	2.9	132.3	129.8	2.5
MM	97.8	98.8	-1.0	130.3	131.5	-1.2
SM	98.6	97.5	1.1	131.6	133.5	-1.9
JM	101.9	106.0	-4.1	122.4	130.9	-8.5
TM	108.3	105.7	2.6	108.3	108.1	0.2
JS	86.0	84.2	1.8	97.7	93.1	4.6
PS	100.8	102.3	-1.5	117.8	119.6	-1.8
KS	79.9	84.2	-4.3	136.2	135.7	0.5
Mean	97.5	98.2	-0.72	120.7	121.8	1.15

ipated in the present investigation displayed any difficulty with the response task. Moreover, an analysis of the within and across session intra-subject variability indicated that the modified Pascoe procedure provided reliable results. The across session intra-subject variability observed with the modified Pascoe procedure was comparable to the test-retest variability indices previously reported for adults with a conventional audiometric psychophysical procedure (i.e., Jerger, 1962; Tyler & Wood, 1980). Pearson product moment correlation analyses revealed that absolute DT levels obtained with the conventional audiometric procedure and those obtained with the modified Pascoe procedure were highly correlated. Also, the differences in absolute thresholds obtained with each psychophysical procedure were negligible. Based on these findings, the method used to measure DT in the present investigation (including the modified Pascoe procedure and the stimulus delivery/real-ear measurement system) produced reliable and valid measurement of DTs among hearing impaired adolescents with a severe/profound hearing loss.

Present results, as well as the results of the companion report (see: Gagné et al., 1991), suggest that the modified Pascoe procedure could be implemented clinically into a hearing aid selection and fitting protocol. Use of the modified Pascoe procedure would make it possible to use the same psychophysical procedure to measure all components of the auditory area (i.e., DTs, MCLLs, LDLs). Moreover, the procedure can easily be implemented into most clinical facilities. It is simple to administer and is time efficient. Further investigations are required to determine whether the modified Pascoe procedure could be used with younger subjects as well as children with a less severe hearing loss.

Acknowledgements

This work was supported primarily by a grant from VOICE for Hearing-Impaired Children. Additional support was provided by the University Research Incentive Fund (Ontario Ministry of Colleges and Universities) and the Hearing Health Care Research Unit (a Health System Linked Research Program sponsored by the Ontario Ministry of Health). The authors would like to express their appreciation to the staff and students of The Robarts School, London, Ontario, for their participation in the research project.

Address all correspondence to: Jean-Pierre Gagné, PhD, Hearing Health Care Research Unit, Department of Communicative, Disorders, Elborn College, The University of Western Ontario, London, Ontario, Canada N6G 1H1

References

ANSI (1969). ANSI S3.6 -1969, "Specifications for audiometers" (American National Standards Institute, New York).

ASHA (1978). Guidelines for manual pure-tone audiometry. *ASHA, 20*, 297 - 301.

Berger, K.W., Harrison, L.D., Monack, N., & Ferren, G.E. (1980). Comfortable loudness judgments for discrete frequency signals. *Journal of Auditory Research, 20*, 119-27.

Burns, W., & Hinchcliffe, R. (1957). Comparison of the auditory threshold as measured by individual pure-tone and by Bekesy audiometry. *Journal of the Acoustical Society of America, 29*, 1274-1277.

Byrne, D., & Dillon, H. (1981). Comparative reliability of warble tone thresholds under earphones and in sound field. *Australian Journal of Audiology, 3*, 12-14.

Carhart, R., & Jerger, J. (1959). Preferred method for clinical determination of pure tone thresholds. *Journal of Speech and Hearing Disorders, 24*, 330-345.

Cox, R. (1981). Using LDLs to establish hearing aid limiting levels. *Hearing Instruments, 32(5); 16*, 18,20.

Cronbach, L. J. (1970). *Essentials of psychological testing* (3rd edition). New York: Harper and Row.

Dirks, D., & Kamm, C. (1976). Psychometric functions for loudness discomfort and most comfortable loudness levels. *Journal of Speech and Hearing Research, 19*, 613-627.

Gagné, J.-P., Seewald, R.C., Zelisko, D.L.C., & Hudson, S.P. (1991). Procedure for defining the auditory area of hearing-impaired adolescents with a severe/profound hearing loss. II: Loudness discomfort thresholds. *Journal of Speech-Language Pathology and Audiology* (in press).

Green, D.S. (1978). Pure tone air-conduction testing. In J. Katz (ed) *Handbook of Clinical Audiology* (2nd ed., pp.98 -109). Baltimore, MD: Williams and Wilkins, 98-109.

Harris, J.D. (1978). Proem to a quantum leap in audiometric data collection and management. *Journal of Auditory Research, 18*, 1-29.

Harris, J.D., & Smith, P.F. (1979). A comparison of a standard and computerized adaptive paradigm in Bekesy frequency audiometry. *Journal of Auditory Research, 19*, 1-22.

Hawkins, D.B. (1980). Loudness discomfort levels: A suggested procedure for hearing aid evaluations. *Journal of Speech and Hearing Disorders, 45*, 3-15.

High, W.S., & Glorig, A. (1962). The reliability of industrial audiometry. *Journal of Auditory Research, 2*, 56-65.

Jerger, J. (1962). Comparative evaluation of some auditory measures. *Journal of Speech and Hearing Research, 5*, 3-17.

Kawell, M.E., Kopun, J.G., Stelmachowicz, P.G. (1988). Loudness discomfort levels in children. *Ear and Hearing, 9*, 133 - 136.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *Journal of the Acoustical Society of America, 49*, 467-477.

Martin, F. N. (1983). *Introduction to Audiology*. (3rd edition). Englewood Cliffs, New Jersey: Prentice-Hall.

Pascoe, D.P. (1978). An approach to hearing aid selection. *Hearing Instruments, 29*, 12 - 12, 36.

Pascoe, D.P. (1986). Hearing aid selection procedure used at Central Institute for the Deaf in Saint Louis. *Audiological Acoustics, 25*, 90-106.

Pascoe, D.P. (1988). Clinical measurements of the auditory dynamic range and their relation to formulas for hearing aid gain. In Jensen, H. J. (Ed.) *Hearing Aid Fitting: Theoretical and Practical Views - 13th Danavox Symposium*. Copenhagen: Stougaard.

Pascoe, D.P., Miller, J.D., Skinner, M.W., Albee, D., Freiert, D., & Hack, Z. (1980). Evaluation of the Pascoe Hearing-Aid Selection Procedure. *Central Institute for the Deaf Periodic Progress Report No. 23*, 51.

Pelmear, P.L., & Hughes, B.J. (1974). Self-recording audiometry in industry. *British Journal of Industrial Medicine, 31*, 304-309.

Skinner, M.W. (1988). *Hearing Aid Evaluation*. Englewood Cliffs, N.J.: Prentice-Hall.

Skinner, M.W., & Miller, J.D. (1983). Amplification bandwidth and intelligibility of speech in quiet and noise for listeners with sensorineural hearing loss. *Audiology, 22*, 253-279.

Stephens, S.D.G., Blegvad, B., & Krogh, H.J. (1977). The value of some suprathreshold auditory measures. *Scandinavian Audiology, 6*, 213-221.

Taylor, M.M., & Creelman, C.D. (167). PEST: Efficient estimates on probability functions. *Journal of the Acoustical Society of America, 41*, 782-787.

Tyler, R.S., & Wood, E.J. (1980). A comparison of manual methods for measuring hearing levels. *Audiology, 19*, 316-329.

Zelisko, D.L.C., Seewald, R.C., & Gagné, J.-P. (1990). Reliability of a procedure for measuring loudness discomfort in children. *Journal of Speech-Language Pathology and Audiology, 14*, 56, 1990.