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**Measurement of the Validity and Reliability of
Hearing Aid Listening Checks as
Performed by Speech-Language Pathologists**

By:

Patrice M. Tourné

B.A. Humboldt State University, 1985

Presented in partial fulfillment of the requirements

for the degree of

Master of Arts

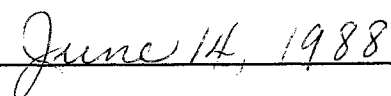
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1988

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Tourne, Patrice M., M.A., June 1988

Communication Sciences & Disorders

Measurement of the Validity and Reliability of Hearing Aid Listening Checks as Performed by Speech-Language Pathologists (74 pages).

Director: Michael K. Wynne, Ph.D.



The purpose of the present study was to determine whether school-based speech-language pathologists could accurately and consistently identify electroacoustic malfunctions in hearing aids by performing listening checks. In addition, this study investigated the correlation between subject performance and reported academic training and professional experience. Ten hearing aids (five behind-the-ear (BTE) and five in-the-ear (ITE)) were used. Four of the hearing aids were judged to be operating within specifications while six of the hearing aids exhibited electroacoustic malfunctions (internal feedback, an inappropriate volume control taper, and excessive harmonic distortion). The subjects were asked to perform listening checks on the ten hearing aids over two trials. The subjects also completed a questionnaire soliciting information regarding their academic training in amplification and their professional experience.

The results indicated that overall the subjects could identify the appropriately functioning hearing aids and hearing aids exhibiting internal feedback and an inappropriate volume control taper with a relatively high degree of accuracy. The subjects exhibited relatively poor accuracy in identifying the defect of harmonic distortion. The subjects obtained higher accuracy scores with the BTE hearing aids than with the ITE hearing aids. Subject performance during the second trial could not be predicted from their performance during the first trial. There was no significant correlation between subjects' accuracy in identifying the defective hearing aids and their academic training or professional experience with hearing aids.

Further research is suggested to investigate the effectiveness of training programs for performing listening checks, with specific attention given to the training of identification of more subtle electroacoustic defects such as harmonic distortion, internal noise and intermittancy.

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Chapter I: Introduction

Teachers, speech-language pathologists and audiologists agree that the proper fit and maintenance of hearing aids are critical elements in any child's aural (re)habilitation program. Unfortunately, several studies (Bess, 1977; Porter, 1973; Zink, 1972; Gaeth & Lounsbury, 1966) have reported that the performance of children's hearing aids used in the classroom is frequently inadequate and unreliable. These studies have estimated that as many as 40-50% of children's hearing aids in the educational setting perform unsatisfactorily.

Daily listening and visual checks have been instituted in schools to monitor and maintain adequate function of the hearing aids. A visual check can easily reveal hearing aid malfunction caused by dead batteries, frayed cords and poorly fitted earmolds (Kemker, McConnell, Logan, and Grann, 1979). However, as much as 48% of the hearing aid malfunctions found in the classroom are a result of electroacoustic malfunctions such as insufficient output, and/or excessive levels of harmonic distortion (Bess and McConnell, 1981). These problems are only identifiable by a listening check or by an electroacoustic analysis of the hearing aid. The electroacoustic malfunctions reduce the overall benefit of the hearing aid, with the potential impact of adversely affecting the child's academic performance or progress. Reports that

the overall performance of hearing aids used in classrooms had seen little improvement over the past 15 years suggest these listening checks are "less than effective" (Bess & McConnell, 1981; Porter, 1973; Zink, 1972; Gaeth & Lounsbury, 1966).

In a study undertaken to determine whether listening checks, as typically performed by classroom personnel, could reveal electroacoustic malfunctions in hearing aids, Busenbark and Jenison (1986) found that classroom personnel displayed extremely poor consistency in evaluating hearing aid function. In addition to poor test-retest reliability, they indicated that the accurate identification of hearing aid malfunction by classroom personnel was possible, but unlikely. Recently, Woodford (1987) assessed speech-language pathologists' knowledge and skills regarding hearing aids. He reported that the majority of the speech-language pathologists in his sample lacked the basic knowledge and practical skills necessary to provide help with children's amplification.

The purpose of this study was to investigate the validity and reliability of listening checks of hearing aids performed by speech-language pathologists employed in a school setting. In addition, this study investigated the correlation between the ability of the speech-language pathologists to identify an electroacoustic malfunction with the amount of experience the speech-language pathologist has had working with hearing-impaired children who wore hearing aids.

Chapter II: Literature Review

In recent years, due at least in part to the implementation of the Education of All Handicapped Children Act of 1975 (PL 94-142), there has been an increase in the numbers of hearing-impaired children in the regular public school classrooms. For those children wearing hearing aids, PL 94-142 mandates that "Each public agency shall insure that the hearing aids worn by deaf and hard of hearing children in school are functioning properly" [Federal Register (1977). Tuesday, Aug. 23, Vol. 42, no. 163. p. 42488]. Thus, if these children are to be served appropriately, then their hearing aids must be checked daily through an ongoing program of effective, efficient monitoring.

Considering this national mandate, one would expect that the hearing aids worn by school-age, hearing-impaired children are being adequately monitored. However, the adequacy of monitoring programs is dependent upon responsible school personnel having the skills necessary to perform the hearing aid check.

Condition of Hearing Aids in School Settings

The first detailed examination of the performance of hearing aids used by children in school settings was provided by Gaeth and Lounsbury in 1966. Gaeth and Lounsbury evaluated behavioral and physical characteristics of the hearing aids of 134 children, ranging in age from 3 to 18 years. The most significant findings of this landmark study dealt with the

percentage of hearing aids which were found to be functioning inadequately. Different data were presented for "adequacy", and these differences were differentiated by the criteria used to assess "adequacy". The authors stated:

If we were to define an adequate hearing aid as one worn by the child when he came for his clinic appointment, with the volume control set at less than "full", and with all parts present and functioning, then 31 percent of the total 134 children had adequate hearing aids. If the requirements are liberalized and the facts overlooked that the child did not wear the hearing aid when he came to the clinic, that live batteries had to be installed as necessary, and that the hearing aid was worn at full volume, then 55 percent of the hearing aids could be considered adequate. (Gaeth and Lounsbury, 1966, p. 286).

Overall, their results indicated, that at least half the children were not obtaining maximum assistance from the use of their hearing aids, regardless of which criteria were used.

Zink, in 1972, provided a follow-up study by presenting a detailed analysis of the hearing aids worn by children in a regular school setting. Over a 2-year period, he evaluated the electroacoustic performance of 195 hearing aids worn by hearing-impaired children. The criteria used for considering adequacy of hearing aid performance were:

- (1) an increase or decrease within the frequency range of the instrument of more than 15 dB, or two or more increases or decreases of greater than 6 dB,
- (2) the gain and output measures were not within 6 dB of manufacturer's specifications,
- (3) harmonic distortion was more than 17 percent at any one frequency, and

(4) gain control taper did not demonstrate adequate linearity to provide sufficient reserve gain.

In the first year, Zink found that 60 of the 103 aids evaluated (59%) were rejected as not meeting his criteria. Fifty two of the 60 (86%) rejected aids were re-examined after they were presumably repaired and 18 (35%) were still rejected. Of the 92 hearing aids evaluated in the second year of the study, 41 (45%) were unacceptable. Zink attributed the slight improvement in hearing aid performance (13%) from the first to the second year, to an increased awareness toward care of the instruments by teachers, parents, and children.

Porter (1973) evaluated 82 hearing aids worn by children at the Kansas School for the Deaf. The hearing aids were examined through visual, listening and electroacoustic analyses. For the listening check, a hearing aid was judged inadequate if feedback was observed at any time during the evaluation. A hearing aid was also judged inadequate if the battery was dead, if it distorted the output, it provided very low gain, or it operated intermittently during the listening check. During the electroacoustic analysis, Porter measured frequency response curves and maximum power output of the hearing aids. A hearing aid was judged defective if it deviated significantly from either the manufacturer's specifications or from previous explanations of the same hearing aid. The results revealed that 42 (51%) of the hearing aids were judged defective at the time of the

evaluation. Of the defective aids, 32 (77%) of the hearing aids were found to have problems which were easily observable and were detected by the visual and listening inspection. However, the problems found did not represent major electroacoustic malfunctions. Rather they included dead batteries, inadequate earmolds, and broken switches, cords or volume controls. The author emphasized that these problems were both easily detectable and correctable. Ten (8%) hearing aids passed the visual and listening inspection but still failed to meet manufacturer's specifications when evaluated electroacoustically. The problems noted here included a marked change in the frequency response, usually a reduction of the low frequency gain, or high harmonic distortion at the user gain setting.

Bess, in 1977, contributed further information relative to poor condition of children's hearing aids as used in a large metropolitan school system (Nashville, TN). He evaluated a total of 121 hearing aids, and each hearing aid was assessed in an "as worn" condition. The evaluation consisted of both a physical inspection (visual check) and a behavioral assessment (an electroacoustic analysis using a hearing aid analyzer). Out of the total 121 hearing aids assessed, 32 (27%) hearing aids were judged unsatisfactory in at least one category of physical wear: 30% of these hearing aids had poor tubing, 5% exhibited broken or cracked cases, 8% of the earmolds were cracked or occluded, 9% of the body

aids had cracked or broken receivers, and 14% of the cords were rated unsatisfactory. Additionally, he found that 15% of all of the hearing aid batteries were not operating at full strength.

An examination of the total harmonic distortion (THD) for the 121 hearing aids used was included in the electroacoustic evaluation. Bess computed the average THD (at 500, 700, and 900 Hz) for the hearing aids in both an "as worn" condition (same volume setting and battery the child was using) and a "standard" condition ("standard" setting measures consisted of acoustic gain, saturation output, total harmonic distortion, and a basic frequency response). His results indicated high average THD values for both the "as worn" and "standard" conditions, with some hearing aids exhibiting THD levels exceeding 20%, 30%, and 40%. Under "standard" conditions, 58 (48%) of the hearing aids exceeded 20% THD, 29 (24%) exceeded 30% THD, and 17 (14%) of the hearing aids produced distortion greater than 40%. These data represent a significant concern due to the high distortion values (in excess of 20%) are thought to produce degradation in speech understanding (Harris, Haines, Kelsey, & Clack, 1961, as cited in Chial, 1977). While the acceptable amount of harmonic distortion in a hearing aid is not standardized, some authors have demonstrated that harmonic distortion values greater than 10% have appreciably negative influences on word recognition (Lotterman and Kasten, 1967; Jerger, Speaks & Malmquist, 1966;

Jirsa and Hodgson, 1970; Bode and Kasten, 1971). The Veteran's Administration and other laboratories have recommended that the audiologist or hearing aid dispenser reject any hearing aid with harmonic distortion greater than 10% (Jeffers, Behrens, Rubin, et al, 1973).

Overall, these studies (Gaeth and Lounsbury, 1966; Zink, 1972; Porter, 1973; and Bess, 1977) indicated little or no improvement in the operational performance of hearing aids worn by children in the classroom through the late 1970's.

Hearing Aid Monitoring Programs

Several studies have indicated that the institution of a hearing aid monitoring program can significantly reduce the high prevalence of malfunctioning hearing aids (Diefendorf and Arthur, 1987; Potts and Greenwood, 1983; Mynders, 1981; Bendet, 1980; Kemker et al., 1979; Hanners and Sitton, 1974).

Hanners and Sitton (1974) described a successful daily hearing aid monitoring program that they had instituted at Vanderbilt University in Nashville, TN. Their program included training for parents on the daily inspection of their child's hearing aids. Additionally, daily visual and auditory inspections of each child's hearing aids were completed by graduate students in audiology and speech pathology. The program resulted in reduced hearing aid malfunction, better overall condition of the children's hearing aids, and positive response from the teachers.

Kemker, McConnell, Logan & Green, (1979) described the

results of a survey they conducted on the condition of hearing-impaired children's hearing aids over a five-year inspection program at two school settings in Nashville, TN. During the first three years of the survey, the hearing aids were checked weekly by an audiologist. A thorough visual and auditory inspection of each hearing aid was conducted. During the last two years of the survey, the teachers and teacher's aides conducted daily inspections of each child's hearing aid, while the audiologist continued to conduct the weekly inspections. The primary finding of their survey was that the percentage of hearing aid malfunctions decreased by approximately 50% in the fourth and fifth years of the program. This decrease may have been attributed to the daily inspection program conducted by the teaching staff in addition to the weekly inspections conducted by the audiologist.

Bendet (1980) described a hearing aid monitoring program instituted in the Pittsburgh, PA public school system, in which teacher-training was the primary focus. Bendet offered a specific protocol for a daily hearing aid check, along with practical experience, to the participating teachers. Her results indicated that over an 18-month period, a significant decrease in hearing aid malfunctions was noted, which she attributed to the maintenance program.

Potts and Greenwood (1983) examined the effectiveness of a daily hearing aid monitoring program conducted at a private day school for hearing-impaired children. In addition to the

routine hearing aid monitoring conducted by the teacher's aides, they provided detailed visual-auditory inspections and electroacoustic analysis of the hearing aids. Their results suggested that by adding the detailed visual-auditory inspections, in addition to periodic electroacoustic inspections, the effectiveness of the monitoring program improved considerably. They stressed the importance of including regular electroacoustic assessments of hearing aids in a monitoring program, as an electroacoustic analysis can reveal malfunctions that are not identifiable by subjective visual-auditory checks.

Diefendorf and Arthur (1987) examined the effectiveness of parent training in hearing aid maintenance. They developed a protocol for daily monitoring of children's hearing aids, and provided parent education/training on such topics as the anatomy of hearing, hearing loss, audiogram interpretation, hearing aid function, and hearing aid maintenance. Their study included results of routine monitoring on 10 hearing aids over a one-year period. Over this period, they found that the proportion of undetected malfunctions decreased and the parent's knowledge and understanding of hearing aids increased.

The primary findings of these studies indicate that the institution of routine hearing aid maintenance programs in the school setting can decrease the number of malfunctioning hearing aids worn by hearing-impaired children.

Unfortunately, there are other indications that routine hearing aid monitoring is not normally performed in most school settings. Elfenbein, Bentler, Davis, and Niebuhr (1986) examined a variety of hearing aid monitoring practices. A portion of their study included administering a questionnaire to teachers of the hearing-impaired in public school settings across the state of Iowa. They requested information regarding the frequency with which children's hearing aids were monitored by school personnel. Their results indicated that a large number of the children's hearing aids were rarely or never checked. For hearing-impaired children between 12 and 18 years of age (N = 108), 40% of the children's hearing aids were never checked, and for the hearing-impaired children between 5 and 11 years of age (N = 158), 18% of the children's hearing aids were never checked. This indicated that a significant proportion of the children's hearing aids were not monitored at all.

Responsibility for Hearing Aid Maintenance

The responsibility for supervising the maintenance of children's hearing aids has been diffusely distributed among a variety of individuals. Training programs designed for parents of hearing-impaired children recommend that parents perform a daily hearing aid check (Thompson, Atcheson & Pious, 1985; Clark and Watkins, 1978). Other programs have insisted that the person primarily responsible for providing hearing aid maintenance must be the teacher who comes in direct, daily

contact with the hearing-impaired child in the classroom (Lass, Tecca & Woodford, 1987; Potts & Greenwood, 1983; Bendet, 1980). Due to the need for specialized training of personnel who conduct listening checks, the school speech-language pathologist has also been designated as the most appropriate person to monitor hearing aids in the schools (Woodford, 1987). However, speech-language pathologists do not view themselves as being capable of dealing with monitoring hearing aids and usually suggest the audiologists should be the professional responsible for this maintenance. The educational audiologist has been traditionally considered to be the most qualified individual for taking on the responsibility of overseeing a hearing aid maintenance program, since the educational audiologist possesses the greatest degree of professional expertise in the area of hearing aids in the public school setting (Ross, 1976). Although educational audiologists have the theoretical and practical knowledge regarding hearing aid maintenance, typically there are too few audiologists employed by most school districts to meet the hearing aid maintenance needs of the hearing-impaired children in their districts. Thus, the task of routine maintenance of hearing aids is generally assigned to the public school staff member who most often comes in contact with the child with a hearing aid (namely, teachers and speech-language pathologists). Unfortunately, previous studies have demonstrated that teachers and speech-

language pathologists lack the basic knowledge and skills necessary for dealing with the routine maintenance of amplification systems used by hearing-impaired children in the schools.

Jones (1982, cited in Berg, et al., 1986) found that regular school teachers, who are often expected to monitor the hearing aids, have little or no knowledge of hearing aids. Lass, Tecca & Woodford (1987) also examined teachers' knowledge of hearing aids. They found this knowledge essentially deficient, especially regarding where the hearing-impaired child could obtain hearing aids and the role of the audiologist in the management of the hearing-impaired child. Busenbark and Jenison (1986) assessed the reliability of hearing aid assessments made by classroom personnel. They asked classroom personnel to perform listening checks on several malfunctioning hearing aids, and then had them reassess the same hearing aids at a later date. Their results indicated that classroom personnel displayed extremely poor consistency in evaluating the electroacoustic performance of hearing aids.

Speech-language pathologists have also demonstrated similar deficits in knowledge regarding the use and care of hearing aids. Woodford (1987) administered a written and practical examination on hearing aids to 102 speech-language pathologists in West Virginia. For the practical examination, the subjects were asked to assess the function of two hearing

aids. The results of his study revealed very poor performance by the speech-language pathologists on both the written and practical examinations. The participating speech-language pathologists displayed significant deficits in knowledge in the areas of acoustic feedback, battery voltage, and telecoil function. The results of the practical examination indicated that only one fourth of Woodford's sample changed the hearing aid setting from the telephone to microphone position appropriately, and that less than one fourth of the sample completed any of the other functions correctly. Woodford then examined the relationship between level of performance and experience with a hearing-impaired client. His results indicated that those subjects who had experience with hearing aids performed better on both examinations. Woodford also assessed the correlation between the amount of instruction in hearing aids and performance on the examinations. He found that those subjects that had received more than two hours of instruction performed better on the written examination than those who had received two hours or less of instruction. The results of the practical examination were relatively homogenous across subjects. This suggested that a speech-language pathologist's knowledge and skill with hearing aids generally improves with experience. Still, the primary findings of this study indicated that many speech-language pathologists lack the minimum skills involving hearing aids which are considered necessary to meet the requirements of PL

94-142.

The diffuse distribution of responsibility for monitoring hearing aids in the schools may likely be attributed to inadequate training in amplification among school personnel. Regular classroom teachers typically do not receive any training in audiology, hearing aids, or (re)habilitation needs of the hearing-impaired child. A specialized teacher of the deaf may receive some instruction in amplification, but they generally feel that hearing aids should be maintained by other school personnel. In regards to speech-language pathologists, the American Speech-Language-Hearing Association requires that the speech-language pathologist must complete six semester hours in audiology prior to obtaining the Certificate of Clinical Competence in Speech-Language Pathology. Three of these semester hours must address pathologies of the auditory system and assessment of auditory disorders while the other three semester hours must address habilitative/rehabilitative procedures with speech and language problems associated with hearing-impairment (ASHA, 1975). These requirements are rather general and may allow for the total absence of training in amplification and assistive listening devices. As a result, the school personnel who are typically given the responsibility of hearing aid maintenance, traditionally have not received sufficient instruction on the use, care, and maintenance of hearing aids.

Hearing Aid Malfunctions

The studies outlined above have generally indicated that the most common hearing aid malfunctions are the most easily detected. In Bendet's (1980) assessment of hearing aid status, the visual and listening checks revealed the most common problems as being:

- 1) the hearing aid was not worn;
- 2) the hearing aid was switched to "telephone" or "off";
- 3) dead battery; and
- 4) earmold blocked with cerumen.

All of these problems were easily correctable by the teachers. The most common problems found by both Gaeth and Lounsbury (1966) and Zink (1972) were dead batteries and broken cords - - difficulties which are easily diagnosed and remediated. Diefendorf and Arthur (1987) stated that simple mechanical problems such as broken hooks, problems with tubing, and earmold problems can be identified easily with a simple visual inspection. The electroacoustic malfunctions, though less common, may be more difficult to detect, and most certainly require a subjective listening assessment.

Visual and Listening Checks

A hearing aid check involves both a visual and listening assessment. The visual check generally involves inspecting each normally visible component of a hearing aid system for problems. The visual component of the check typically

includes assessing the following:

- 1) battery voltage (utilizing a volt meter),
- 2) proper battery insertion,
- 3) earmold appearance (e.g., presence of cracks, rough areas, patent vent and sound bore),
- 4) tubing appearance (e.g., presence of cracks, moisture, debris),
- 5) connection of tubing to earmold and hearing aid,
- 6) hearing aid casing (e.g., presence of cracks, dirt),
- 7) microphone integrity (e.g., visible damage; presence of debris), and
- 8) hearing aid controls (e.g., proper settings; appropriate maneuverability).

A listening check entails listening to the sound output of the hearing aid system for problems while manipulating the sound input and controls of the hearing aid. Several listening check protocols have been described by various authors (Berg, 1987; Thompson, et al., 1985; Potts & Greenwood, 1983; Hodgson & Skinner, 1981; Ling & Ling, 1978; Ling, 1975). While the components of these listening check protocols vary somewhat, most of these protocols consist of the same basic elements. A conventional listening check, as described by Potts and Greenwood (1983), involves assessment of the following aspects of the hearing aid (using the Ling Five Sounds as input, and with the hearing aid coupled to the listener's ear):

- 1) hearing aid controls/switches (turn the hearing aid on and off, listen for static, intermittent sound or loose contacts),
- 2) Volume control (turn volume control up and down, slowly while listening for scratchiness, dead spots, or non-linear growth in volume),
- 3) Variable controls (listening for clear amplification of all five speech sounds; listening for appropriate gain setting for the hearing aid)
- 4) Hearing aid casing (gently tapping the hearing aid on all sides to check for interruptions in amplification or loose connections),
- 5) Overall sound quality (listening for distortion, static, reduced gain), and
- 6) Earmold tubing (remove the receiver from ear and cover the opening of the earmold: turn volume control to maximum gain, listening for acoustic feedback).

These listening checks should be performed with the hearing aid gain settings in the position normally used by the child, or adjusted to provide as much output the listener can tolerate comfortably, since this generally approaches the power output required by the child (Ling, 1975). The hearing aid should also be coupled to the listener's ear with a hearing aid stethoscope or a custom fitted earmold, an adapter, and a connecting tube. The Ling Five-Sounds (Ling,

1978) are conventionally used as input when assessing the acoustic properties of a hearing aid. These sounds, [u], [a], [i], [s], and [ʃ], are felt to represent sample points across the entire range of speech frequencies, thus enabling the listener to identify the presence of significant distortion occurring at any frequency within the speech range (250 Hz to 4000 Hz).

When the listening check indicates any possible malfunction, the parents should be notified in writing regarding the exact nature of the problem. Parents should also be provided with instructions regarding the need for repairs. Finally, appropriate referrals to the child's hearing aid dispenser or audiologist should be provided to the parents (Ross and Calvert, 1976).

Hearing Aid Fittings on Children

There are four basic types of hearing aids dispensed to children: 1) behind-the-ear (BTE) hearing aids; 2) in-the-ear (ITE) hearing aids; 3) body worn hearing aids; and, 4) eyeglasses hearing aids. A recent survey of audiologists obtained information regarding the attitudes and practices in the fitting and recommendation of these four types of hearing aids (Curran, 1985). The primary objective was to obtain information about dispensing/recommendation practices with reference to ITE hearing aids for children between birth to 18 years of age. Based on responses from 190 audiologists, Curran presented estimates describing the percentage of each

type of hearing aid dispensed/recommended to adults and to children. For adults, 51.9% of the hearing aids dispensed/recommended were BTE hearing aids, 46.1% were ITE hearing aids, 1.1% were body hearing aids, and 0.9% were eyeglass hearing aids. For children, 75.4% of the hearing aids dispensed/recommended were BTE hearing aids, 15.5% were ITE hearing aids, 8.4% were body hearing aids, and 0.7% were eyeglass hearing aids. Curran's analysis of these figures indicated that BTE hearing aids were by far the amplification system of choice for children. In addition, ITE hearing aids were dispensed/recommended nearly twice as much (15.5%) as body aids (8.4%) for children. Finally, his results indicated that most of the ITE hearing aid fittings/recommendations were for older children (6 - 18 years), who exhibit mild to moderately-severe hearing losses. Overall, these survey results suggested that while the vast majority of school-age hearing-impaired children are wearing BTE hearing aids, a significant portion of this population are wearing ITE hearing aid systems. With the trend toward increasing numbers of ITE hearing aid fittings on hearing-impaired adults, the percentage of ITE hearing aid fittings on school-aged hearing-impaired children is likely to increase in the future.

Chapter III: Methods

Statement of the Problem

The purpose of this study was to investigate the validity and reliability of listening checks on hearing aids as performed by speech-language pathologists employed in public school settings. Additionally, subject performance was correlated with the amount of instruction and experience with hearing aids and hearing-impaired children. Specifically, this study addressed the following questions:

- 1) Can speech-language pathologists employed in the schools detect electroacoustic malfunctions present in hearing aids through a listening check?
- 2) Is their performance on the listening checks accurate over time?
- 3) Is their performance on this task related to:
 - a) their prior training in amplification, and,
 - b) their prior experience with hearing-impaired children who wore hearing aids?

Subjects

The subjects participating in this study included 11 normally hearing speech-language pathologists employed in a public school setting in the Missoula, MT area. All subjects were licensed by the state of Montana to practice speech-language pathology.

Materials

Ten hearing aids were obtained from Starkey Northwest in Portland, OR. Five of the hearing aids were behind-the-ear (BTE) hearing aids, and the other five were in-the-ear (ITE) hearing aids. Table 1 provides a description of the make, model, and malfunctions of the hearing aids. Two of the BTE hearing aids and two of the ITE hearing aids were judged to be functioning appropriately by the lab technicians at Starkey labs (Portland, OR).

The six remaining hearing aids exhibited electroacoustic malfunctions that were induced and verified by the lab technicians at Starkey Labs. One ITE hearing aid and one BTE hearing aid was judged to have an inappropriate or a non-linear volume control taper. One ITE hearing aid and one BTE hearing aid was judged to have excessive harmonic distortion ($>10\%$ THD). Harmonic distortion occurs when new frequencies are generated that are whole number multiples of the original or fundamental frequency, and that are not part of the input signal. "Psychologically, it results in a change in the perceived quality of the signal and, if sufficiently severe, in loss of clarity or identifiability of the signal" (Kasten & Franks, 1981). One ITE hearing aid and one BTE hearing aid was judged to have internal feedback. Feedback is the squeal from a hearing aid receiver that is produced when amplified sound from the receiver is picked up by the microphone and reamplified. When the sound leakage is occurring within the

Table 1. Description of Hearing Aids

Type	Make	Model	Serial #	Malfunction
ITE	Electone	P.A.	80-52303	none
ITE	Omni		582174	no volume taper
ITE	Starkey	CE4	019060	internal feedback
ITE	Zenetron	C-400	82-15335	none
ITE	Qualitone	CPE	AA9255	harmonic distortion
BTE	Belton	Minuet	Y50119	none
BTE	Belton	Aria	B90428	no volume taper
BTE	Sears		DA03856	internal feedback
BTE	Belton	Overture	N53354	harmonic distortion
BTE	Oticon	E25P	025615	none

hearing aid casing, it is considered internal feedback.

The output characteristics of each hearing aid was confirmed by electroacoustic analysis at the University of Montana Speech, Hearing and Language Clinic. (See Appendix A) The electroacoustic analysis was performed by the Fonix 5500 Hearing Aid Test Set, with a Sony ECM-16 electret condensor microphone, and HA-1 and HA-2 type couplers, and according to the ANSI S3.22-1982 specifications for measurement of hearing aid characteristics. Listening checks on each of the ten hearing aids were performed by five trained individuals (audiologists, or advanced master's level students in audiology) to confirm the electroacoustic malfunctions. Table 2 provides a description of the malfunctions identified by each of the trained examiners.

A portable audiometer (Qualitone, Auditory-Screener), with TDH-39P earphones was utilized to perform the hearing screening on each subject. The output of the audiometer was calibrated to meet the ANSI S3.6-1969 specifications for audiometers.

A Hal-Hen hearing aid stethoscope was provided for the purposes of coupling the hearing aids to the subject's ears. A battery volt meter was also provided to assess battery voltage prior to each subject's initiation of the listening checks.

A questionnaire was designed and implemented to measure the subject's amount of instruction and experience with

Table 2. Description of Hearing Aid Malfunctions as Assessed by Listening Checks Performed by Trained Examiners

Examiner #:	1	2	3	4	5
H.A. # 1	no malf.	no. malf.	no malf.	no malf.	no malf.
H.A. # 2	inapprop. vol.taper	inapprop. vol.taper	inapprop. vol.taper	inapprop. vol.taper	inapprop. vol.taper
H.A. # 3	internal feedback	internal feedback	internal feedback	internal feedback	internal feedback
H.A. # 4	no malf.	no malf.	no malf.	no malf.	no malf.
H.A. # 5	distort.	distort.	distort.	distort.	distort.
H.A. # 6	no malf.	no. malf.	no malf.	no malf.	no malf.
H.A. # 7	no vol. taper	no vol. taper	no vol. taper	no vol. taper	no vol. taper
H.A. # 8	internal feedback	internal feedback	internal feedback	internal feedback	internal feedback
H.A. # 9	distort.	distort.	distort.	distort.	distort.
H.A. # 10	no malf.	no malf.	no malf.	no malf.	no malf.

hearing aids and with hearing-impaired children. (See Appendix B). Finally, a form was provided to each subject to allow them to record the results of their listening checks. (See Appendix C).

A video camera (Hitachi, VKC15), VHS video tape recorder (Hitachi, MTS) and video tapes (Sony Dynamicron ESI, VHS format) were used to videotape each subject performing the listening checks.

A form for recording observations of subject performance on the listening checks was adapted from the listening check protocol presented by Potts and Greenwood (1983). (See Appendix D).

Procedures

Each subject underwent a hearing screening prior to their performance of the listening checks. The subjects were required to respond to pure tones presented at 20 dB HL at the octave frequencies between 500 Hz to 8000 Hz. If the subject failed to respond to any of the pure tone stimuli presentations at this intensity level, they were dismissed from participating in the rest of the study.

The subjects were seated at a table, in a quiet room, and presented with the ten hearing aids, a hearing aid stethoscope, a battery volt meter, and a recording form. The ear tips of the stethoscope were cleansed by an alcohol prep pad prior to each listening check. They were instructed to perform a listening check as they would normally perform one

in the school setting on each of the ten hearing aids. No training on hearing aid assessment was provided. Each hearing aid was marked and identified throughout the study with a number (1 through 10). The subjects were given the following instructions:

"I would like you to perform a listening check on each of these ten hearing aids. Please assess the function of each hearing aid, and record a pass or fail next to the corresponding number on the recording sheet. In addition, please describe on the recording form provided, in writing, any problems with the sound output of the hearing aid you may have noticed after you performed each listening check. Do you have any questions?"

The subjects were asked to repeat the above procedure not less than two days after they performed the initial assessment. Each subject returned for the follow-up assessment under the guise of completing a questionnaire. The hearing aids were re-numbered to minimize any effects of learning. The same directions were provided to each subject. After they completed the second listening check, they were requested to complete a questionnaire regarding their academic training and professional experience in the area of amplification. Additionally, each subject was videotaped during their performance of the listening checks for purposes of determining measures of reliability.

The videotaped recordings of each subject performing the task was analyzed by two observers. The observers were asked to record in writing the procedures each subject was observed to follow during their performance of the listening checks. A recording form was provided for each observation.

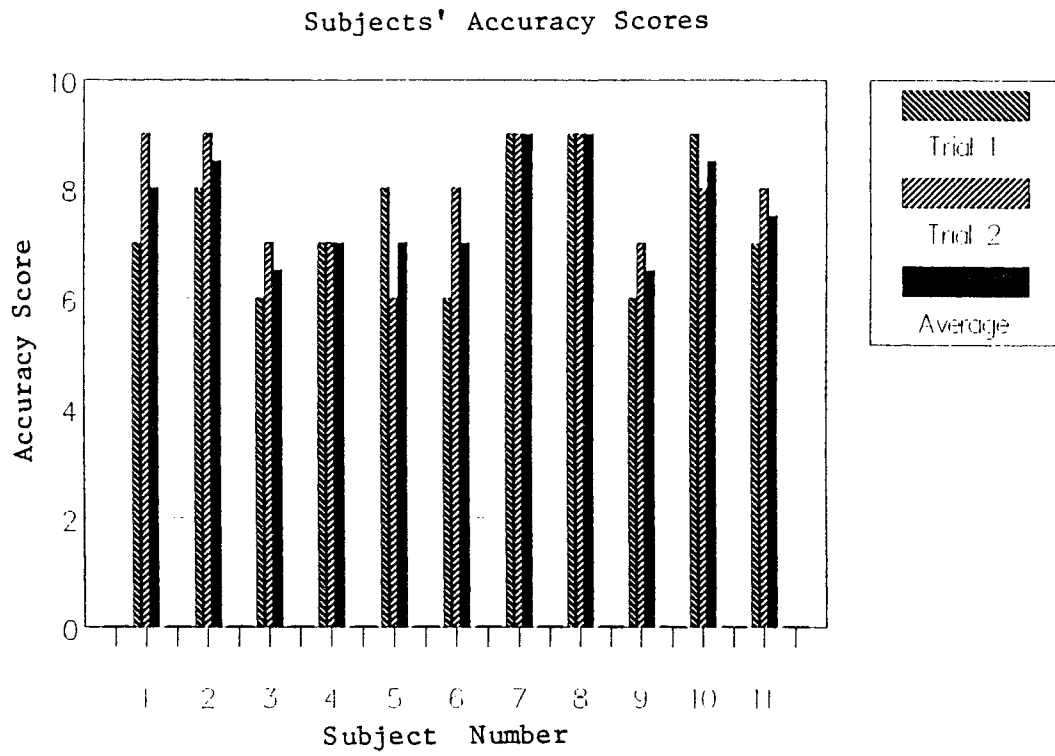
Chapter IV: Results

The purpose of this study was to determine whether school-based speech-language pathologists could accurately identify electroacoustic malfunctions in hearing aids by performing a listening check, and if so, could they identify these malfunctions consistently over two trials. In addition, this study correlated these speech-language pathologists' accuracy in the identification of electroacoustic malfunctions with their academic training and professional experience.

The results regarding the subjects' accuracy in identifying the operating status the hearing aids are presented in Figure 1 (the raw data are presented in Appendix E). Overall, the subjects exhibited a high degree of accuracy in identifying whether or not the hearing aids were functioning appropriately. The overall accuracy scores across both trials ranged from a high of 90% to a low of 60%. The mean accuracy score across all subjects was 76%, with a standard deviation of 0.92. The mean accuracy scores improved slightly from Trial 1 ($\bar{x} = 74\%$, s.d.= 1.15) to Trial 2 ($\bar{x} = 79\%$, s.d.= 0.99).

The phi coefficient measuring the degree of association between the conditions of the hearing aids and the identification of these conditions was computed for both trials. A phi coefficient was obtained at 0.53 for Trial 1 and at 0.60 for Trial 2. These values indicated that the subjects' identification of whether or not the hearing aid

Figure 1.



was functioning appropriately could be partially predicted from the condition of a hearing aid, particularly in the second trial. Tables 3 and 4 present the four fold matrices describing the association between the conditions of the hearing aid and the identification of these conditions across trials. As is illustrated in Table 3, the subjects tended to pass more defective hearing aids in Trial 1 than in Trial 2. As a consequence, their performance in identifying whether or not the hearing aid was functioning appropriately improved in Trial 2.

The subjects' performance in the second trial could not be predicted from their performance in the first trial. The Pearson Product-Moment Correlation Coefficient [$r = 0.47$] between the subjects' performance during Trial 1 and Trial 2 was not statistically significant. Six of the 11 subjects' accuracy scores improved during the second trial while two of the subjects exhibited poorer accuracy scores, and three of the subjects showed no change in overall accuracy scores during the second trial.

While the overall accuracy scores may have indicated relatively consistent performances across the two trials, each subject's ability to identify the problems with each individual hearing aid varied across trials. In the second trial, eight of the subjects accurately failed a defective hearing aid that they had incorrectly passed in the first trial. However, six of the subjects either passed a defective

Table 3. Conditions of the Hearing Aids and the Identification of these Conditions during Trial 1

	Pass	Fail	
No Malfunction	39	5	44
Malfunction	23	43	66
	62	48	110

Table 4. Conditions of the Hearing Aids and the Identification of these Conditions during Trial 2

	Pass	Fail	
No Malfunction	39	5	44
Malfunction	18	48	66
	57	53	110

hearing aid in the second trial that they had accurately failed to identify in the first trial, or they failed an appropriately functioning hearing aid after they had accurately passed it in the first trial.

The subjects' ability to identify the different types of electroacoustic malfunctions also varied as a function of the type of hearing aid. Overall, the subjects displayed a higher degree of accuracy in correctly scoring the BTE hearing aids than the ITE hearing aids. Figure 2 illustrates the percent accuracy of correctly passing a hearing aid as a function of the type of hearing aid. Figure 3 illustrates the individual subjects' accuracy score as a function of the type of hearing aid.

Table 5 presents the percent correct identification of the hearing aids over both trials. The total percent correctly identified in each trial is the sum of the number of correctly identified BTE hearing aids and the number of correctly identified ITE hearing aids divided by the total number of hearing aids. Figure 4 illustrates the percent accuracy of correctly identifying the hearing aids exhibiting internal feedback. All of the subjects accurately failed both the ITE hearing aid and the BTE hearing aid that exhibited internal feedback during both trials, with the exception of one subject who incorrectly passed the BTE hearing aid with internal feedback during the second trial.

The subjects were also highly accurate and consistent

Figure 2.

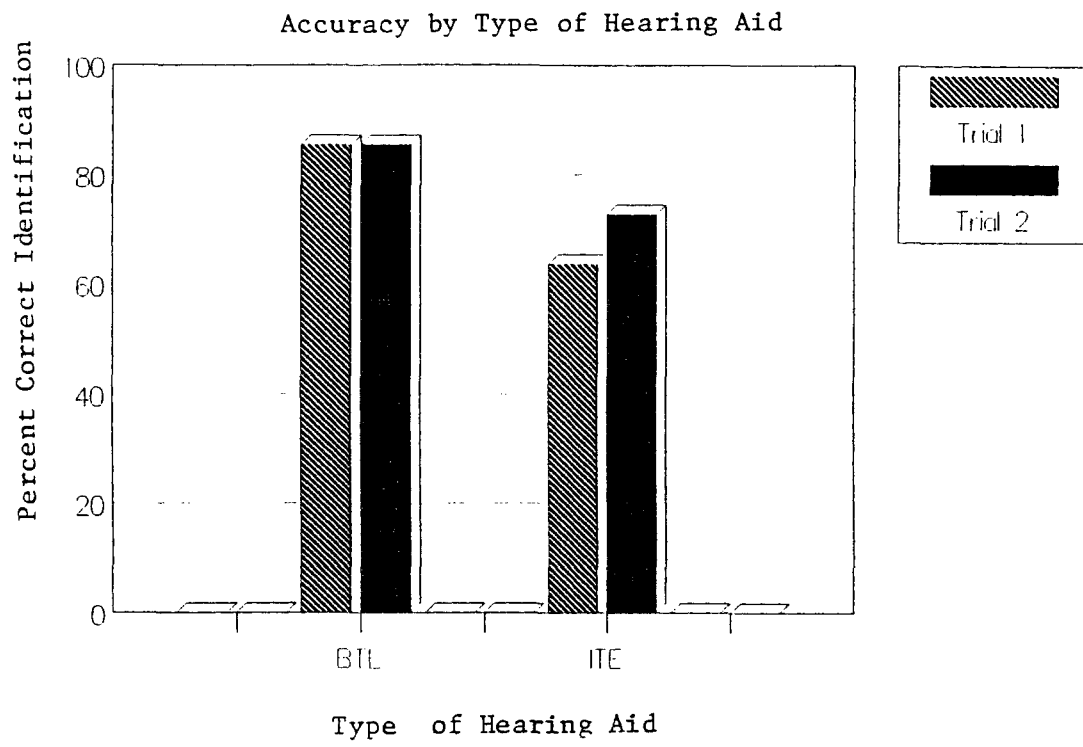


Figure 3.

Subject Accuracy by Type of Hearing Aid

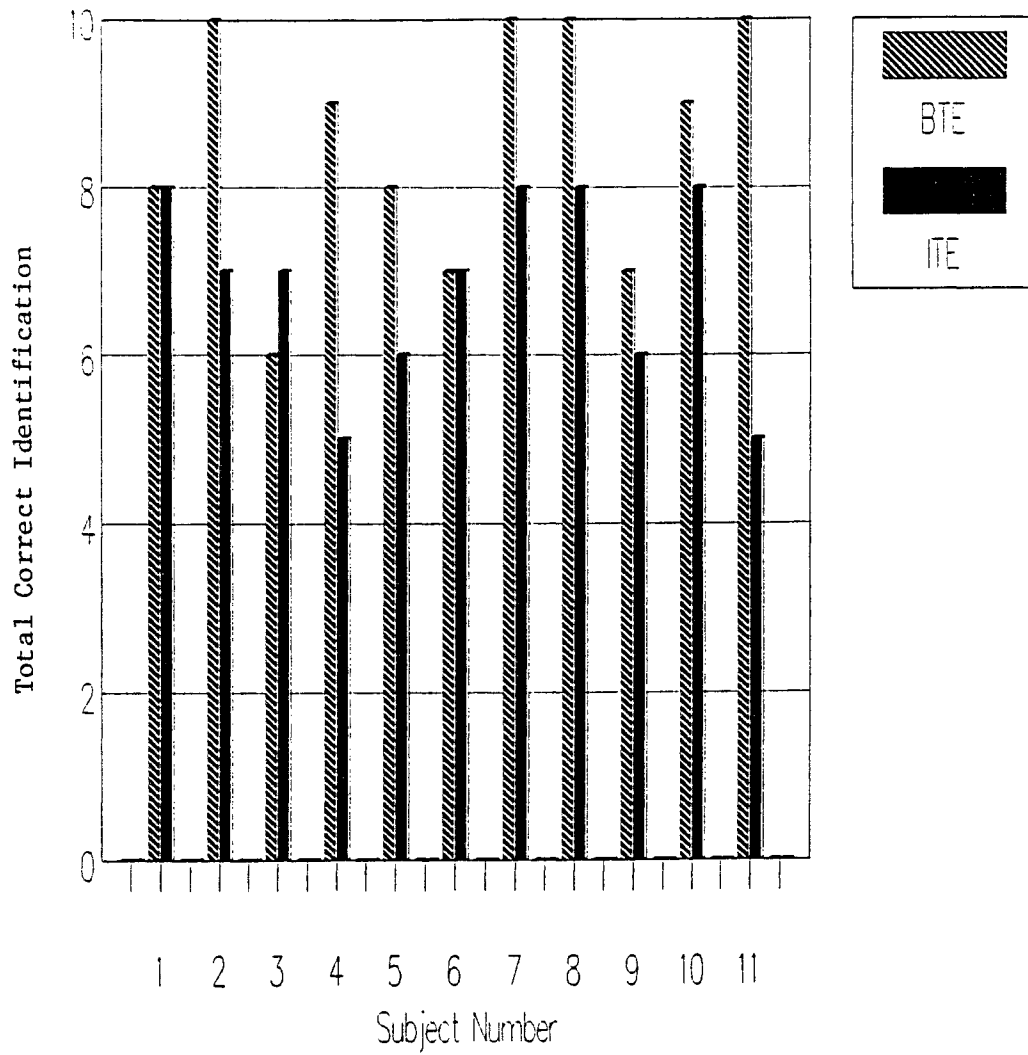
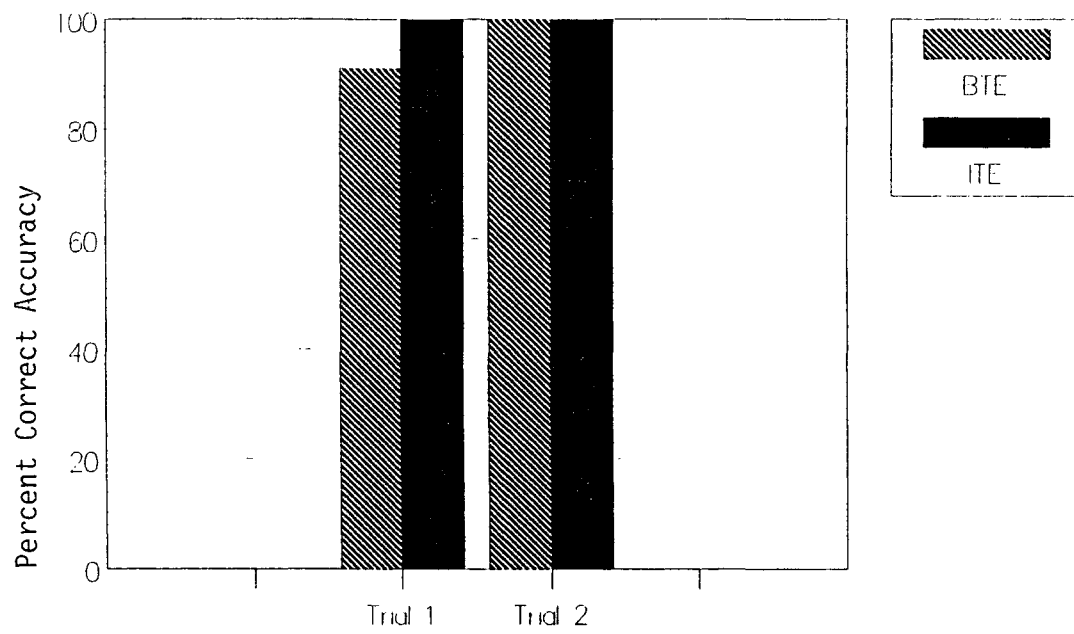


Table 5. Percent Correct Identification of Hearing Aids
Across Subjects

<u>DEFECT</u>	<u>Trial 1</u>		<u>Trial 2</u>	
	BTE	ITE	BTE	ITE
Internal Feedback	91%	100%	100%	100%
Inappropriate Volume Control Taper	100%	27%	100%	55%
Harmonic Distortion	55%	18%	66%	18%
Within Specifications/ No malfunctions	91%	86%	82%	95%

FIGURE 4.

Identification of Internal Feedback



in identifying the BTE hearing aid that exhibited the inappropriate volume control tapers, during both trials, as is illustrated in Figure 5. However, the subjects displayed relatively poor accuracy and consistency in identifying the ITE hearing aid that exhibited this defect. For the ITE hearing aid, only three of the subjects accurately identified the inappropriate volume control taper in the first trial, while six of the subjects identified the malfunction in the second trial.

Figure 6 illustrates the percent accuracy of subjects in identifying the hearing aids exhibiting excessive harmonic distortion. Overall, the subjects displayed the poorest accuracy in correctly identifying the defective hearing aids with the excessive harmonic distortion. Only two subjects accurately failed the defective ITE hearing aid, and only one of these two subjects correctly identified this defective hearing aid across both trials. For the BTE hearing aid exhibiting harmonic distortion, six subjects accurately failed this hearing aid in the first trial, and seven subjects accurately failed the hearing aid in the second trial. The subjects' overall consistency in identifying the hearing aids with harmonic distortion was poorer than their consistency with identifying the hearing aids which either exhibited internal feedback and an inappropriate volume taper.

Figure 7 illustrates the percent correct accuracy in the identification of hearing aids functioning within

FIGURE 5.

Identification of Volume Taper

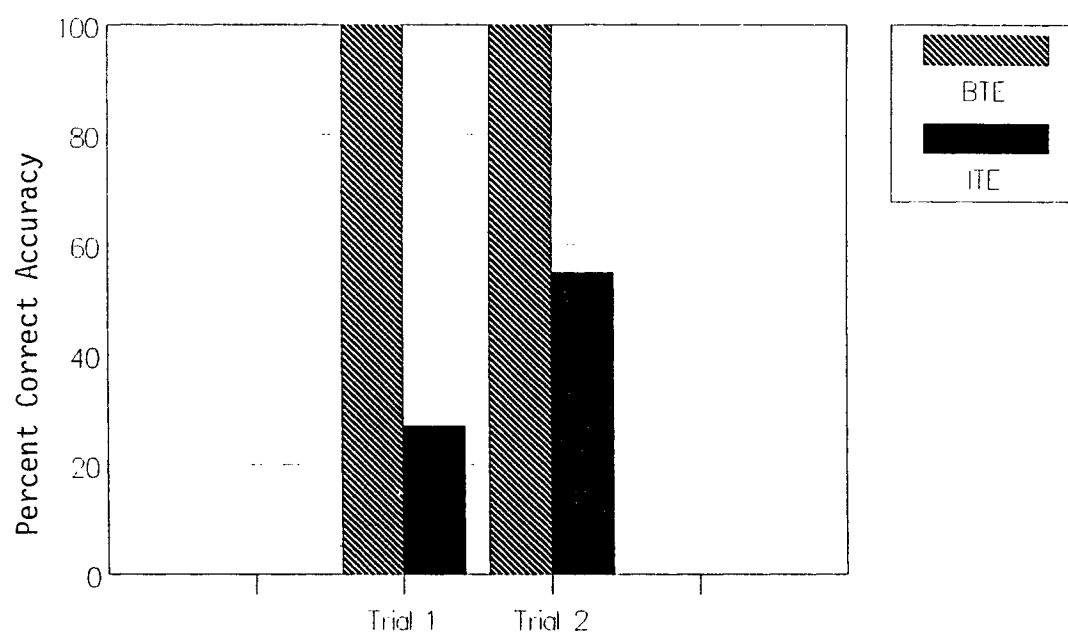


FIGURE 6.

Identification of Harmonic Distortion

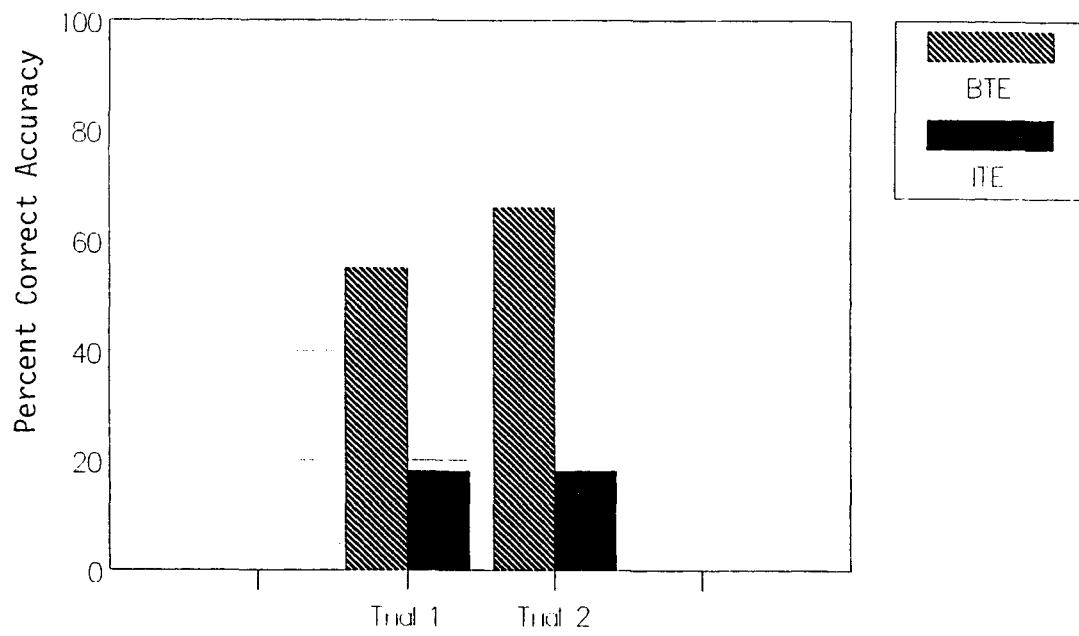
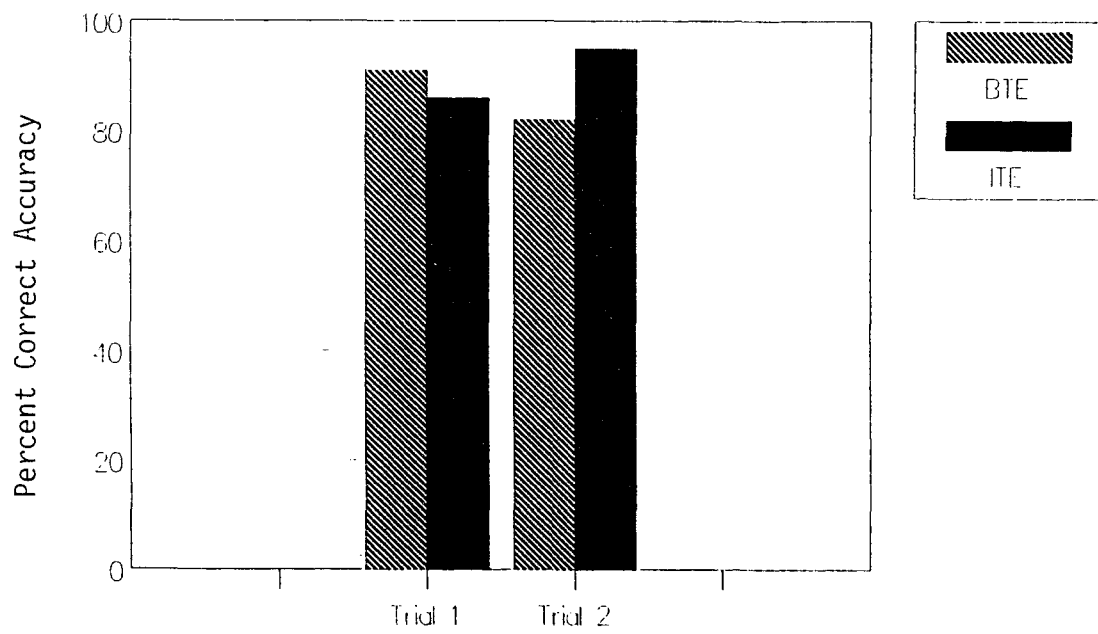


FIGURE 7.

Identification of Appropriate Function



specifications. Overall, the subjects were relatively accurate in correctly passing the appropriately functioning hearing aids. For the ITE hearing aids, a total of four subjects across both trials incorrectly failed the appropriately functioning hearing aids. For the BTE hearing aids, a total of six subjects across both trials incorrectly failed appropriately functioning hearing aids.

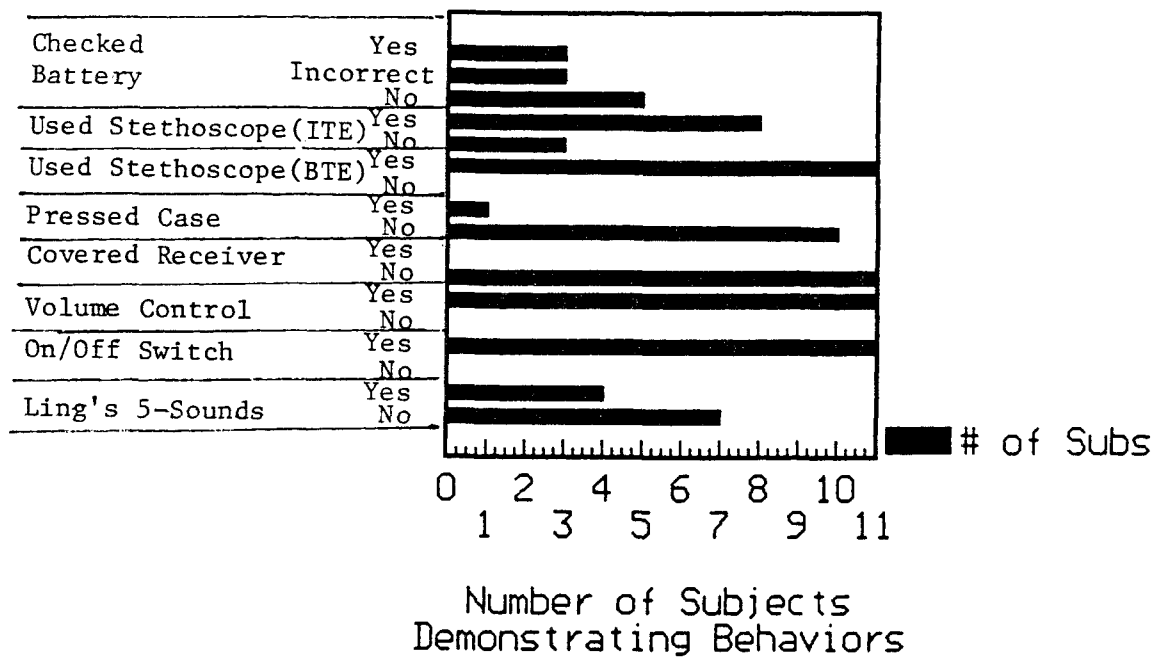
Observation of Listening Checks

The subjects were videotaped during their performance of the listening checks. The videotapes were viewed by two observers who recorded the behaviors that the subjects used in their assessment of the hearing aids. (See Appendix D for the Recording Form for Observations of Listening Checks). The inter-judge agreement was computed to be 98%. Figure 8 illustrates the number of subjects who correctly performed the behaviors outlined in the listening check protocol described by Potts and Greenwood (1983).

Description of the Malfunction

The accuracy score does not reflect the subject's ability to accurately describe the electroacoustic malfunctions exhibited. While this ability was investigated, it was not incorporated into the rating of the subject's performance as an accuracy score. For the hearing aids exhibiting internal feedback, 82% of the subjects (nine of the 11 subjects) correctly described the malfunction as either "feedback or "squeal". In contrast, for the hearing aids exhibiting an

Figure 8.
Listening Check Behaviors



These listening check behaviors are listed in the protocol described by Potts and Greenwood (1983). The data was taken from the observations of listening checks performed during Trial 2.

inappropriate volume control taper, not one of the subjects accurately described this defect in the ITE hearing aid, and only 64% of the subjects (seven of the 11 subjects) accurately described this defect in the BTE hearing aid as a "broken volume control". For the hearing aids exhibiting excessive harmonic distortion, only two subjects (18%) accurately described the malfunction in either the BTE or ITE hearing aids as "distortion". However, neither subject consistently labeled this malfunction across the two trials.

Correlation of Performance with Training and Experience

Table 6 presents the data concerning the subjects' reported number of hours in hearing aid instruction they had received, the total number of hearing-impaired children in their case loads, the estimated number of listening checks they had performed prior to their participation in this study, and their accuracy scores. The Pearson Product-Moment Correlation Coefficient [$r = 0.25$] between the subjects' performance and the number of hours of instruction regarding hearing aids they had received was not statistically significant. The Pearson Product-Moment Correlation Coefficient [$r = -0.17$] between the subjects' performance and the number of hearing-impaired children they have worked with was also not statistically significant. Finally, the Pearson Product-Moment Correlation Coefficient [$r = -0.36$] between the subjects' performance and the reported number of listening checks they had performed was not statistically significant.

Table 6. Subjects' reported experience with hearing aids and hearing-impaired children.

Subject #	Hours-H.Aids	#H-I Clients	# L.C.s	Ave. Scor.
1	80	8	10	8
2	8	1	1	8.5
3	0	1	0	6.5
4	3	4	15	7
5	20	2	5	7
6	30	0	0	7
7	30	6	2	9
8	+	1	+	9
9	10	20	25	6.5
10	3	8	5	8.5
11	30	0	0	7.5

Hours-H.Aids = Reported number of hours received in hearing aid instruction

#H-I Clients = Reported number of hearing-impaired children subject has worked with

#L.C.s = Reported number of listening checks performed prior to participating in this study

+ = Subject did not report

Ave. Scor. = Average accuracy score

Chapter V: Discussion

This study investigated the degree to which school speech-language pathologists could accurately and consistently detect electroacoustic defects in hearing aids by listening checks. In addition, this study correlated the subjects' accuracy in the identification of the electroacoustic malfunctions with their academic and professional experience. The literature suggested that the speech-language pathologists would display relatively poor accuracy in identifying the defects in hearing aids by performing listening checks.

The results of this investigation indicated that 1) speech-language pathologists were able to identify two of the three types of hearing aid malfunctions (internal feedback and an inappropriate volume taper) with a relatively high degree of accuracy; 2) the subjects' performance on this task during a second trial could not be predicted from their performance during the first trial; and 3) there was no significant correlation between subjects' accuracy in identifying the defective hearing aids and their academic training or professional experience with hearing aids.

Accuracy

The data from the present study departed from the findings of previous investigations in that the subjects performed the task with a relatively high degree of accuracy. Several trends were observed in regards to the relationship between the subjects' accuracy in the identification of defective hearing

aids and the type of hearing aid, as well as the type of malfunction. These relationships are discussed below.

BTE Hearing Aids vs. ITE Hearing Aids. The speech-language pathologists displayed a higher degree of accuracy in identifying the defective behind-the-ear (BTE) hearing aids than in identifying the defective in-the-ear (ITE) hearing aids. This may have been attributed to a general unfamiliarity with the operation, function and maintenance of ITE hearing aids. When initially presented with the hearing aids for the listening checks, several of the subjects reported that they had never seen an ITE hearing aid prior to their participation in this study. The observations of the subjects' listening check behaviors indicated that three of the 11 subjects performed the listening checks on the ITE hearing aids with the ITE hearing aid inserted in their ear rather than coupled to the hearing aid stethoscope. The ITE hearing aid is encased in a custom fit shell, and as a result, it will only fit appropriately on the ear for which the impression of the shell was taken. For those subjects who were observed to insert the ITE hearing aids into their ears for their listening checks, the hearing aid was not correctly coupled to their ear. This may have allowed for leakage of the acoustic output of the hearing aids, which could have had an adverse affect on their ability to accurately assess the output. As a consequence, their use of inappropriate methods of coupling the ITE hearing aids to their ear may have

contributed to the poorer accuracy scores obtained on the BTE hearing aids.

Type of Malfunction. The speech-language pathologists displayed the greatest accuracy and consistency in identifying and describing the defective hearing aids with internal feedback. This malfunction is relatively simple to detect, and can be observed by the listener even when the hearing aid is not coupled to the listener's ear. For both the ITE and the BTE hearing aids exhibiting internal feedback, this malfunction was quite obvious. These hearing aids produced constant feedback which was present whenever the hearing aid was in operation. The saliency of the internal feedback present in these particular hearing aids may have contributed to the high degree of accuracy in identification of the malfunction seen here.

The subjects also displayed a high degree of accuracy and consistency in identifying and describing the malfunction of inappropriate volume control taper produced by the BTE hearing aid. They displayed significantly poorer accuracy and consistency in identifying and describing this same malfunction present in the ITE hearing aid. This difference may be attributed to a difference in the severity of the defect. In the BTE hearing aid, the volume control was completely nonfunctional, providing a constant output of full-on gain. In the ITE hearing aid the volume control was functional, but the taper was nonlinear, providing a minimal

increase in gain throughout three quarters of the range in gain control. The detection of the nonfunctional volume control is assumed to have been a simpler task, as this defect was much more obvious. The detection of the nonlinear volume control taper in the ITE hearing aid would have required a more careful and controlled assessment of the acoustic output during the listening check.

Differences in the accurate description of the defects (inappropriate volume control taper) were observed between the two types of hearing aids. Of the nine correct failures of the ITE hearing aid (across both trials), not one of the subjects correctly described the defect as being anything related to volume control function. In comparison, of the 22 correct failures of the BTE hearing aid, 12 of the subjects accurately described the malfunction as a "broken volume control". The differences noted in the accuracy of identification of this problem may also be attributed to the subjects' lack of familiarity with ITE hearing aids. The observations of the subjects' listening check behaviors indicated that three of the subjects incorrectly manipulated the volume controls on the ITE hearing aids. Still, the differences seen in the subjects' accuracy in identifying the defective volume controls in these hearing aids was most likely due to the differences in the severity of this problem exhibited in the two hearing aids.

The subjects exhibited the poorest accuracy and consistency in their identification and description of the hearing aids exhibiting excessive harmonic distortion. Both of the ITE and BTE hearing aids with harmonic distortion were incorrectly passed by most of the subjects. This type of hearing aid defect is relatively common in hearing aids worn by school-age children, and it is considered to produce a significant degradation in speech understanding (Harris, et al., 1961). Bess, (1977), in his investigation of the condition of 121 hearing aids worn by school-aged children, found excessive harmonic distortion levels (in excess of at least 20% THD) present in 86% (104 hearing aids) of the hearing aids in his sample. As a consequence, this defect may present significant detriments in the auditory comprehension of language in hearing-impaired students who rely on their amplification system for speech input. It is imperative that this defect be identified and remediated in order to insure that the hearing-impaired child obtain the maximum benefit from his/her amplification system. However, these results indicated that the subjects in the present study could not recognize the excessive harmonic distortion present in the hearing aids, and identified the hearing aids as appropriately functioning.

Appropriately Functioning Hearing Aids. The subjects exhibited a relatively high degree of accuracy in identifying the hearing aids that were within specifications. However,

four of the subjects failed functioning ITE hearing aids, and six of the subjects failed functioning BTE hearing aids. This indicated that some speech-language pathologists did not demonstrate the ability to accurately and consistently identify an appropriate functioning hearing aid. This may also be due to subject bias due to the nature of the task. As the subjects were instructed to perform the listening checks, they may have expected at least a portion of the ten hearing aids to exhibit a defect. In addition, the slight differences noted here between the BTE and ITE hearing aids may be attributed to differences in the apparent condition of the hearing aids. The BTE hearing aids used were generally older and appeared more worn than the ITE hearing aids.

Listening Checks

The subjects were videotaped during their performance of the listening checks. The videotapes were viewed by two observers who recorded the behaviors that the subjects used in their assessment of the hearing aids. (See Appendix D for the Recording Form for Observations of Listening Checks). The inter-judge reliability was excellent in identifying listening check behaviors. Figure 8 illustrates the number of subjects who performed each of the behaviors described in the listening check protocol.

When performing a listening check, the listener is required to introduce some form of acoustic input to the hearing aid in order to make an assessment of the clarity of

the acoustic output. A speech signal is considered the most appropriate form of input to use when making the assessment of speech clarity, and the Ling Five-Sounds (Ling, 1978) are conventionally used for this purpose. These five sounds, [u], [a], [i], [s], and [ʃ], are believed to represent points across the range of speech frequencies, and enable the listener to identify the presence of harmonic distortion occurring at frequencies within the speech range (250 to 4000 Hz). The observations of the subjects' performance of the listening checks revealed that only four of the subjects used the Ling Five-Sounds as acoustic input during the listening checks. Three of the subjects produced other forms of speech input (e.g., "hello, hello"; "testing"; counting). The remaining four subjects failed to produce any form of speech input, and were observed to rely on other acoustic signals, such as tapping a pen on the table, snapping their fingers, or crumpling paper.

All of the subjects were observed to correctly manipulate the volume control of the hearing aids, and to turn the hearing aid on and off. In addition, all of the subjects correctly used the hearing aid stethoscope to couple the BTE hearing aids to their ears, and eight of the subjects correctly used the hearing aid stethoscope to couple the ITE hearing aids to their ears. The three remaining subjects were observed to insert the ITE hearing aids into their ears for the listening checks. This indicated that most of the subjects

correctly performed the behaviors relating to the basic functioning of the hearing aids (i.e., turning the hearing aid on and off, manipulating the volume control). In addition, most of the subjects displayed the ability to correctly couple the hearing aid to their ears for purposes of assessing the output.

Only three of the subjects correctly used the battery volt meter to check the hearing aid batteries. Five of the subjects did not check the batteries at all, and three of the subjects were unable to properly operate the volt meter to obtain a battery voltage reading. These subjects reported that they were unfamiliar with the operation of the volt meter provided, and essentially gave up on their attempts to obtain a battery voltage reading. None of the subjects were observed to cover the hearing aid receiver to assess whether the feedback present was internal feedback. Also, only one of the subjects was observed to press the casing of the hearing aid while listening to the output in order to detect any possible intermittency in the output of the hearing aids. These three listening check behaviors (checking the battery, covering the receiver, and pressing the casing) are behaviors that are generally only carried out during the performance of a listening check. These are somewhat specialized behaviors that are typically included in the training of listening checks, and they are considered critical for the detection of specific electroacoustic malfunctions.

Overall, the subjects performed similar listening check behaviors. Most of the subjects performed the basic behaviors accurately. However, their exclusion of the specialized listening check behaviors raises concerns about the thoroughness of their hearing aid assessments. The low accuracy scores observed in the subjects' ability to detect excessive harmonic distortion may be a direct result of the type of acoustic input produced by the subjects. A small portion of the subjects used the Ling Five-Sounds as input. Of these, one of the subjects accurately identified and described the hearing aids exhibiting harmonic distortion across both trials. It is assumed that this particular listening check behavior would best facilitate detection of harmonic distortion due to the nature of its frequency response. The small number of subjects who accurately checked battery function also raises concern. A dead or weak battery is one of the most common malfunctions identified in hearing aids worn by children in the schools (Bendet, 1980; Gaeth and Lounsbury, 1966; Zink, 1972). While this problem was not assessed in this study, it can be assumed that these subjects would have displayed poor accuracy in the identification of an inappropriate battery voltage.

Consistency in Performance of Listening Checks

The overall accuracy scores (obtained from the group data) indicated relatively consistent performances across the two trials. However, 91% of the subjects exhibited

inconsistency in the identification of the defects. The observations of the subjects' listening check behaviors indicated that the subjects performed the same behaviors across both trials. As such, the inconsistency in identification of the hearing aids was not attributable to an inconsistency in listening check behaviors across the trials.

The data revealed an overall improvement in accuracy scores between the two trials. The improvement was exhibited in the increased number of subjects who accurately failed a defective hearing aid, and conversely, in the reduced number of subjects who incorrectly failed an appropriately functioning hearing aid in the second trial. The slight improvement in overall accuracy scores could possibly be attributed to learning effects. While none of the subjects reportedly practiced listening checks during the interim between trials, the nature of the task may have enhanced their awareness of hearing aid function and operation.

Implications

The speech-language pathologists participating in this study performed better than expected based on the findings of previous investigations in this area. The subjects' proximity and accessibility to the University of Montana, Department of Communication Sciences and Disorders may be a contributing factor to this finding. Several of the subjects had recently received specialized training in amplification systems presented in post-graduate seminars or workshops at the

University of Montana. As a result, the recency of their specialized training in the performance of listening checks may have influenced their performance to a greater degree rather than the degree of their academic training and professional experience. Future studies should address the question of recency of academic training. Recency effects may be a critical value in the correlation between performance on listening checks and academic training.

The lack of a significant correlation between the subjects' performance and their academic and professional experience may also be the result of a sampling problem. Small sample sizes tend to limit the ability to identify strong correlations in group data. Eleven subjects participating in the current study may not have provided sufficient amounts of data to draw inferences about the relationship between subject performance and experience. A larger sample size, with the inclusion of subjects who are not in close proximity to the University of Montana, may allow for a clearer indication of any correlation between their performance and their academic training and professional experience.

The data obtained in this study also indicated that the school-based speech-language pathologists could identify certain defective hearing aids with a relatively high degree of accuracy. This suggests that these professionals may be an appropriate specialist to assume the responsibility for

daily monitoring of hearing-impaired children' hearing aids. Still, the review of the subjects' responses on the questionnaire indicated that only two of the nine subjects (22%) who had reportedly worked with a hearing-impaired child had ever monitored the function of the child's amplification system. In response to the question addressing the subjects' opinion of who should be responsible for hearing aid monitoring, seven of the subjects (64%) identified speech-language pathologists. Several of the subjects identified more than one professional (e.g., "either the teacher or the speech-language pathologist"; "the speech-language pathologist or the audiologist", or, "a team, including the teacher, speech-language pathologist, audiologist and the family") as being responsible for hearing aid monitoring. One subject indicated that the classroom teacher should be solely responsible for hearing aid monitoring, and two subjects identified the audiologist as the professional responsible for hearing aid monitoring. These responses suggest that while many of the speech-language pathologists believe they should be responsible for monitoring hearing aid function in the schools, a very small percentage of them had routinely performed listening checks. In light of these results, the Montana Office of Public Instruction could mandate that the Individual Educational Programs (I.E.P.) for hearing-impaired children require routine and appropriate hearing aid monitoring be performed by a qualified professional(s). In

addition, these professionals could be provided with written protocols describing how to perform and record these listening checks.

In response to the question soliciting their opinion on how often the hearing aids should be checked in the schools, six of the subjects indicated that the hearing aids should be checked daily, one subject indicated they should be checked 2 to 3 times a week, two subjects indicated they should be checked once a week, and two subjects indicated they should be checked once a month. This suggests that most of the subjects understand the need for frequent monitoring of the hearing aids worn by school-aged hearing-impaired children. Still when this data is combined with the responses regarding responsibility for hearing aid monitoring, there is an indication that the subjects in this cohort believe that school speech-language pathologists should be the professional responsible for routine and frequent monitoring of the hearing aids.

Further Research

Further research is warranted in this area to determine the effectiveness of specialized training in the performance of listening checks. A future study may wish to investigate whether the speech-language pathologists' performance improves when they are provided with a protocol for listening checks. A similar study may attempt to investigate the effectiveness of a videotaped training program in improving the performance

of listening checks. Other investigations may attempt to measure improvements in the identification of defects in ITE hearing aids following training in the operation and function of this type of hearing aids. Another future study may wish to examine whether the speech-language pathologists can be trained to identify the defect of excessive harmonic distortion. Related to the issue of training effects, an investigation may attempt to identify any correlation between performance and recency of specialized academic training in the performance of listening checks.

Additional studies may attempt to examine the relationship between performance on listening checks and the saliency of the defects. Similarly, another investigation may wish to determine the abilities of speech-language pathologists in the identification of the more subtle electroacoustic malfunctions, such as, internal noise, intermittency, and harmonic distortion. Finally, a future investigation may wish to investigate the abilities of this cohort in the performance of listening checks on other amplification systems, such as, in-the-canal hearing aids, and assistive listening devices.

The present study indicates that school speech-language pathologists can be used to monitor the function of hearing aids worn by hearing-impaired children. However, further training is necessary to ensure that this group of professionals would perform appropriate listening checks when

evaluating the performance of hearing aids. Considering the importance of amplification of the hearing-impaired child the school setting, the prevalence of speech-language pathologists in the school setting, and the established protocols which can effectively identify defective hearing aids, educational institutions and professional organizations must emphasize training the speech-language pathologist to perform appropriate and effective listening checks on hearing aids.

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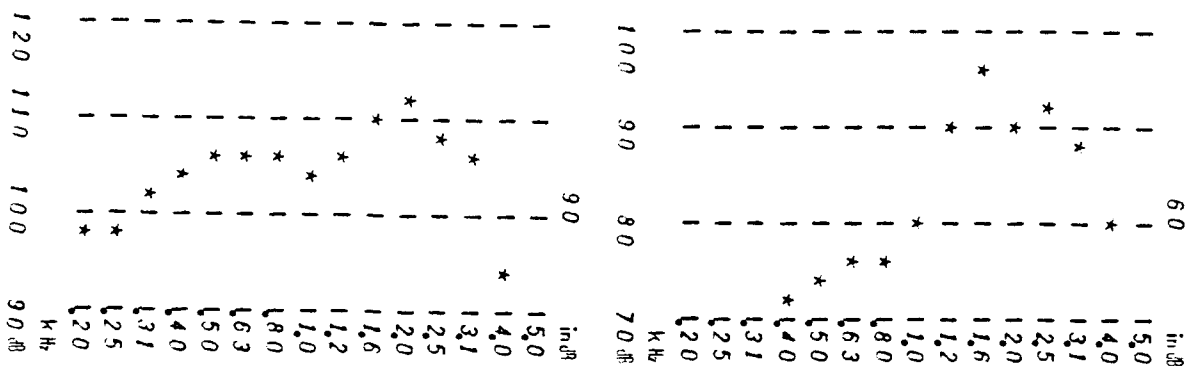
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Appendix A

Hearing Aid Output Characteristics

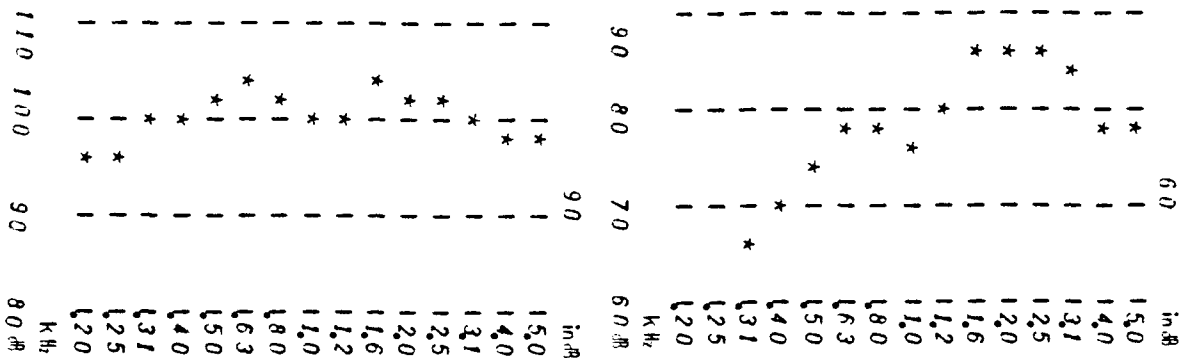
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SSPL-90 Curve

Frequency Response Curve

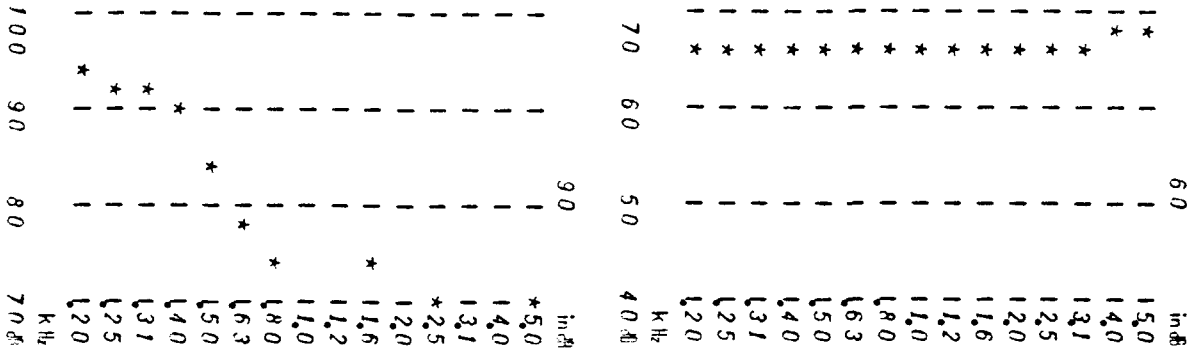
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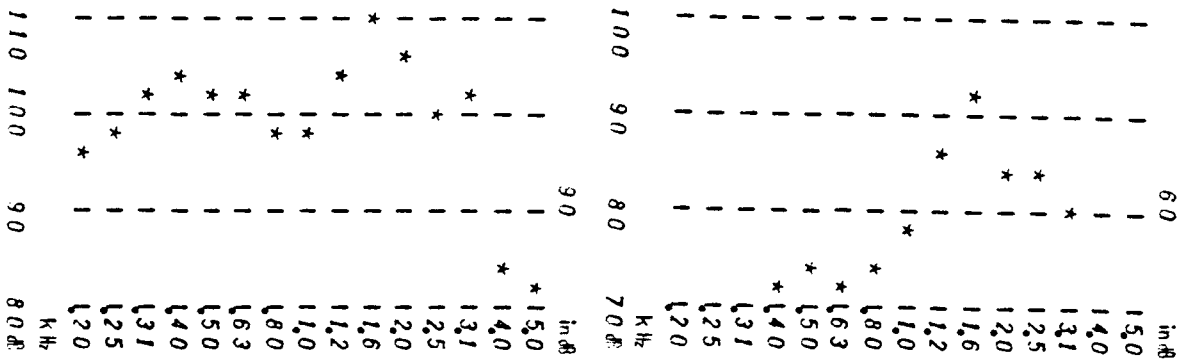
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SSPL-90 Curve

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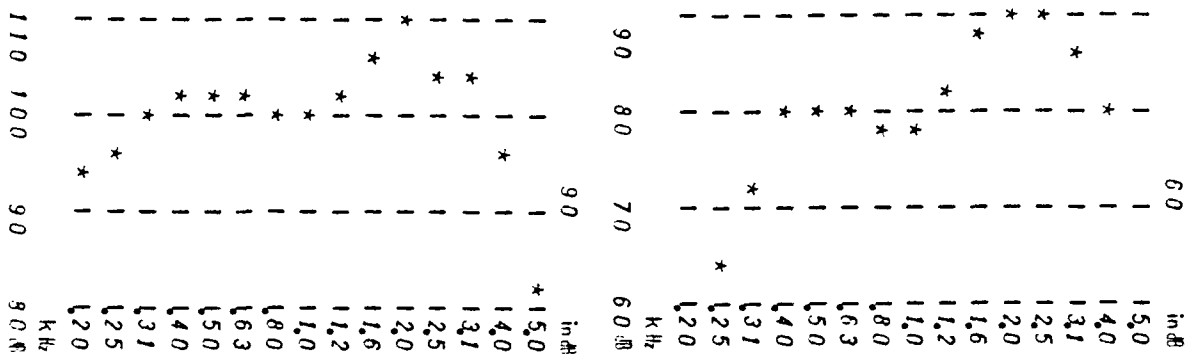
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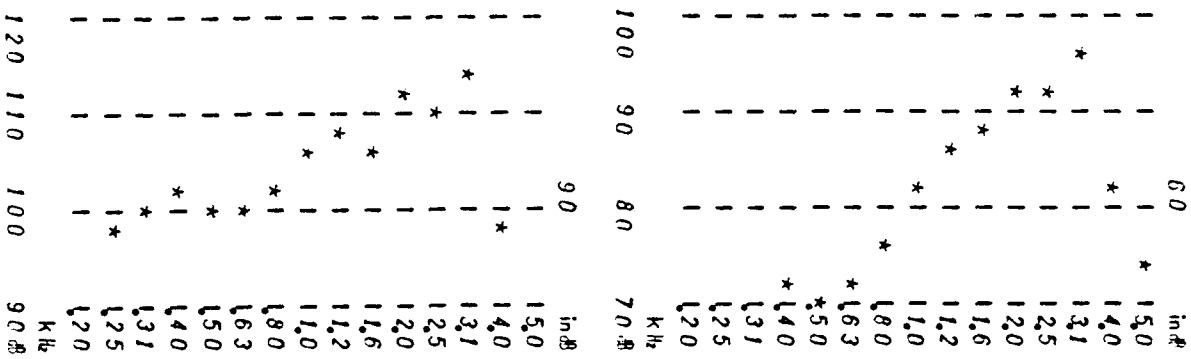
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SSPL-90 Curve

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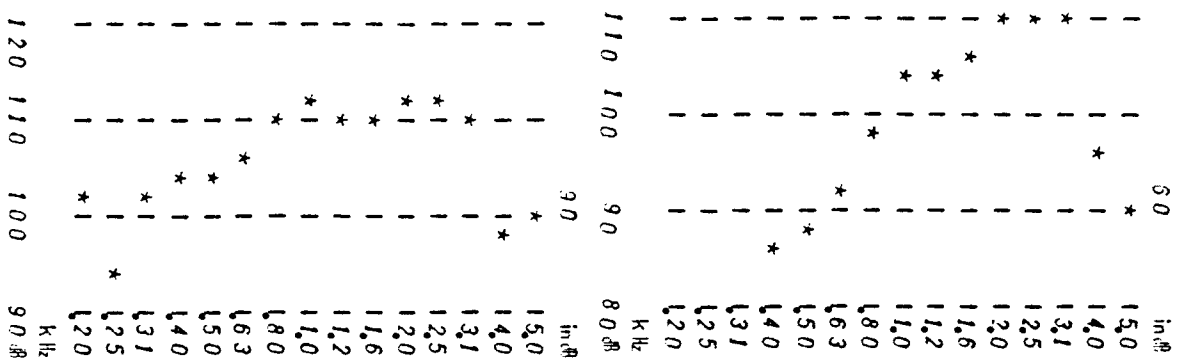
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SSPL-90 Curve

Frequency Response Curve

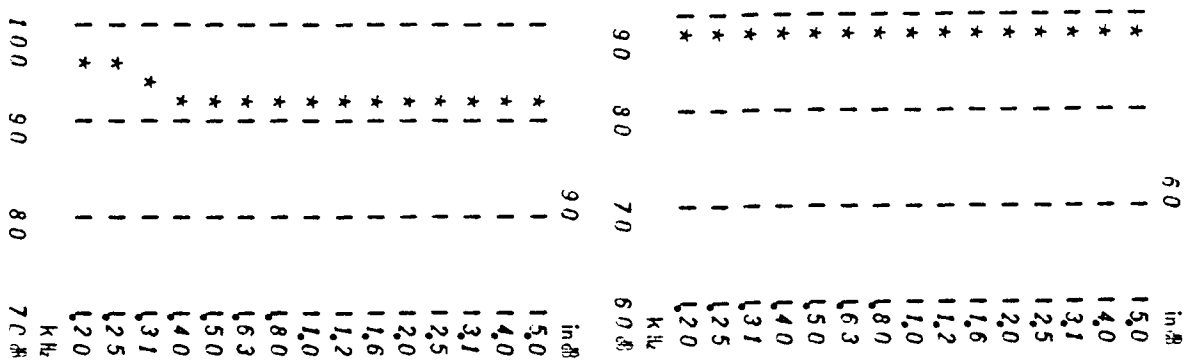
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SSPL-90 Curve

Frequency Response Curve

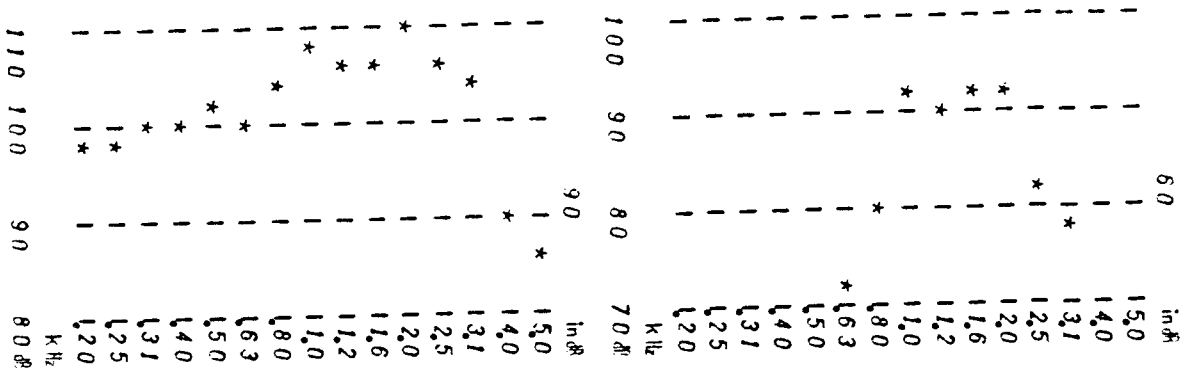
BTE Sears Serial #DA03856



SSPL-90 Curve

Frequency Response Curve

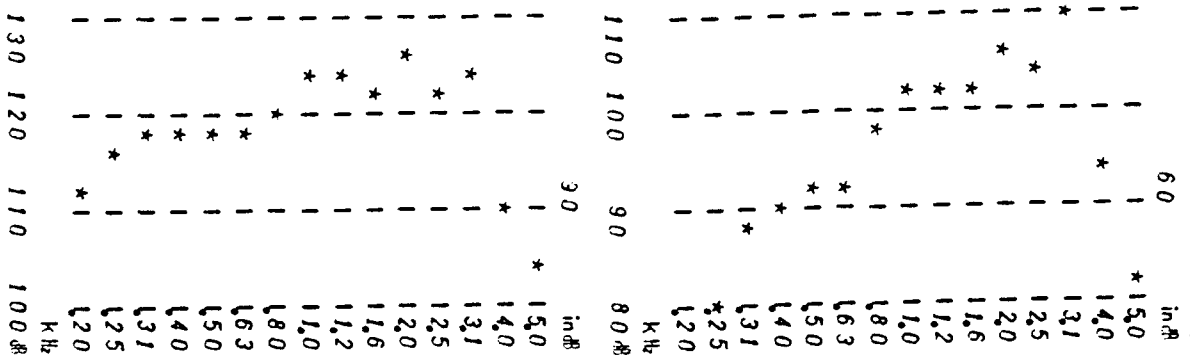
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SSPL-90 Curve

Frequency Response Curve

BTE Oticon E25P Serial # 025615



SSPL-90 Curve

Frequency Response Curve

Appendix B

Survey of Academic and Professional Experience
with Amplification

Subject Number: _____

1. Where did you receive your training in Speech-Language Pathology? _____
2. Please indicate your educational status:
 _____ Bachelor's Degree
 _____ Bachelor's Degree plus _____ credit hours
 _____ Master's Degree
 _____ Master's Degree plus _____ credit hours
3. Did you obtain the Certificate of Clinical Competence in Speech-Language Pathology? Yes _____ No _____

 If so, is the certificate valid at this time? Yes _____ No _____
4. Are you dually certified (CCC-SLP/A)? Yes _____ No _____
5. When was your training completed? 19 _____
6. How many years have you been practicing in the field of Speech-Language Pathology?
 a. less than 1 year
 b. less than 2 years
 c. between 2 and 5 years
 d. between 5 and 10 years
 e. more than 10 years
7. Estimate how many hours of instruction you have received regarding the evaluation, fitting, use and care of hearing aids?
 a). Number of hours within graduate courses: _____
 b). Number of hours in workshops or post-graduate training:

8. Do you feel that your training in the area of amplification has been adequate or inadequate? _____

 How much training in hearing aids do you feel would be adequate for you to effectively habilitative a hearing-impaired child?
 a. none
 b. less than 1 hour
 c. 1 to 2 hours
 d. 2 to 5 hours
 e. more than 5 hours
9. Did your training in hearing aids include instruction on performing listening checks on hearing aids? Yes _____ No _____

10. Prior to this study had you ever performed a listening check on a hearing aid? Yes _____ No _____
- Estimate the number of listening checks you have performed: _____
11. Have you ever worked with a child, or children, who wore a hearing aid? Yes _____ No _____
12. Estimate the number of hearing-impaired children you have worked with: _____
13. Did you routinely monitor the hearing aids in your practice? Yes _____ No _____
14. If you did not monitor the hearing aids, who did?
- the classroom teacher
 - an audiologist
 - no one; the hearing aids were not monitored
15. How often did you check the children's hearing aids?
- never
 - once a year
 - once a month
 - once a week
 - 2 to 3 times a week
 - daily
16. In your opinion, who should be responsible for monitoring the hearing-impaired child's hearing aids in the schools?
- the teacher
 - the speech-language pathologist
 - the audiologist
 - no one; the school should not be responsible
 - other: _____
17. How often should hearing aids be checked in the schools?
- never
 - once a year
 - once a month
 - once a week
 - 2 to 3 times a week
 - daily
18. Did you practice or rehearse any listening checks prior to participating in this study? Yes _____ No _____
19. Do you think you were accurate in your assessment of the sound output of the hearing aids you evaluated? Yes _____ No _____;
- Why, or why not? _____

(Adapted from Woodford, C.M., "Speech-language pathologist's knowledge and skills regarding hearing aids", *LSHSS*. Vol. 18(4), Oct. 1987, p. 312-322).

Appendix C

Recording Form for Listening Checks

Subject Number: _____

H. Aid #	PASS	FAIL	If Fail, Please Describe Problem
1.	P	F	_____
2.	P	F	_____
3.	P	F	_____
4.	P	F	_____
5.	P	F	_____
6.	P	F	_____
7.	P	F	_____
8.	P	F	_____
9.	P	F	_____
10.	P	F	_____

Appendix D

Recording Form for Observations of Listening Checks

Subject Number: _____

Observer: _____

	YES correct	YES incorrect	NO
Checked Battery with the voltmeter by assessment feedback			
Used hearing stethoscope			
Manipulated volume control			
Turned hearing aid ON/OFF			
Pressed case of hearing aid			
Covered receiver and vent to assess internal feedback, with volume control turned to maximum gain.			
Used Ling 5 Sounds [a, i, u, s, ∫]			

Estimated time required to complete all listening checks: _____

NOTES: (describe any other acoustic input used)

(Adapted from Potts, P.L. and Greenwood, J. (1983) "Hearing aid monitoring: Are looking and listening enough?". LSHSS, 14, 157-163).

Appendix E

Table E1. Trial 1: Subject Responses

S U B.#	ITE Hearing Aids					BTE Hearing Aids					Acc. Score
	W.S.	W.S.	M1	M2	M3	W.S.	W.S.	M1	M2	M3	
1	1	1	1	1	0	1	0	1	1	0	7
2	1	1	0	1	0	1	1	1	1	1	8
3	1	0	0	1	1	0	1	1	1	0	6
4	1	1	0	1	0	1	1	1	1	0	7
5	1	1	0	1	0	1	1	1	1	1	8
6	1	1	0	1	0	1	1	1	0	0	6
7	1	1	0	1	1	1	1	1	1	1	9
8	1	1	1	1	0	1	1	1	1	1	9
9	1	0	0	1	0	1	1	1	1	0	6
10	1	1	1	1	0	1	1	1	1	1	9
11	0	1	0	1	0	1	1	1	1	1	7
	10	9	3	11	2	10	10	11	10	6	82

W.S. = hearing aid is within specifications

M1 = malfunction 1, inappropriate volume taper

M2 = malfunction 2, internal feedback

M3 = malfunction 3, excessive harmonic distortion

1 = Correct Response 0 = Incorrect Response

Appendix E (cont.)

Table E2. Trial 2: Subject Responses

S U B.#	ITE Hearing Aids					BTE Hearing Aids					Acc. Score
	W.S.	W.S.	M1	M2	M3	W.S.	W.S.	M1	M2	M3	
1	1	1	1	1	0	1	1	1	1	1	9
2	1	1	1	1	0	1	1	1	1	1	9
3	1	1	0	1	1	1	0	1	1	0	7
4	1	0	0	1	0	1	1	1	1	1	7
5	1	1	0	1	0	1	0	1	1	0	6
6	1	1	1	1	0	1	1	1	1	0	8
7	1	1	1	1	0	1	1	1	1	1	9
8	1	1	1	1	0	1	1	1	1	1	9
9	1	1	1	1	0	0	1	1	1	0	7
10	1	1	0	1	1	0	1	1	1	1	8
11	1	1	0	1	0	1	1	1	1	1	8
	11	10	6	11	2	9	9	11	11	7	87

W.S. = hearing aid is within specifications

M1 = malfunction 1, inappropriate volume taper

M2 = malfunction 2, internal feedback

M3 = malfunction 3, excessive harmonic distortion

1 = Correct Response 0 = Incorrect Response