Comparison of directional and omnidirectional hearing aids

Nancy Jo Connell

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A COMPARISON OF DIRECTIONAL
AND OMNIDIRECTIONAL HEARING AIDS

By

Nancy Jo Connell
B.A., University of California, 1974

Presented in partial fulfillment of the requirements
for the degree of
Master of Arts
UNIVERSITY OF MONTANA
1976

Approved by:

[Signatures]
Chairman, Board of Examiners
Dean, Graduate School

Date: Aug 4, 1976
The purpose of this study was to objectively and subjectively compare the effects of directional and omnidirectional hearing aids on school age children. Based on previous research it was hypothesized that discrimination scores obtained when wearing the directional aid (DA) under various signal/noise conditions would be significantly better than those obtained with the omnidirectional aid (OA), and that improved performance with the DA over the OA would be noted by the children, their teachers and/or parents. It was further hypothesized that discrimination scores with each aid would improve after a period of adjustment to the aid.

The subjects used for this study were twelve individuals with moderate-severe bilateral sensorineural losses; ages ranged from nine to eighteen years. Nine subjects were from a "total communication" environment, and three from an "oral" environment.

Objective data consisted of aided speech discrimination scores obtained for each subject wearing each of the aids under S/N conditions of +6, 0 and -6 dB. Subjects were tested with each aid before and after a three-week period in which they wore that aid.

Subjective data consisted of daily and final questionnaires completed by teachers and parents of the subjects, and final questionnaires and personal interviews with the subjects.

It was concluded that directional aids allow for significantly better speech discrimination scores compared to omnidirectional aids under S/N conditions of +6, 0 and -6 dB. It was further concluded that in terms of speech discrimination skills directional aids offer an immediate benefit to wearers accustomed to wearing hearing aids but unaccustomed to wearing directional aids, and this benefit does not appear to change after a period of adjustment to the aid. Finally, it was concluded that subjective advantages for directional aids over omnidirectional aids are not strongly evident in a "total communication" environment. Conclusions could not be drawn regarding an "oral" environment.
ACKNOWLEDGEMENTS

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The contribution of the Easter Seal Society in allowing the author access to its audiological facilities is gratefully acknowledged.

Great appreciation is due to all members of the thesis committee for their individual viewpoints and constructive criticism. To Barb Bain and Ralph Leonard, thanks are extended for the generous amount of time devoted to the author.

Finally, to Charles Parker, for his sustained encouragement and support throughout the past year, a special thank you.
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Chapter 1
INTRODUCTION

The understanding of speech in the presence of background noise has long been considered a major problem by hearing aid users and those concerned with fitting hearing aids. Arentsschild and Frober (1972) reported disturbing secondary noises to be the primary source of hearing aid dissatisfaction. This is not surprising when one considers that until recently hearing aids have been equipped with microphones having omnidirectional characteristics whereby sound is equally amplified regardless of the direction from which it arrives. Hence, when the hearing aid wearer is in a noisy situation not only is the desired speech signal transmitted, but also the disturbing background noises. Background noises may be as intense or more intense than the wanted signal, and consequently speech intelligibility suffers.

Directional microphones, which have recently been miniaturized and incorporated into hearing aids, were developed to help alleviate this problem. By having two sound inlets, and placing a time delay on sounds arriving at the rear opening, sounds arriving from one origin (near the front) are accentuated in relation to unwanted sounds from other directions (near the rear). These microphones are sound pressure gradient receivers, and respond only to
the difference of the sound pressure in front of and behind the microphone diaphragm.

Arentsschild and Frober (1972) found that when directional aids were placed on normal hearing persons, with the sound source stationery and the head rotated, a clear directional effect was noted. Sound reception dropped rapidly from $90^\circ$, with considerable attenuation occurring between $140^\circ$-$300^\circ$. Veit (1975) also found the maximum of the directional sensitivity to occur between $10^\circ$-$90^\circ$, and further showed that this directional effect was operative over the entire frequency range measured, up to at least 5000 Hz. Since a person normally turns to a speaker or conversational partner, speech would be directed to the area of maximum sensitivity. Consequently, speech would be accentuated, background noise diminished, and discrimination may be expected to improve.

Statement of Problem and Purpose of Study

The purpose of this investigation was to compare objectively and subjectively the effects of directional and omnidirectional hearing aids on wearers. Limited research (Lentz 1972 and 1974, Frank and Gooden 1973) has indicated that hearing aids with directional microphones allow for better speech discrimination in the presence of background noise than do hearing aids with
omnidirectional microphones. However, directional hearing aids have not been considered routinely in hearing aid evaluations at most facilities (Lentz 1973). It was the author's opinion that more extensive and conclusive research was needed to further assess the benefits of directional hearing aids.

Research thus far has dealt almost exclusively with normal hearing subjects (Frank and Gooden 1973) or hearing impaired adults (Nielsen 1973, Lentz 1972 and 1974). Very little research has been done involving school age children, and none investigating the potential advantages of directional aids in the classroom. In order that children take full advantage of their learning potential, it is critically important that they make maximum use of their residual hearing during their educational years. Considering the relatively noisy settings in which children must constantly perform, and the suggested benefits of directional aids, such aids could prove to be particularly advantageous to this population.

Therefore, in view of the lack of any research involving the educational advantages of directional aids for school age children, and considering the inconclusive evidence regarding the benefits of directional aids in general, an investigation into the effects of hearing impaired children wearing such aids seemed appropriate.

The following questions were of central concern: Do
speech discrimination scores of children under various signal/noise conditions differ significantly when they are wearing directional hearing aids from those obtained when they are wearing omnidirectional hearing aids? Can subjective advantages be noted by the wearer for one type of aid over the other? Do the teachers and/or parents of children note differences in the children's behavior while wearing one type of aid as compared to the other? In addition, will discrimination scores under various signal/noise conditions improve after a period of adjustment to wearing a directional aid and of "learning" to use it optimally?

**Hypotheses**

In order to answer the preceding questions the following null hypotheses have been proposed.

1) Discrimination scores obtained under various signal/noise situations when wearing directional aids will not be significantly better than when wearing omnidirectional aids.

2) Improved performance with the directional aids compared to the omnidirectional aids will not be noted by the subjects or their teachers or parents.

3) Discrimination scores obtained under various signal/noise conditions when wearing directional or omnidirectional aids will not improve significantly after a
period of adjustment to wearing these aids.

Definition of the Experimental Variables

The independent variables were: 1) Monaural fitting of a hearing aid with a directional microphone 2) Monaural fitting of a hearing aid with an omnidirectional microphone.

The dependent variables were: 1) Speech discrimination in noise 2) Practical effects of wearing a directional aid.

Directional microphone: Defined as a microphone having a front and rear opening, with an acoustical delay element which places a time delay on sounds arriving at the rear opening. This delay causes sounds arriving near the front to be accentuated by an average of approximately 20-24 dB at 500, 1000 and 2000 Hz.

Omnidirectional microphone: Defined as a microphone having one opening only, which is at the front of the aid.

Speech discrimination in noise: Defined as the score obtained on a test of monosyllabic words, under signal/noise conditions of +6, 0 and -6 dB.

Practical effects: Defined as responses by teachers, parents and experimental subjects to questionnaires concerning the subject's behavior in a variety of situations.
Review of the Literature

Most research investigating directional aids has been concerned with comparing discrimination scores obtained under adverse conditions when wearing such an aid with those obtained when wearing an omnidirectional aid. Aids with directional capabilities have been reported in the literature to substantially improve speech discrimination in the presence of background noise (Lentz 1972 and 1974, Frank and Gooden 1973, Nielsen 1973, Sung 1975).

Effect of Noise Level

However, there is evidence to indicate that the degree of improvement directional aids afford may partially be a function of the level of the interfering noise. Frank and Gooden (1973) found that when the noise source was at 180° it must be as intense or more intense than the signal (that is, $S/N$ of 0 dB or less), in order to demonstrate the effectiveness of a directional aid. On the other hand, Nielsen (1973) found a significant improvement with the directional aid over the omnidirectional aid at $S/N$ conditions of +5 and +10 dB. However, his noise sources were at three locations simultaneously rather than one, which may explain part of the discrepancy.

It appears that the more adverse the condition, the
more benefit the directional aid affords. Lentz (1972) reported directional aids to be slightly better than omnidirectional aids at S/N conditions of 0 dB, and twice as good at S/N conditions of -6 dB. Nielsen's study also supported this in that significant improvement was found at +5 and +10 dB S/N conditions, but not at +15 and +20 dB S/N conditions.

Effect of Noise Location

Research also indicates that speech discrimination scores are influenced by the location of the interfering noise. Frank and Gooden (1973) found that when the noise source was at 0° and the signal at 45° discrimination scores with the directional aid were not significantly different from scores obtained with the omnidirectional aid. This is as would be expected considering that the noise was not directed to the area that directional aids attenuate. However, with the noise source at 180°, and at both 0° and 180°, the directional aid showed significant improvement over the omnidirectional aid. Lentz (1974) also found improved discrimination with directional aids over omnidirectional aids when noise was delivered from five locations 60° apart.

On the other hand, Kelly and Miller (1975) investigated the effect of four different noise locations and found that overall omnidirectional aids were superior. However,
their study appears poorly designed with many uncontrolled variables concerning subject selection, physical design of the hearing aids, etc. The findings are therefore extremely questionable.

Monaural vs. Binaural

The literature on directional aids also contains discussions and studies concerned with whether these aids should be fitted monaurally or binaurally for optimal performance (Veit 1975, Schlosser 1974, Lentz 1974). Controversy exists in this area, and definitive findings have not yet emerged. However, the monaural-binaural issue is not a consideration in the present study, as all subjects were fitted monaurally. A more thorough review of the literature in this area therefore does not seem necessary.

Variability Among Directional Aids

With an increasing number of directional aids now becoming available for purchase, it is critical to discriminate between those aids that offer good directionality and those that do not. The lack of extensive research concerning the differences among directional aids has lead to the misuse and mismanagement of such aids. Lentz (1974) and Sung (1975) both warned against the indiscriminate
recommendation of just any aid which is advertised as being directional. Lentz and Trimm (1973) found that as the front/back ratio of the directional aid decreased, discrimination became markedly poorer. They recommended that an aid have a front/back ratio of 24 dB for optimal benefits. These findings were confirmed by Sung (1975) who also found that the amount of directionality varied among directional aids available on the market, and strongly encouraged the careful evaluation of each directional aid before making any recommendations.

Methods of Evaluating Directional Aids

Controversy exists over the optimal methods for evaluating directional aids. Some researchers (Frank and Gooden 1973, Kelly and Miller 1975) maintained that the examiner must vary the source of the noise and the signals when testing directional aids in order to accurately determine the benefits such aids afford. However, Lentz (1974) asserted that although multiple noise sources more closely approximate a realistic situation, they are not necessary for the purposes of comparing omnidirectional and directional aids in routine testing. He explained that the cost of installing a multi-speaker system is prohibitive for many facilities, and that having one speaker at 0° for speech and one at 180° for noise is sufficient.
However, authorities have agreed that it is essential to at least test in some sort of competing noise situation in order for the differences between the two types of aids to be assessed. Yet, in a survey conducted by Zenith Corporation (1973) it was found that nearly half of the facilities that do consider directional aids in their evaluations of the hearing impaired do not test in any sort of a noise environment at all, and only 8.4% test in a noise environment that is at all adequately arranged. Inadequate evaluative procedures may be masking the benefits such an aid can provide, thereby preventing the more routine utilization of such aids.

The subjective responses of wearers to the directional aid should also be a routine part of any evaluation; this too has been generally omitted. Most researchers and facilities have considered only the objective measuring of the differences between directional and omnidirectional aids, thus sacrificing valuable information. The research which has considered subjective evaluations has been generally positive for directional aids. Nielsen (1973) found that approximately 79% of his subjects preferred directional aids, and Lentz (1974) found 75% satisfaction with directional aids and 79% refusal to return to omnidirectional aids. Reported benefits included improved discrimination in noise, longer wearing time, and more comfort and less irritability. Sung (1975) also found the majority
of his subjects to prefer the directional aids.

It appears that the degree of satisfaction is a function of one's listening environment. Those that rarely encounter noisy environments may prefer to retain a conventional omnidirectional aid. Nielsen (1973) and Lentz (1974) both stressed that the patient's environment be considered when recommending such an aid.

Effect of Reverberation

Lentz (1974) found no benefits to wearing a directional aid when in a highly reverberant room, and consequently recommended that the reverberation characteristics of a patient's environment be considered before recommending such an aid. This was not investigated in the present study.

Need for Further Research

A review of the literature on directional hearing aids reveals the obvious need for more research in this area. Many questions remain unanswered concerning the type of person who may benefit most from such an aid, the conditions under which the aid is most beneficial, and the objective and subjective advantages it may afford. Some areas have scarcely been investigated yet, and others which have been investigated have at times presented conflicting findings.
It is hoped that this study may clarify some of these areas.
Chapter II

METHODS

Subjects

Twelve subjects with moderate-severe bilateral sensorineural hearing losses were included in this study. Subjects ranged in age from nine to eighteen years. The following criteria for selection of subjects were employed:

1) Must have worn some type of amplification for at least six months prior to the investigation. This was to prevent any possible variation due to an initial adjustment to amplification.

2) Must be capable of performing the routine audiological test tasks (pure tone, speech reception threshold, and discrimination tests).

3) Must be willing to wear the hearing aid for a minimum of five hours during the school day and two hours after school hours.

Subjects were randomly assigned into one of two possible experimental groups. The groups were divided by the order in which they underwent the two experimental conditions. Both groups received both types of amplification, that is, directional and omnidirectional, but on an alternate basis. Group A wore the directional aid first, and Group B the omnidirectional aid first. Each subject
therefore served as his own control.

Test Environment

All objective testing was conducted in a sound treated room. The experimental setting contained a chair with a head restraining device and two loudspeakers. The chair was positioned so that the subject's head was equidistant from the two loudspeakers placed at azimuths of 0° and 180° relative to the subject.

Test Equipment

The words from the Word Intelligibility by Picture Identification test (WIPI), and spondaic words were spoken by the experimenter live voice and monitored with a VU meter such that all words were within 1 dB of one another. The WIPI test was used so that the subjects could respond by pointing to pictures and not be required to speak or write. These words were delivered either through a Grason-Stadler Model 1701 or a Tracor RA-115A audiometer, which are both two channel, to the loudspeaker in the test room located at 0°.

Broad band white noise was generated by the audiometer to the loudspeaker located at 180°. S/N ratios were determined be using a B&K 2203 sound pressure level meter and
taking SPL readings for speech and noise in the test room at the location of the middle of the subject's head in the sound field. Necessary adjustments were made in the hearing level dial in order to establish the appropriate S/N condition. Calibration checks were carried out each day subjects were tested to insure the stability of the test environment.

All aids were tested in a HC 2000 Phonic Ear Acoustic Computer or a Fonix 5000, both of which are hearing aid test chambers, prior to and immediately following each test session. All aids were placed with great care in the test box to assure the same placement relative to the microphone. Those aids which did not meet the Hearing Aid Industry Conference (HAIC) standards established for that aid were eliminated from the study.

Test Materials

All hearing aids were selected from a single manufacturer's production line, and physically looked identical which the exception of the rear inlet on the directional aids. The directional and omnidirectional aids were matched as closely as possible except for the microphone. That is, frequency response characteristics, gain, MPO, and distortion were as similar as possible. The front/back ratio of the directional aids was approximately 20-24 dB at 500,
1000 and 2000 Hz.

Each subject was allowed to use his own ear mold, but the same mold was required to be worn under both experimental conditions. Size 13 tubing was used with each subject under both conditions.

Procedures

Each subject was seated in the chair in the test room with his head in a restraining device. Pure tone thresholds were obtained at the speech frequencies (500, 1000 and 2000 Hz). Each subject in Group A was fitted with a directional aid; each in Group B with an omnidirectional aid. Aided speech reception thresholds were established using spondaic words, the words having been randomized to avoid order effects on retesting. Subjects were familiarized with the words prior to testing.

Subjects were then familiarized with the words from the WIPI test, and discrimination scores were obtained using these words presented live voice at a sensation level of 30-40 dB, depending on the subject's preference. Entire lists were administered in conditions of S/N +6, 0, and -6 dB. The order in which the words were presented was randomized, and arranged so that the repetition of any words would not occur within a given condition. Subjects were requested to respond to each stimulus word by pointing to
one of six pictures presented for each item in the WIPI test booklet. All words were presented from the speaker situated at 0° and the white noise from the speaker situated at 180°.

After testing, each subject was issued his respective aid and instructed to wear it a minimum of seven hours daily for three weeks. Batteries were provided and instructions given to change the batteries weekly, regardless of apparent necessity.

Since the aids were matched as closely as possible with respect to all parameters except the microphone, it was possible to conduct this study as a double blind test. Neither the subjects, teachers and parents, nor the examiner knew which type of aid a subject was wearing at any given time.

The double blind condition was fulfilled by having an assistant help in the issuing of the aids. She was given a list of the subjects' names which had been randomly assigned to the two experimental groups (by a person other than the experimenter). As each subject arrived for testing, the assistant selected the appropriate aid for the subject according to the group to which he'd been assigned, recorded the serial number and gave the subject the aid. A small piece of sponge had previously been taped over the back of all of the aids so that the rear inlet of the directional aids was not visible and consequently all aids looked
identical. After the subject had received the aid from
the assistant, the experimenter was then able to fit the
subject with proper tubing, check ear molds and assure
the aid was worn properly without knowing which type of
aid the subject was wearing. Immediately prior to testing
the subject was instructed to remove the sponge and tape.

Following the first three week period all subjects
returned and again underwent the testing procedures described
above using the aids they had worn during the previous
three weeks. These aids were then removed and tested on
the Phonic Ear or the Fonix. Aids which did not meet HAIC
standards were eliminated from the rest of the study, and
note was made of this on the test sheet of the subject who
had worn that particular aid.

At this time, individuals in Group A were fitted with
omnidirectional aids; Group B with directional aids. The
double blind condition was again upheld with the help of an
assistant. The volume setting of each aid was adjusted so
that each subject's speech reception threshold was within
5 dB of that obtained with the previous aid. Discrimina-
tion testing was then conducted as previously described.
Following testing, each subject was issued his respective
aid and given the same instructions as for the previous per-
iod.

No information was given to the subjects, teachers or
parents regarding the specific nature of the change. However,
they were informed that they were now wearing a different aid. This was considered necessary so that they would be cognizant of the two distinct periods when subjectively comparing the two conditions at the end of the six weeks.

All subjects returned after the second three week period for the same discrimination testing previously described. All aids worn during this period were again tested on the Phonic Ear or the Fonix and note made of any which failed to meet the HAIC standards.

The subjective assessment of the hearing aids was attained through the use of questionnaires and personal interviews. Daily and final questionnaires were completed by teachers and parents which provided their assessment of the subject's performance when wearing the two different aids. Daily questionnaires were considered necessary so that teachers and parents were continually reminded to observe the subject's behavior, and would not have to rely solely on memory when completing the final questionnaire at the end of the six weeks. The subjective evaluations of the two aids by the subjects was acquired by final questionnaires and personal interviews. There was an inherent weakness in this type of assessment with this particular group of subjects because all subjects were relatively unfamiliar with the examiner. Responses to the interview may have been different had the interviewer not been a stranger.
Therefore, throughout the six weeks of the experiment, two teachers and one parent (either natural or houseparent in a dormitory) for each subject were involved in the study. At the onset of the study, each was given a sufficient number of copies of the daily questionnaires which required rating the subject, using a scale provided, in terms of a given list of behaviors. The teachers and parents received two different questionnaires. In addition, the teachers and parents were asked to check daily to make sure the subject was wearing the aid the prescribed length of time and to note on the questionnaire if it was not worn. The questionnaires were collected by the experimenter on a weekly basis and further instructions or assistance given when necessary. Some of the teachers and parents were allowed to complete questionnaires weekly due to time and schedule factors.

At the end of the study, a final questionnaire was given to the teachers and parents asking them to compare the two periods in terms of the same behaviors noted on the daily questionnaires. At this time the subjects also completed a questionnaire, providing their evaluation of the two different aids. Following completion of the subjects' questionnaire, the experimenter interviewed each subject to gain further information regarding subjective responses to the two aids.
Chapter III
RESULTS

The objective data for this study consisted of speech
discrimination scores for each of twelve subjects obtained
under different experimental conditions. The subjective
data consisted of daily and final questionnaires completed
by parents and teachers of subjects, and final questionnaires
and personal interviews with the twelve subjects.

Objective Data

The results of the objective testing were subjected
to statistical treatment.

Differences in Discrimination Scores Before and After
a Period of Adjustment to the Aid

A correlated $t$ test was employed to determine if
there were any significant differences between subjects'
discrimination scores before and after a period of adjust­
ment to each type of aid. The differences were computed
for each aid under each S/N condition and $t$ values were
determined. Referral to a table of critical values of $t$
produced the .05 levels of significance for a one-tailed
test, and the results of this analysis are presented in
Table I and Figure 1. The results indicate there was not
TABLE I

COMPARISONS BETWEEN SCORES WITH DA AND OA

BEFORE AND AFTER ADJUSTMENT PERIOD

<table>
<thead>
<tr>
<th>Aid</th>
<th>Condition</th>
<th>t Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA</td>
<td>S/N +6 dB</td>
<td>.49</td>
</tr>
<tr>
<td>DA</td>
<td>S/N 0 dB</td>
<td>1.14</td>
</tr>
<tr>
<td>DA</td>
<td>S/N -6 dB</td>
<td>.98</td>
</tr>
<tr>
<td>OA</td>
<td>S/N +6 dB</td>
<td>.50</td>
</tr>
<tr>
<td>OA</td>
<td>S/N 0 dB</td>
<td>1.05</td>
</tr>
<tr>
<td>OA</td>
<td>S/N -6 dB</td>
<td>1.79</td>
</tr>
</tbody>
</table>

* Significant difference at .05 level

Fig. 1. Comparisons between scores with DA and OA before and after adjustment period.

% Correct

- = \bar{x} score with DA before adjustment period
- = \bar{x} score with DA after adjustment period
- = \bar{x} score with OA before adjustment period
- = \bar{x} score with OA after adjustment period
a significant difference at the .05 level between the two sets of scores for either aid under any of the conditions.

Differences in Discrimination Scores with a Directional Hearing Aid as Opposed to an Omnidirectional Hearing Aid

A correlated t test was again employed to determine if there were any significant differences between discrimination scores with a directional hearing aid (hereinafter "DA"), and discrimination scores with an omnidirectional hearing aid (hereinafter "OA"), for three S/N conditions. Since the t test previously mentioned established that the first and second scores with each aid did not differ significantly, only the first scores obtained with each aid were subjected to statistical treatment. T values were again determined for each S/N condition, and the .01 level of significance for a one-tailed test obtained from a table of critical values of t. The results are listed in Table II and Figure 2, and indicate a significant difference between scores at all three S/N conditions. The mean scores for each aid indicate that the significant difference was in favor of the DA for all S/N conditions.

Acoustical Analysis of Aids Before and After Each Period They Were Worn

Each aid was tested on either a Phonic Ear or a Fonix
TABLE II
COMPARISONS BETWEEN DA AND OA SCORES
UNDER EACH CONDITION

<table>
<thead>
<tr>
<th>Condition</th>
<th>$\bar{x}$ DA Score</th>
<th>$\bar{x}$ OA Score</th>
<th>$t$ Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/N +6 dB</td>
<td>75.7 %</td>
<td>62 %</td>
<td>3.71 *</td>
</tr>
<tr>
<td>S/N 0 dB</td>
<td>69.2 %</td>
<td>48.7 %</td>
<td>4.52 *</td>
</tr>
<tr>
<td>S/N -6 dB</td>
<td>58 %</td>
<td>41.3 %</td>
<td>21.14 *</td>
</tr>
</tbody>
</table>

* Significant difference at the .01 level

Fig. 2. Comparisons between DA and OA scores under each condition

% Correct

$\boxed{\bar{x}} = \bar{x}$ of first scores obtained with DA

$\boxed{\bar{x}} = \bar{x}$ of first scores obtained with OA

<table>
<thead>
<tr>
<th>Condition</th>
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prior to and following each period it was worn (see Appendix A). Any aid that did not meet HAIC standards, or varied by more than ± 3 dB in gain and ± 5% in distortion from previous testing with the same equipment was eliminated from the study. Only one aid, aid #11, had to be eliminated.

Variability measurements were only calculated between results obtained from the same equipment because it was noted that the Phonic Ear and the Fonix did not produce similar measurements. The Phonic Ear consistently measured gain at a lower level than the Fonix, and the Fonix often produced higher distortion measurements than the Phonic Ear. Consequently, only measurements obtained on a single instrument were used to compare performance data of individual aids.

Subjective Data

The subjective data was analyzed on an item-by-item basis and the results are presented descriptively.

Teacher Responses to Daily and Final Questionnaires

Ten teachers completed daily and final questionnaires, several of whom reported on more than one subject. The intent was to have two teachers complete questionnaires for
each subject, but this was not always possible due to scheduling problems. Consequently, there were two subjects in Group A (those who wore the DA first), on whom no data was collected from teachers, and two subjects in Group B (those who wore the OA first), on whom only one teacher provided data. Results of the daily and final questionnaires are presented in Figure 3.

The daily questionnaires required teachers to use a five point scale to rate subjects on a variety of classroom behaviors (see Appendix B). Ratings of these individual behaviors compiled over each of the two three-week periods were computed into mean scores and the means for each period were paired for analysis (see Appendix C). 141 pairs were obtained for the nine behaviors listed on the questionnaire, and 86 had component scores that differed. In 62 of these cases the DA received higher behavioral ratings, while in the remaining 24 the OA was rated higher. The mean difference between the scores in each pair was .68, less than one increment on the rating scale.

Fourteen of the sixteen pairs of overall mean scores had components that differed. Nine of these were higher for the DA period, and five for the OA period. The average difference between the components of these pairs was .42, less than half of an increment on the scale.

The final questionnaire required teachers to compare the two three-week periods in terms of the same behaviors
Fig. 3. Teachers' responses to daily and final questionnaires

- □ = DA rated better
- ■ = OA rated better
- ● = Both aids rated the same

### Question 1-9 (Daily)
Refer to specific classroom behaviors
N = 141

### Question 4-11 (Final)
Refer to specific classroom behaviors
N = 140

### Question 13 & 14 (Final)
Overall performance ratings for both periods
N = 18
noted on the daily questionnaires, as well as respond to some additional questions (see Appendix D).

The responses appear in Appendix E. Since the double blind condition was still maintained, teachers responded by selecting either the first or second period. However, the author converted the responses to the type of aid worn during the specified period in order to present the results in a more meaningful manner.

Of the 140 responses to the eight questions that asked directly which period was better in terms of specific behaviors (Questions 4-11), 94 indicated that both periods were the same. 42 of the remaining 46 responded that the DA period was better, and 4 that the OA period was better.

Of the eighteen responses to Questions 13 and 14, twelve rated the two periods as being different regarding overall performance. Eleven of these twelve gave the DA period higher ratings than the OA period. Five of these eleven attributed the difference in behavior to the different hearing aids; six were uncertain as to the reason for the difference.

On the questions which dealt with the length of time the two experimental aids were worn (Questions 1-3), nine responses specified that both aids were worn the same amount of time. Eight reported that the DA was worn more, and one the OA.

Either or both experimental aids were reported to have
been worn more than the subject's own aid in six of the eighteen responses to Question 2. Two of these stated that the DA was worn more, and four that both aids were worn more. Subjects were reported to have worn either or both experimental aids less than their own in five of the eighteen responses to Question 3. One reportedly wore the DA less, and four wore the OA less.

Unusual irritability was reported in seven of the eighteen responses to Question 12. Five reported this irritability was during the OA period, one during the DA period, and one during both periods.

Parent Responses to Daily and Final Questionnaires

Six parents completed daily and final questionnaires. Three of these were dormitory houseparents who completed questionnaires on several subjects, and three were natural parents. Parental data was obtained on eleven of the twelve subjects. The daily questionnaires required the parents to rate the subjects on various behaviors (see Appendix F). Mean scores for individual behaviors were again computed for each period and paired for analysis (see Appendix G).

Results of the daily and final questionnaires are presented in Figure 4. Of the 68 pairs obtained for the eight behaviors listed, 36 had component mean scores which differed for each period. 23 of these had higher behavioral
Fig. 4. Parents responses to daily and final questionnaires

- □ = DA rated better
- ▢ = OA rated better
- ◼ = Both aids rated the same

# Responses

50
40
30
20
10

Question
# 1-8 (Daily)
Refer to specific behaviors
N = 68

# 4(a-e)-6 (Final)
Refer to specific behaviors
N = 63

# 9 (Final)
Refers to overall behavior rating
N = 11
ratings for the DA period, and thirteen had higher ratings for the OA period. The mean difference between the scores in each of these pairs was .91, less than one increment on the rating scale.

Eight of the eleven pairs of overall mean scores had components that differed. Four resulted in higher overall means for the DA period, and four for the OA period.

The final questionnaire required parents to compare the two periods in terms of the same behaviors noted on the daily questionnaires, as well as respond to additional questions (see Appendix H).

The responses are listed in Appendix I. Of the 63 responses to Questions 4 (a-e) - 6, which directly asked which period was better in terms of specific behaviors, 28 reported both periods to be the same. 18 stated the DA period was better, and 16 the OA period.

Six of the eleven subjects were reported to have worn both aids the same amount of time. Three were reported to have worn the DA more, and two the OA (Question 1).

Five subjects were reported to have worn either or both of the experimental aids more than their own. Two of these reportedly wore both aids more, one the DA more, and one the OA. (The remaining one did not specify) (Question 2).

Only one subject was noted by a parent to have worn either or both of the aids less than his own, and this subject reportedly wore both aids less (Question 3).
It was stated that three subjects were more irritable when wearing the OA. The remaining subjects were rated as being the same during both periods in terms of irritability (Question 7).

Five subjects received different overall behavioral ratings for the two periods. Three of these were rated higher for the OA period, and two for the DA period. Parents were uncertain in all five cases as to whether the difference could be attributed to the difference in aids (Question 9).

Subjects' Responses to Final Questionnaires and Personal Interviews

All twelve subjects completed final questionnaires and were interviewed personally by the examiner. The questionnaires required subjects to specify which aid was better in terms of understanding speech in a variety of different noisy situations, and to respond to additional questions (see Appendix J). During the interview they were asked to explain their responses to the questionnaire and encouraged to offer additional comments or criticisms of the aids (see Appendix K).

The data collected from the final questionnaire is presented in Appendix L and Figure 5. Again, the double blind condition was still maintained but the author converted the responses to the type of aid worn during the period specified in the responses. Five of the twelve subjects
Fig. 5. Subjects' responses to final questionnaire

- = DA rated better
- - = OA rated better
- - - = Both aids rated same

# Responses
50
40
30
20
10

Question

# 1 Which aid preferred overall
N = 12

# 3-8 Which aid better when noisy
N = 68

# 10 Which aid better for distance
N = 12

# 11 Which aid can wear longer
N = 12
preferred the OA, four the DA, and three had no preference. Ten subjects reported that a difference was noticeable between the two aids.

68 responses were obtained for Questions 3-8 which asked specifically which aid was better in terms of understanding speech in different noisy situations. 32 of these specified that both aids were the same. 21 reported the OA was better, and fifteen the DA.

Six subjects reported that loud noises were more bothersome when wearing the OA. Five did not notice a difference between aids in this respect, and one reported loud noises to be more annoying with the DA (Question 9).

Five of the twelve said they could hear things better from far away with the OA. Four stated the aids were the same in this regard, and three said the DA was better (Question 10).

Seven subjects reported they could wear the OA for a longer time without getting tired. Three did not observe differences between aids in this respect, and two stated the DA could be worn longer (Question 11).

Five subjects reported they liked either or both of the experimental aids more than their own. Three of these preferred the OA and two the DA (Question 12).

Eight of the twelve said they wore one of the aids more than the other. Of these, six stated the OA was worn more and two the DA (Question 13).
Three subjects reported they wore either or both of the aids more than their own. Two said the OA was worn more, and one said both aids were worn more (Question 14).

Two subjects reported wearing both the OA and the DA less than they usually wear their own aid (Question 15).

Data obtained from the personal interviews was highly variable and for the most part consisted of scattered individual comments with no discernible patterns (see Appendix M). One exception, however, was that eight subjects agreed that the OA was "stronger" or "louder" than the DA. Four preferred this greater amplification, two did not, and two did not specify. Only two subjects commented that the DA was better in noisy situations.

Six of the subjects reported that they wore either or both of the aids for less time daily than they were instructed. Four said they wore both aids less, one the OA, and one the DA.
Chapter IV
DISCUSSION

The purpose of the objective portion of this study was twofold: first, to determine if discrimination scores with either the DA or the OA improve after a period of adjustment to the aid; and second, to determine if discrimination scores under various S/N conditions differ when wearing the DA as opposed to the OA.

The purpose of the subjective portion was to determine if advantages could be noted for one aid over the other by the wearer, his teachers or his parents.

Null hypotheses were accepted or rejected in the following manner:

1. The null hypothesis that discrimination scores obtained under various S/N conditions when wearing a DA or OA will not improve significantly after a period of adjustment to wearing the aids could not be rejected. This result was not unexpected for the OA considering all subjects had worn some type of OA previous to the study and therefore were probably already adjusted to such an aid at the onset. But with the DA it seemed more probable that a learning effect might occur since none of the subjects had ever worn an aid with a directional characteristic. However, results showed that the subjects were able to gain immediate benefit from the DA (as evidenced by the improved discrimination scores
to be discussed later), and did not require an adjustment period.

Nevertheless, although initial test scores were high with the DA, the potential still existed for scores to be even better on the second testing, and as stated previously this did not occur. A possible explanation may be found in the environment of most of the subjects. Nine of the twelve subjects were being educated in and residing in a "total communication" setting in which the majority did not rely on their hearing to a maximal degree. Very few subjects appeared to utilize the auditory channel substantially when communicating, and consequently their "listening skills" seemed poorly developed. It is therefore possible that the full potential of the DA's was not exploited, and a learning effect that might have occurred otherwise did not occur.

However, neither was a learning effect indicated in the scores of the remaining three subjects who were from an oral environment. Although this number is too small to completely invalidate the explanation proposed above, it does lend support to the previous assertion that maximum benefit in terms of discrimination scores can be derived immediately from these aids. An adjustment period may not affect these scores regardless to what extent the aid is used.

2. The null hypothesis that discrimination scores obtained under various S/N conditions when wearing DA's will not be significantly better than when wearing OA's was rejected.
There was a significant difference in favor of the DA at all three S/N conditions at the .01 level of significance.

The more adverse the condition was, the greater the t values were. The differences between the overall mean scores of the DA and the OA at the 0 and -6 dB conditions were approximately the same. However, there were individuals whose differences between scores with each aid greatly increased at the -6 dB condition, and this caused the t value to increase considerably. This is in accordance with findings by Lentz (1972) and Nielsen (1973), who both found that the more adverse the condition, the more benefit the DA affords.

The significant difference between aids found at the +6 dB condition contradicts Frank and Gooden's (1973) assertion that if the noise source is at 180° it must be as intense or more intense than the signal (S/N 0 dB or less), in order to demonstrate the effectiveness of a DA. In this study the noise source was at 180° and significant differences still emerged when the noise was less intense than the signal.

These findings also support Lentz' (1974) statement that multiple noise sources are not necessary for the purpose of comparing OA's and DA's in routine testing, and contradict Frank and Gooden (1973) and Kelly and Miller (1975), who maintain that the source of the noise and the signals must be varied. In this study the signal and noise sources
were always at 0° and 180° respectively, and significant differences were still clearly demonstrated.

These results also offer additional information which may help resolve the present controversy over whether DA's must be fitted binaurally in order for advantages to be gained over OA's. Although the monaural-binaural issue was not a consideration in the present study and all subjects were fitted monaurally, the findings do indicate that the monaural fitting of such aids can be beneficial.

3. The null hypothesis that improved performance with the DA compared to the OA will not be noted by the subjects or their teachers or parents could not be either accepted or rejected in its entirety. However, tendencies were observed by analyzing the subjects', teachers' and parents' responses separately to questionnaires given throughout the experimental period.

Teachers' Responses

The subjective data obtained from teachers revealed some tendencies which would allow for a rejection of the above null hypothesis. Although in many cases the two periods were rated the same, those ratings that did differ were strongly weighted in favor of the DA. On the daily questionnaires the DA was favored approximately 3:1 over the OA on individual behavioral ratings. Of those responses
to the final questionnaire that specified one period as being better than the other in terms of specific behaviors, almost all were in favor of the DA period. This was also true of the overall performance ratings.

However, whether these findings revealed improved performance in a practical, realistic sense is questionable. The mean differences computed for the ratings just mentioned seem realistically to be very small. However, there were select individuals (subjects A2 and B1), whose overall mean ratings differed by as much as two points, and for those it can be assumed that "real" advantages did occur.

In addition, since the results were analyzed for all of the subjects as a whole, the findings may be misleading. A closer analysis revealed that the select individuals mentioned previously contributed strongly to the weighting of scores in favor of the DA, and that higher ratings for the DA were not distributed evenly across subjects. It appears, therefore, that improved performance with the DA was definitely noted by teachers for two of the subjects, but that for the remainder advantages were probably minimal.

These findings did not support the DA to the degree that would be expected based on the objective test results. This lack of more positive findings favoring the DA may again be at least partly attributed to the educational environment of most of the subjects. Although all teachers involved in the study spoke in the classroom along with using
sign language, the primary mode of communication at this school is manual and most subjects rely on signs much more than on speech. Several of the teachers commented on this initially and expressed extreme doubt that they would be able to observe any differences in classroom behaviors that could be attributed to different hearing aids.

Of the three subjects who were from an oral school, teacher responses were obtained on only two. Of these two, one strongly favored the DA and the other did not. However, the one that did not was a teacher who worked with the subject primarily in a tutorial sense and consequently did not observe in noisy situations where advantages for the DA are most likely to be noted. Again, it should be emphasized that the small number of subjects available make it unrealistic to generalize.

Another possible explanation for the lack of strong subjective data favoring the DA may be that it was unrealistic to expect teachers to observe individual behaviors when teaching relatively large classes. However, for the most part during this study the teachers were very cooperative, provided the requested data on a regular basis, and appeared to have made a conscientious effort to record observations reliably. Therefore, the former explanation relating to the environment seems to be the more probable reason for the inconsistent subjective evaluations.
Parents' Responses

Even less of a tendency in favor of the DA emerged from the parents' responses. The ratings from the daily questionnaires were slightly less than 2:1 in favor of the DA, and the mean difference between paired scores was very small.

Again considering the objective test results, this lack of strong advantages being noted by parents for the DA is surprising. However, the explanation offered earlier is even more applicable to the parental data. Nine of the eleven subjects on which parental data was obtained resided in a "total communication" setting which was even less "oral" than the educational setting; this may explain why even less advantages were noted by parents than teachers. The examiner observed that the houseparents, who provided data on nine of the subjects, often communicated with the subjects through sign language only and did very little if any speaking in the dormitory situation. In addition, the subjects themselves rarely used speech in the dorm, and hearing aids were usually removed. Although most of the subjects reported that they wore the aids the prescribed length of time, it is doubtful that they were worn very much in the dorm. Considering this general paucity of verbal interaction it is quite logical that improved performance was not noted by the houseparents to the degree that
would be expected.

Of the two subjects from an oral home setting on which parental data was obtained, one favored the DA and one the OA. The parent whose ratings favored the OA reported that the subject was dissatisfied with the DA because it did not offer sufficient gain. As with the data discussed previously, this number is too small to determine whether advantages would be more evident in an oral environment.

Subjects' Responses

The data obtained from the subjects showed even less of a tendency in favor of the DA than did the teachers' or parents' responses. In fact, a slight tendency emerged in favor of the OA. Although subjects were almost evenly divided in terms of which aid they preferred overall, there were slightly more responses stating the OA was better in terms of understanding speech in specific noisy situations. Also, more subjects reported being able to wear the OA longer without becoming tired or irritable. However, six subjects reported noise to be more bothersome with the OA, and only one reported this with the DA. Responses to the remaining questions were fairly evenly distributed between the two aids and showed no tendencies for one aid over the other.

These results too were unexpected considering how much better most subjects performed with the DA in objective
testing. One subject obtained as much as a 56% difference in scores between aids (subject A3), yet did not report a preference for the DA. Again, the most reasonable explanation lies in the "listening" environment of most of the subjects and their lack of orientation towards the use of amplification. The examiner observed that most subjects were extremely apathetic towards hearing aids in general, and some even admitted a dislike for any type of amplification. Consequently, it's possible that the fact that the OA offers slightly more gain and may "sound" a little louder, may have been enough to cause subjects to prefer it in some cases. The degree of hearing loss of most of the subjects was the maximum that would be considered for this particular type of aid. It's therefore possible that their need for powerful amplification caused them to prefer the aid that seemed "louder."

The personal interviews also revealed a disinterest on the part of many of the subjects towards amplification, and an inability to rationally and constructively comment on the aids. Many offered comments which directly contradicted their responses on the questionnaire, and when this was brought to their attention they simply changed their answers. However, one comment recorded frequently was that the OA was louder. It appears that although these aids were matched as closely as possible, the inevitable difference in gain between an OA and a DA was noticeable to the wearers.
In summary, the subjective data was not nearly as supportive of the DA as would be expected based on the objective results. It in general was not in accordance with subjective data obtained by Lentz (1974), Nielsen (1973), and Sung (1975) who all found strong favorings for the DA through subjective analyses. However, both Nielsen and Lentz stressed that the individual's environment must be considered when determining whether a DA will be beneficial, and this study strongly supports this. Unless an individual relies on his hearing and has the ability to use it in noisy situations, it appears that practical advantages for the DA can not be expected to be noticed.
Chapter V
SUMMARY AND CONCLUSIONS

The purpose of this study was to objectively and subjectively compare the effects of directional and omnidirectional hearing aids on school age children. Based on previous research it was hypothesized that discrimination scores obtained when wearing the DA under various S/N conditions would be significantly better than those obtained with the OA, and that improved performance with the DA over the OA would be noted by the children, their teachers and/or parents. It was further hypothesized that discrimination scores with each aid would improve after a period of adjustment to the aid.

The importance of this study centered around the possibility of gaining increased understanding of the benefits directional aids can afford. Although a review of the literature revealed experimental findings that have emerged in favor of the DA, the amount conducted was relatively small, and none had been carried out using children, whether normal or hearing impaired, as subjects; nor had any research investigated the educational advantages of such aids.

The subjects used for this study were twelve individuals with moderate-severe bilateral sensorineural losses; ages ranged from nine to eighteen years. Nine subjects were from a "total communication" environment, and three from an "oral" environment.
Objective data consisted of aided speech discrimination scores obtained for each subject wearing each of the aids under S/N conditions of +6, 0 and -6 dB. Subjects were tested with each aid before and after a three-week period in which they wore that aid.

Subjective data consisted of daily and final questionnaires completed by teachers and parents of the subjects, and final questionnaires and personal interviews with the subjects.

Correlated t test results did not indicate significant differences between subjects' discrimination scores before and after a period of adjustment to each type of aid. However, significant differences were found between discrimination scores obtained with the DA and scores obtained with the OA for all three S/N conditions. This difference favored the DA in all S/N conditions.

The subjective data did not favor the DA to the degree that would be expected based on the objective test results. Moderate judgemental tendencies were noted in favor of the DA on the part of the teachers, and slight tendencies on the part of the parents. The subjective data obtained from the subjects did not reveal any tendencies in favor of the DA; in fact, a minimal preference emerged supporting the OA.

The primary explanation offered for the above findings related to the environment of the subjects, most of whom
were from a "total communication" setting with a strong reliance on manualism. The findings were also discussed in reference to previous research, with agreements and contradictions emphasized.

Conclusions

1) Directional hearing aids allow for significantly better speech discrimination scores compared to omnidirectional hearing aids under S/N conditions of +6, 0 and -6 dB.

2) Directional hearing aids offer an immediate benefit in terms of speech discrimination skills to wearers accustomed to wearing amplification but unaccustomed to wearing directional aids, and this benefit does not appear to change after a period of adjustment to the aids.

3) Subjective advantages for directional hearing aids over omnidirectional aids are not strongly evident. However, the social/educational environment of this experimental population must be considered.

Implications for Future Research

Information obtained from this study indicated that the following questions might be suggested for future study:
1) Would subjective advantages on the part of children, their parents and teachers in favor of the DA be observable in an "oral" educational and home environment?

2) Would a learning effect occur after adjusting to the DA in terms of learning to use it more advantageously in everyday situations, even if measurable objective changes did not occur?

3) Would greater subjective advantages for the DA be noted by children with mild-moderate losses as opposed to moderate-severe losses?

4) What advantages would the binaural fitting of a DA have over the binaural fitting of an OA?


APPENDIX A

RESULTS OF ACOUSTICAL ANALYSIS OF AIDS

P = Analyzed with Phonic Ear
F = Analyzed with Fonix
V = Variability between measurements taken on same equipment
* = Aid eliminated from study

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% Distort:

1. **1st (F)**: 9, 6, 2, 2, 1, 1, 2
2. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
3. **3rd (F)**: 16, 10, 3, 1, 2, 2
4. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
5. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
6. **3rd (F)**: 16, 10, 3, 1, 2, 2
7. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
8. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
9. **3rd (F)**: 16, 10, 3, 1, 2, 2
10. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
11. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
12. **3rd (F)**: 16, 10, 3, 1, 2, 2
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14. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
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17. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
18. **3rd (F)**: 16, 10, 3, 1, 2, 2
19. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
20. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
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22. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
23. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
24. **3rd (F)**: 16, 10, 3, 1, 2, 2
25. **5th (F)**: 9, 6, 2, 2, 1, 1, 2
26. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
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41. **2nd (P)**: 13, 8, 2, 1, 0, 1, 1
42. **3rd (F)**: 16, 10, 3, 1, 2, 2
## APPENDIX A
(Continued)

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9 OA dB Gain

| 1st (F) | 41 | 52 | 65 | 59 | 62 | 57 | 43 | 60 |
| 2nd (P) | 35 | 46 | 56 | 57 | 59 | 54 | 35 | 54 |
| 3rd (F) | 34 | 44 | 56 | 56 | 59 | 54 | 38 | 53 |
| V       | -1 | -2 | 0  | -1 | 0  | 0  | +3 | -1 |

| % Distort | 1st (F) | 10 | 8  | 2  | 3  | 1  | 2  | 2  | 8  |
|           | 2nd (P) | 16 | 20 | 2  | 1  | 2  | 2  | 14 |    |
|           | 3rd (F) | 10 | 11 | 3  | 1  | 1  | 2  | 9  |    |
| V        | -6      | -9 | +1 | 0  | -1 | 0  | 0  | -5 |    |

10 OA dB Gain

| 1st (F) | 45 | 47 | 64 | 59 | 62 | 56 | 44 | 58 |
| 2nd (P) | 40 | 39 | 56 | 56 | 57 | 54 | 35 | 51 |
| 3rd (F) | 37 | 38 | 57 | 53 | 61 | 57 | 41 | 52 |
| V       | -3 | -1 | +1 | -3 | +4 | +3 | +6 | +1 |

| % Distort | 1st (F) | 12 | 12 | 3  | 3  | 1  | 1  | 1  |    |
|           | 2nd (P) | 20 | 17 | 3  | 2  | 1  | 1  | 6  |    |
|           | 3rd (P) | 15 | 16 | 3  | 2  | 2  | 1  | 5  |    |
| V        | -5      | -1 | 0  | 0  | +1 | 0  | -1 |    |

* 11 OA dB Gain

| 1st (F) | 41 | 46 | 62 | 58 | 61 | 56 | 38 | 56 |
| 2nd (P) | 17 | 9  | 11 | 9  | 9  | 7  | 4  | 9  |
| 3rd     |     |    |    |    |    |    |    |    |

| % Distort | 1st (F) | 9   | 6   | 2   | 2   | 2   | 1   | 2   |
|           | 2nd (P) | 17  | 16  | 7   | 9   | 6   | 9   | 20  |
| 3rd       |         |     |     |     |     |     |     |     |
APPENDIX A
(Continued)

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<th>1600</th>
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| 13 OA dB Gain | 1st (F) | 46 | 46 | 67 | 61 | 64 | 58 | 43 | 59 |
|              | 2nd (F) | 46 | 47 | 66 | 60 | 63 | 59 | 45 | 59 |
|              | 3rd (F) | 48 | 45 | 66 | 61 | 65 | 60 | 40 | 59 |
|              | V       | +2 | +2 | -1 | +1 | +2 | +2 | +3 | 0  |
| % Distor    | 1st (F) | 23 | 9  | 3  | 3  | 1  | 2  | 7  |
|            | 2nd (F) | 19 | 8  | 2  | 2  | 1  | 2  | 8  |
|            | 3rd (F) | 21 | 10 | 3  | 1  | 1  | 1  | 6  |
|            | V       | +4 | +1 | +1 | +2 | 0  | -1 | +2 |
APPENDIX B

DAILY TEACHER QUESTIONNAIRE

Using the scale provided below, please rate the student on the following list of behaviors. Ratings should reflect your judgement of his present behavior as compared to his usual behavior.

5 = Much more (or much better)
4 = Slightly more (or slightly better)
3 = Same
2 = Slightly less (or slightly worse)
1 = Much less (or much worse)

___ 1. Attends (eye contact, etc.)
___ 2. Completes tasks
___ 3. Voluntarily participates in class discussions
___ 4. Follows directions
___ 5. Accurately responds to questions
___ 6. Initiates interactions with peers
___ 7. Is contacted for interactions by peers
___ 8. Classwork performance
___ 9. Irritability
## APPENDIX C

### MEAN RATINGS OF TEACHER'S RESPONSES TO DAILY QUESTIONNAIRES

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APPENDIX D

FINAL TEACHER QUESTIONNAIRE

Please circle the appropriate response to the following questions:

1) Which of the two aids did the student wear more?
   A. Aid worn first three week period
   B. Aid worn second three week period
   C. Both the same

2) Did the student wear either or both of these aids more than he usually wears his own aid?
   A. Yes
   B. No
   If yes, which aid or aids did he wear more?
   A. Aid worn first period
   B. Aid worn second period
   C. Both aids

3) Did the student wear either or both of these aids less than he usually wears his own?
   A. Yes
   B. No
   If yes, which aid or aids did he wear less?
   A. Aid worn first period
   B. Aid worn second period
   C. Both aids

4) During which period did the student "attend" more?
   A. First period
   B. Second period
   C. Both the same
5) During which period did the student complete tasks more effectively?
   A. First period
   B. Second period
   C. Both the same

6) During which period did the student voluntarily participate more often in class discussions?
   A. First period
   B. Second period
   C. Both the same

7) During which period did the student follow directions better?
   A. First period
   B. Second period
   C. Both the same

8) During which period did the student respond more accurately to questions?
   A. First period
   B. Second period
   C. Both the same

9) During which period did the student initiate more interactions with his peers?
   A. First period
   B. Second period
   C. Both the same

10) During which period was the student contacted more for interactions by peers?
    A. First period
    B. Second period
    C. Both the same
APPENDIX D
(Continued)

11) During which period was the student's classwork performance better?

A. First period
B. Second period
C. Both the same

12) During this six week period did the student display unusual irritability?

A. Yes
B. No

If yes, during which period or periods?
A. First period
B. Second period
C. Both periods

13) Please rate the student's overall behavior during the first three week period compared to his usual behavior.

Much poorer 2 Same 3 Much better
1 4 5

14) Please rate the student's overall behavior during the second three week period compared to his usual behavior.

Much poorer 2 Same 3 Much better
1 4 5

If you rate items 13 and 14 differently, would you attribute this difference to the different hearing aids?

A. Yes
B. No
C. Uncertain

If not, or if uncertain, what would you attribute the difference to? If you are aware of other factors that were operating which may have influenced the student's behavior, please explain.
## APPENDIX E

### TEACHER RESPONSES TO FINAL QUESTIONNAIRE

#### Group A - Directional Aid Worn 1st Period

<table>
<thead>
<tr>
<th>Subj</th>
<th>Teac</th>
<th>Que.</th>
<th>Que. (a)</th>
<th>Que. (b)</th>
<th>Que. 2</th>
<th>Que. 3</th>
<th>Que. 4</th>
<th>Que. 5</th>
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<td>2</td>
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#### Group B - Omnidirectional Aid Worn 1st Period

| B1   | A    | B    | B    | A    | A    | B    | B    | B    | B    | B    | B    | B    | A    | A    | 2      | 4      | A      |
| B2   | B    | B    | B    | A    | A    | C    | C    | C    | C    | C    | C    | C    | C    | A    | A    | 2      | 3      | A      |
| B3   | A    | C    | B    | A    | B    | C    | C    | C    | C    | C    | C    | C    | A    | 3      | 5      | A      |
| B4   | A    | C    | B    | B    | C    | B    | C    | B    | C    | B    | C    | B    | A    | 3      | 4      | A      |
| B5   | A    | C    | B    | B    | A    | A    | A    | A    | C    | C    | C    | C    | A    | A    | 4      | 2      | C      |
| B6   | A    | C    | B    | B    | C    | C    | C    | C    | C    | C    | C    | C    | A    | 3      | 3      | C      |

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APPENDIX F

GUARDIAN OR PARENT QUESTIONNAIRE

Using the scale provided below, please rate the student on the following list of behaviors. Ratings should reflect your judgement of his present behavior as compared to his usual behavior.

5 = Much more (or much better)
4 = Slightly more (or slightly better)
3 = Same
2 = Slightly less (or slightly worse)
1 = Much less (or much worse)

1. Accurately responds to questions and directions and effectively communicates
   _____ A. At the meal table
   _____ B. Outdoors (playground, downtown, etc.)
   _____ C. Riding in a car
   _____ D. While others are talking simultaneously
   _____ E. While T.V., radio or other background noise is present

2. _____ Responds when called

3. _____ Participates in group games or activities

4. _____ Irritability
APPENDIX G

MEAN RATINGS OF PARENTS' RESPONSES TO DAILY QUESTIONNAIRES

1st = Mean rating of 1st period
2nd = Mean rating of 2nd period

<table>
<thead>
<tr>
<th>Group A - Directional Aid Worn 1st Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quest.1a</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>A1</td>
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<tr>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
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<td>A4</td>
</tr>
<tr>
<td>A5</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Group B - Omnidirectional Aid Worn 1st Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
</tr>
<tr>
<td>B2</td>
</tr>
<tr>
<td>B3</td>
</tr>
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<td>B4</td>
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<tr>
<td>B5</td>
</tr>
<tr>
<td>B6</td>
</tr>
</tbody>
</table>
APPENDIX H

FINAL PARENT OR GUARDIAN QUESTIONNAIRE

Please circle the appropriate response to the following questions:

1) Which of the two aids did the child wear more?
   A. Aid worn first three week period
   B. Aid worn second three week period
   C. Both the same

2) Did the child wear either or both of these aids more than he usually wears his own aid?
   A. Yes
   B. No
   If yes, which aid or aids did he wear more?
   A. Aid worn first period
   B. Aid worn second period
   C. Both aids

3) Did the child wear either or both of these aids less than he usually wears his own aid?
   A. Yes
   B. No
   If yes, which aid or aids did he wear less?
   A. Aid worn first period
   B. Aid worn second period
   C. Both aids

4) During which period did the child respond more accurately to questions and directions and communicate more effectively in the following situations:
   4a) At the dinner table
      A. First period
      B. Second period
      C. Both the same
APPENDIX H
(Continued)

... 4b) Riding in a car
A. First period
B. Second period
C. Both the same

4c) While others were talking simultaneously
A. First period
B. Second period
C. Both the same

4d) Outdoors (playground, downtown, etc.)
A. First period
B. Second period
C. Both the same

4e) While T.V., radio or other background noise was present
A. First period
B. Second period
C. Both the same

5) During which period did the child respond more when called?
A. First period
B. Second period
C. Both the same

6) During which period did the child participate more in group games or activities?
A. First period
B. Second period
C. Both the same

7) During which period was the child more irritable?
A. First period
B. Second period
C. Both the same

8) Please rate the child's overall behavior during the first three week period compared to his usual behavior

<table>
<thead>
<tr>
<th>Much poorer</th>
<th>1</th>
<th>2</th>
<th>Same</th>
<th>3</th>
<th>4</th>
<th>Much better</th>
<th>5</th>
</tr>
</thead>
</table>

9) Please rate the child's overall behavior during the second three week period compared to his usual behavior

<table>
<thead>
<tr>
<th>Much poorer</th>
<th>1</th>
<th>2</th>
<th>Same</th>
<th>3</th>
<th>4</th>
<th>Much better</th>
<th>5</th>
</tr>
</thead>
</table>
APPENDIX H
(Continued)

If you rated items 8 and 9 differently, would you attribute this difference to the different hearing aids?
A. Yes
B. No
C. Uncertain

If not, or if uncertain, what would you attribute it to?
If you are aware of other factors operating which may have influenced the child's behavior, please explain.
## APPENDIX I

**PARENTS' RESPONSES TO FINAL QUESTIONNAIRE**

### Group A - Directional Aid Worn 1st Period

<table>
<thead>
<tr>
<th>Subj</th>
<th>Que.1</th>
<th>Que.2</th>
<th>Que.3</th>
<th>Que.4</th>
<th>Que.5</th>
<th>Que.6</th>
<th>Que.7</th>
<th>Que.8</th>
<th>Comments</th>
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### Group B - Omnidirectional Aid Worn 1st Period

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<td>B</td>
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<td>B</td>
<td>C</td>
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</tbody>
</table>

Comments:
- Possibly problems parents are having caused behavior to vary
APPENDIX J
SUBJECT QUESTIONNAIRE

Please circle your answers to the following questions:

1) Which aid did you like better
   A. First aid
   B. Second aid
   C. Both the same

2) Did the two aids seem different to you?
   A. Yes
   B. No

3) With which aid could you understand the teacher better in class?
   A. First aid
   B. Second aid
   C. Both the same

4) With which aid could you understand better what someone was saying to you when others were talking at the same time?
   A. First aid
   B. Second aid
   C. Both the same

5) With which aid could you understand speech better at the dinner table?
   A. First aid
   B. Second aid
   C. Both the same

6) With which aid could you understand T.V. or radio better when the room was noisy?
   A. First aid
   B. Second aid
   C. Both the same

7) With which aid could you understand speech better in the gym?
   A. First aid
   B. Second aid
   C. Both the same

8) With which aid could you understand speech better when outdoors?
   A. First aid
   B. Second aid
   C. Both the same
9) With which aid did loud noises (such as banging doors or clanking silverware, etc.) bother you the most?
   A. First aid
   B. Second aid
   C. Both the same

10) With which aid could you hear things better from far away?
    A. First aid
    B. Second aid
    C. Both the same

11) Which aid could you wear for a longer time without getting tired or bothered by it?
    A. First aid
    B. Second aid
    C. Both the same

12) Did you like either or both of these aids more than your own aid?
    A. Yes
    B. No

13) Did you wear one of these aids more than the other one?
    A. Yes
    B. No

14) Did you wear either or both of the aids more than you usually wear your own aid?
    A. Yes
    B. No

15) Did you wear either or both of the aids less than you usually wear your own aid?
    A. Yes
    B. No
APPENDIX K

SUBJECT INTERVIEW

1) Why did you like the first (or second) aid best?  
   (If applicable)

2) In what ways did you think the two aids were different?  
   What did you like and not like about each one?

3) Which aid or aids did you like better than your own?  
   Why?  (If applicable)

4) Which of the two aids did you wear more?  Why?  (If applicable)

5) Which aid or aids did you wear more than your own?  
   Which less?  (If applicable)

6) Did you wear either of the aids for less time daily  
   than I asked you to?  If so, which one or ones?  Why?

Additional notes and/or spontaneous questions:
APPENDIX L
SUBJECTS' RESPONSES TO FINAL QUESTIONNAIRE

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<th>Group A - Directional Aid Worn 1st Period</th>
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### APPENDIX M

#### SUBJECTS' RESPONSES TO INTERVIEW

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<th>Question 4</th>
<th>Question 5</th>
<th>Question 6</th>
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<td>A1</td>
<td>DA better - sent sd. str.</td>
<td>Only hear short distance w/OA</td>
<td>Could hear more w/DA</td>
<td>OA-could hear far away</td>
<td>OA</td>
<td>Yes - both aids</td>
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<tr>
<td>A2</td>
<td>OA better - don't know why</td>
<td>Don't know</td>
<td>OA-don't know why</td>
<td>OA because hear better</td>
<td>Wore both</td>
<td>Yes - both aids</td>
</tr>
<tr>
<td>A3</td>
<td>NA</td>
<td>OA was louder</td>
<td>NA</td>
<td>OA-couldn't hear w/DA</td>
<td>Wore both</td>
<td>No - I hate hearing</td>
</tr>
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<td>A4</td>
<td>NA</td>
<td>Don't know</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>No</td>
</tr>
<tr>
<td>A5</td>
<td>NA</td>
<td>DA not as loud</td>
<td>NA</td>
<td>OA - DA too low</td>
<td>NA</td>
<td>No</td>
</tr>
<tr>
<td>A6</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>No</td>
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<tr>
<td>B1</td>
<td>DA better - talk phone</td>
<td>OA too strong</td>
<td>NA</td>
<td>DA-didn't hear backgd.</td>
<td>NA</td>
<td>Yes - OA 2 hrs./day</td>
</tr>
<tr>
<td>B2</td>
<td>OA better - louder</td>
<td>OA strong</td>
<td>Both better in noise</td>
<td>NA</td>
<td>Wore OA more</td>
<td>No</td>
</tr>
<tr>
<td>B3</td>
<td>OA better - comfortable in noise</td>
<td>Hear in noise w/DA</td>
<td>OA smaller - didn't fall off</td>
<td>OA didn't work well</td>
<td>Wore both</td>
<td>No</td>
</tr>
<tr>
<td>B4</td>
<td>DA better - quieter</td>
<td>Don't know</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Yes - both aids</td>
</tr>
<tr>
<td>B5</td>
<td>DA too loud</td>
<td>OA-don't know why</td>
<td>OA-liked more</td>
<td>Wore OA more</td>
<td>Yes - both aids</td>
<td></td>
</tr>
<tr>
<td>B6</td>
<td>DA squeaky - terrible</td>
<td>NA</td>
<td>OA-didn't like DA</td>
<td>Wore both less - Yes - DA</td>
<td>louder than mine</td>
<td></td>
</tr>
</tbody>
</table>