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Subjective preference for a high power hearing aid utilizing a directional microphone

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SUBJECTIVE PREFERENCE FOR A HIGH POWER HEARING AID UTILIZING A DIRECTIONAL MICROPHONE

by

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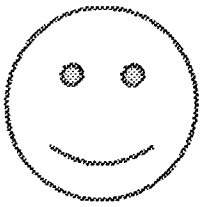

Introduction

What is a directional microphone? How does it work? Does it improve performance? Should I recommend it to my clients? What clients can benefit from this technology? These are a few of the questions that I came up with when I was first introduced to directional hearing aid technology. In this study, we investigated subjective rating of directional microphone performance in a very specific group, the severe to profound hearing-impaired population. The use of directional microphone technology in this group is just beginning to be explored. There is, however, a wealth of research on directional microphone use in general, and on the implementation of this technology in a more moderately hearing impaired population. The purpose of this study was to provide general information about directional microphones and to determine if people with severe or profound sensorineural hearing losses are good candidates for hearing aids with directional microphones.

How does a directional microphone work?

A directional microphone attempts to reduce the signal-to-noise ratio for the user. Many hearing aids attempt to do this by filtering out the range of frequencies that are less important for speech, where noise levels are typically high. The unique thing about a directional microphone system is that it can eliminate noise that is in the same frequency range as the speech signal (Ricketts and Mueller, 1999). The gain is dependent on the spatial orientation of the incoming signal.

Figure 1 is called a polar plot. It graphically displays the amount of attenuation perceived by the listener depending on the azimuth of the signal. Notice that even the

omnidirectional microphone has some attenuation. This is due to the effects of head, pinna and body reflection and diffraction (Ricketts et al, 1999).

How is this attenuation accomplished?

There are two systems that have been used to attenuate sound behind the listener. The first is through the use of a single microphone, and the second is through the use of two microphones.

When a single microphone is used, it incorporates two ports (see Figure 2). The front port leads to the front of the diaphragm, and the back port leads to the back of the diaphragm. When worn on the head, sound from directly behind enters the rear port, and is delayed by an acoustical network for about 57 microseconds. These sounds reach the back of the diaphragm at about the same time sound from behind has traveled to the front port, entered it, and reached the front of the diaphragm. It is in this way that sounds coming from behind are effectively canceled (Katz, 1994).

In a two-microphone system, electronic cancellations are used between separate front and back microphones. (Ricketts et al 1999).

Do directional microphones work?

A popular way to evaluate the benefit of a directional microphone is to measure the signal-to-noise ratio necessary to achieve a 50% correct performance level on a speech recognition task (Ricketts, 1999). Studies have shown this performance level can be reached at a poorer signal-to-noise ratio when using a directional microphone. (Madison

and Hawkins, 1983; Hawkins and Yacullo, 1984; Valente, Fabry, Potts, 1995; Wouters, Litire, vanWieringn, 1999).

Another way to evaluate benefit is subjectively through a survey/questionnaire method. Some studies have shown a subjective preference for directional microphones on measures such as the APHAB (Valente et al, 1995; Kuk, 1996; Preves, Sanneth and Wynne, 1999).

It has been suggested that the characteristics of the hearing aid user may be predicative of how much benefit they perceive. The characteristic that seemed to be the most predicative of perceived benefit was how much time the subject spent communicating in noise in a typical day. The more time in noise, the more advantage perceived (Mueller, Grimes & Erdman, 1983).

What about patients with severe to profound hearing loss?

There is a limited amount of information of the implementation of directional microphone technology in this population. Phonak has recently introduced the Power Zoom, a high power hearing aid that incorporates a directional microphone. One study suggests that there is a large signal-to-noise improvement (13.7dB) and a high amount of subject satisfaction when using this hearing aid (Phonak, 1999).

It was the aim of the present study to assess the subjective benefit of directional microphone use in the severe to profound hearing-impaired population.

Figure 1

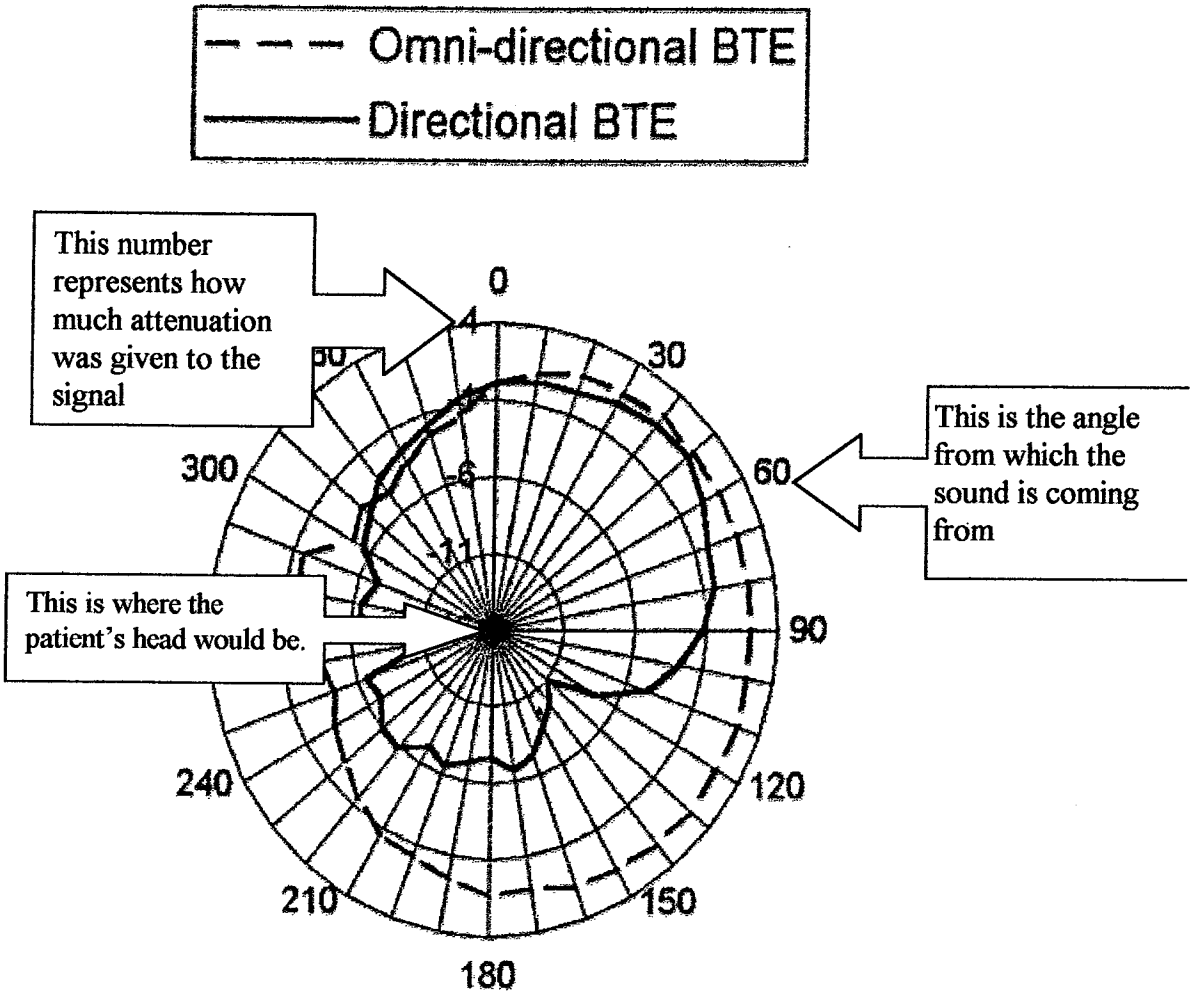

Figure 1: Figure one displays the polar plot of a BTE in the omnidirectional microphone and the directional microphone setting. Notice the effect of body reflection diffraction in the omnidirectional mode. The value shown has been averaged for the responses at 500, 1000, 2000 and 4000Hz (Ricketts et al, 1999).

Figure 2

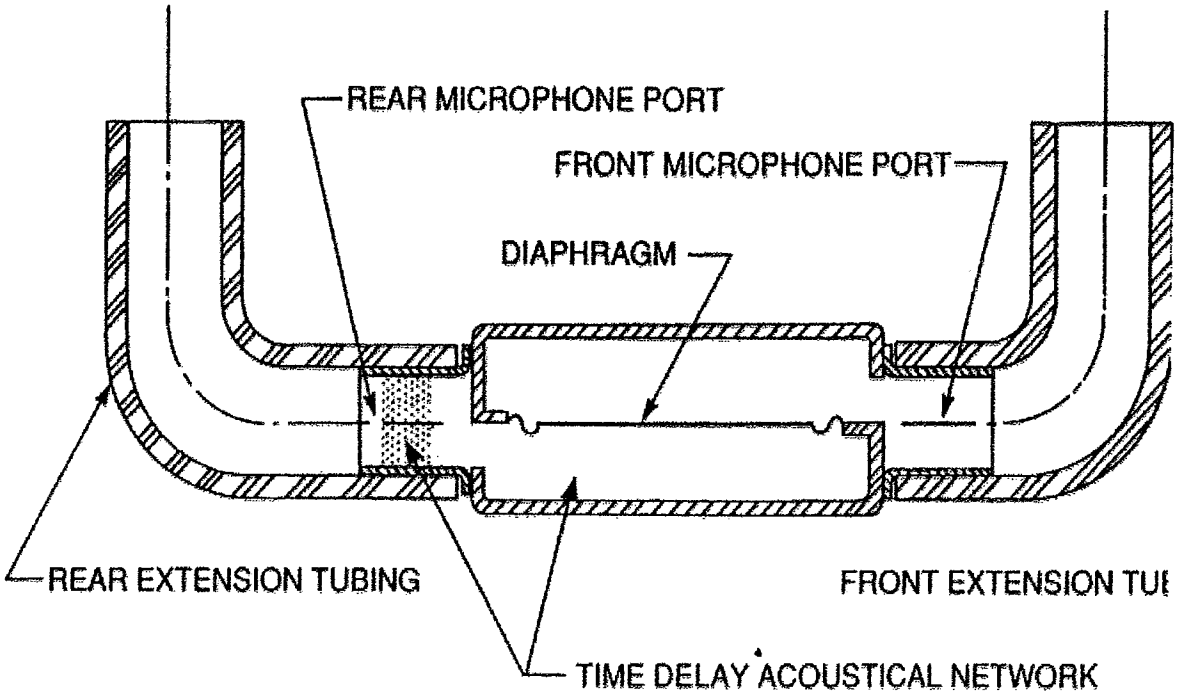

Figure 2: This figure shows the components of a directional microphone system that utilizes one microphone and two ports. (Ricketts et al, 1999).

Methods

Summary of procedures

The14 subjects in the study were given a complete hearing evaluation including pure tone testing, speech discrimination and tympanometry. These results were used to program the Phonak Power Zoom hearing aid (PZ) according to the NAL-RM fitting protocol (Dillon and Storey 1998). Twelve of the subjects were previous monaural users, so they were fitted with a monaural PZ on the ear they normally wore amplification. The two binaural users were fitted with binaural PZs. The patients were then counseled on the proper use of the hearing instrument and the remote control. They then wore the aids for 2-4 weeks. After this period of use, they completed the Washington University Hearing Aid Questionnaire (WUHAQ) to measure their preferences.

Questionnaire information

The Washington University Hearing Aid Questionnaire (WUHAQ) is shown in Table 1. The patient was asked to select the hearing aid or program (option) that provided the best performance in each listening situation (item) by checking the box which corresponded to the preferred option for each item. The questionnaire had six options the subjects could choose from, and 23 items. The options are as follows:

Memory One- the Power Zoom's omnidirectional microphone and basic program, set according to NAL-RM

Memory Two- the Power Zoom's directional microphone and basic program

Memory Three- the Power Zoom's directional microphone and party noise program

Own Aids- the subjects previous aids

Both- all hearing aids and programs performed equally well

None –all hearing aids and programs performed equally poorly

The questionnaire's items fall into one of three categories, neutral, difficult or easy. Eight of the items have been categorized as neutral, meaning they refer to neither a difficult or easy listening situation, but rather refer to some aspect of speech quality or general user attitudes. Five items refer to easy listening situations, and ten items refer to difficult listening situations. The items have been color coded according to their category in Table1.

Subject Information

There were 14 subjects who were fitted with the PZ hearing aids. Their audiometric data is shown in Table 2A: their hearing aid histories are shown in table 2B; and a description of their own aids is shown in Table 3. All subjects had sensorineural hearing loss that was in a severe-to-profound range. They wore a variety of behind-the-ear style hearing aids. There were 12 subjects who were monaural users and 2 who were binaural users.

The Power Zoom

The Phonak Power Zoom is a high power, digitally programmable, multi-memory hearing aid that utilizes analog signal processing as well as a directional microphone system. This aid is meant to give maximum hearing performance for users with severe-to

profound hearing loss while giving them the signal-to-noise ratio improvement that comes with the utilization of a directional microphone system.

The Phonak Power Zoom has three memories. For the purpose of this study, the targets were set according to NAL-RM formula (Dillion et al, 1998); including the correction for severe to profound losses. The targets were confirmed using probe tube measurements. Memory one was set to these targets without engaging the directional microphone. Memory two was set using these targets with the directional microphone engaged. Memory three was set using a feature of the Phonak software that changes the frequency response for "party" noise, and the directional microphone was engaged. The party noise algorithm changes the frequency response by 1) boosting the power in the high frequencies. 2) utilizing a BILL type signal processing and 3) changing the attack and release time. The software does this while assuring there is still enough gain present for the user's needs. (Personal contact L. Potts 2000)

Phonak's SC+aRT compression system was always used. This compression system has a high compression threshold, a compression ratio of 10:1, and a variable release time.

Phonak's directional microphone uses a dual microphone system

Table 1
Washington University Hearing Aid Questionnaire

Speech Quality	Memory One	Memory Two	Memory Three	Own	All	None
Speech was more…						
1. Distinct						
2. Pleasant						
3. Natural						
4.Comfortably Loud						
5.Uncomfortably Loud						
Performance was better…						
6. With a close friend one-on-one						
7. With a stranger one-on-one						
8. Listening to a speaker across the room						
9. Listening to a TV with no one else talking						
10. Listening to TV with one or more people talking						
11. Listening at a meeting with one speaker						
12. Listening at a meeting with several speakers						
13. Listening at a family gathering						
14. Listening to the radio in the car						
15. Listening to a passenger in the car						
16. Listening in an "elegant" restaurant						
17. Listening in a family restaurant						
18. Listening to sounds at a distance						
19. Listening at a house of worship						
20. Listening at a movie theater						
21. Listening to recorded music						
22. Performance was less frustrating						
23. Quiet sounds were more audible						

Blue ~ "Easy" Listening Situation
Red~ "Difficult" Listening Situation
Black~ Neutral Question

Table 1: This table shows the six options and 23 items of the WUHAQ.

Table 2a
Subject Audiometric Data

Subject	Sex	Ear	250	500	1000	2000	3000	4000	6000	8000
JI	M	Right	90	80	90	80	90	105	115	110
		Left	95	90	100	90	90	110	115	110
GF	M	Right	60	70	75	70	85	90	100	105
		Left	70	75	75	80	90	95	90	95
EN	M	Right	60	70	75	70	65	65	70	80
		Left	70	65	70	75	70	65	80	95
CS	F	Right	90	95	95	85	80	80	85	90
PT	F	Right	60	75	110	115	115	120	115	110
		Left	55	65	110	115	120	120	115	110
MM	M	Right	65	65	80	70	70	60	65	60
		Left	65	65	76	70	65	75	65	60
BF	M	Right	75	70	75	85	80	120	115	110
LL	F	Right	55	55	90	115	115	120	115	110
		Left	55	60	105	120	115	120	115	110
JC	M	Right	75	70	80	75	70	85	85	85
		Left	85	80	85	75	75	90	80	85
LR	F	Right	90	105	115	120	120	120	115	110
		Left	95	105	115	115	110	115	115	110
JS	M	Right	65	65	75	80	85	90	80	75
		Left	65	70	90	80	110	120	115	105
AM	M	Right	60	75	85	85	100	110	120	110
		Left								
GL	M	Right	70	65	75	90	105	120	120	120
		Left	60	65	65	80	85	120	120	120
ND	F	Right	60	70	105	105	105	110	120	110
		Left	55	65	100	105	100	110	120	110
Mean R			**69.6**	**73.6**	**87.5**	**88.9**	**91.8**	**99.6**	**101**	**98.9**
Mean L			**70**	**73.2**	**90.1**	**91.4**	**93.6**	**104**	**103**	**101**
SD R			**12.5**	**12.8**	**14**	**17.8**	**17.9**	**20.5**	**20.1**	**17.6**
SD L			**14.9**	**13.4**	**14.9**	**18.7**	**19.2**	**19.6**	**19.5**	**15.6**

Table 2a: This table shows, from left to right 1) The subjects ID 2) The subjects gender 3) The subjects ear that correlates with the subsequent data 4) The subjects threshold at 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000Hz. The last four rows of the table show the mean threshold for the subject's right ears, the mean threshold for the subjects left ears, the standard deviation in threshold for the right ear and the standard deviation in threshold for the left ear.

Table 2b
Subject Hearing Aid Experience

ID	Own Aid	Total years of hearing aid use	Years of hearing aid use with current aid
JI	OTICON 380P	37	8
GF	BOSCH 66F AGC	30	7.5
EN	SENSO C19	34	2
CS	OTICON 380P	38	9
PT	OTICON 380PL UNITRON US80PP	7	7
MM	RESOUND BT2	5	3
BF	PHONAK PP2CD	13	13
LL	OTICON E27P	15	10
JC	RESOUND BTP	20	5
LR	OTICON 380P	35	8
JS	OTICON 390PL STARKEY HDP	44	5.5
AM	VIENNATONE 113PP	33	9
GL	Bernafon T850	25	15
ND	RESOUND BTE	59	6
Mean		**28.21**	**7.85**
Standard Deviation		**15.59**	**2.85**

Table 2b: This table shows, from left to right 1) Subject ID 2) Type of hearing aid worn prior to the study 3) Total years of hearing aid use and 4) Years of use with current hearing aid. The last two rows show the mean number of years of hearing aid experience, the mean number of years the current hearing aid was used, the standard deviation of the number of years of hearing aid experience, and the standard deviation of the number of years use with the subjects current aids.

Table 3
Subject Hearing Aid Information

Subject	Make and Model	Information About Subjects Own Aid
JI	OTICON 380P	Single channel single memory hearing aid with linear signal processing.
GF	BOSCH 66F AGC	Single channel single memory hearing aid with linear signal processing
EN	SENSO C19	Single memory multi-channel hearing aid with non-linear digital signal processing
CS	OTICON 380P	Single channel single memory hearing aid with linear signal processing
PT	OTICON 380PL UNITRON US80PP	Single channel single memory hearing aid with linear signal processing Single channel single memory hearing aid with linear signal processing
MM	RESOUND BT2	2 memory 2 channel hearing aid with non linear signal processing
BF	PHONAK PP2CD	Single channel single memory hearing aid with linear signal processing
LL	OTICON E27P	Single channel single memory hearing aid with linear signal processing
JC	RESOUND BTP	2 memory 2 channel hearing aid with non linear signal processing
LR	OTICON 380P	Single channel single memory hearing aid with linear signal processing
JS	OTICON 390PL STARKEY HDP	Single channel single memory hearing aid with linear signal processing Single channel single memory hearing aid with linear signal processing
AM	VIENNATONE 113PP	Single channel single memory hearing aid with linear signal processing
GL	Bernafon T850	Single channel single memory hearing aid with linear signal processing
ND	RESOUND BTE	2 memory 2 channel hearing aid with non linear signal processing

Table 3: Table three shows, from left to right 1) The subjects ID 2) Make and Model of the subjects previous aid and 3) Information on the processing and memory capabilities of the subjects previous aids.

RESULTS

There were four hypothesis tested. Chi-squared tests were done to analyze the data. The hypotheses were:

1. There are no statistically significant differences among any of the WUHAQ items. Each option was considered a separated category when performing the chi-squared test. Total number of categories = 6

2. There are no statistically significant difference between the Power Zoom and the users own aids for any of the WUHAQ items.
   The three Power Zoom settings were one category, and each of the other options were individual categories. Total number of categories = 4

3. There are no statistically significant differences between the omnidirectional microphone and the directional microphone for any of the difficult listening situations in the WUHAQ. The omnidirectional settings were grouped together, and the directional settings were grouped together. The all and none categories were eliminated to limit the analysis to only those subjects who had a preference for a directional or omnidirectional option.
   Total number of categories = 2

4. When the Power Zoom is preferred, there are no statistically significant preferences for the directional microphone over the omnidirectional microphone in any of the difficult listening situations in the WUHAQ.

The omnidirectional setting of the Power Zoom was compared to the directional settings. The other categories were eliminated to limit the analysis to those subjects who had a definite preference for the Power Zoom.

Total number of categories = 2

Results of statistical analysis

- The analysis for hypothesis #1 showed significant preferences ($p > .05$) for options that depended on the WUHAQ item. The preferences are summarized in Figure 1. The patients experienced less frustration and thought speech had a more pleasant sound quality when using their own aids. Subjects indicated that none of the hearing aids at any of the settings made speech uncomfortably loud. Program 3 was the preferred option in three questions. Those questions involved situations where the subject was listening in noisy areas such as cars and restaurants.

- The analysis for hypothesis #2 showed significant preferences ($p > .05$) for options that depended on the WUHAQ item. The preferences are summarized in Figure 2. When listening with the PZ, the patients experienced better performance in easy listening situations such as one-on-one conversation. They also indicated better performance with the PZ in difficult situations such as listening across a room, listening at a meeting and listening in cars and in restaurants. They also thought that speech was more distinct, pleasant, natural, and conformably loud when listening with the PZ aids. They indicated that performance was less frustrating with their own aids, and that no settings or aids made speech uncomfortably loud.

- The analysis for hypothesis #3 showed a significant preference ($p > .05$) for listening with a directional microphone in a noisy restaurant setting (see Figure 3). There was no significant preference for the directional or omnidirectional microphone settings in the other 22 items.

- The analysis for hypothesis #4 showed a significant preference for the directional microphone of the PZ in noisy situations such as restaurants. The subjects also indicated that the directional microphone made quiet sounds more audible.

Hypothesis #1
Individual Analysis

	Speech was more…	
	1. Distinct	
	2. Pleasant	
	3. Natural	
	4.Comfortably Loud	
	[redacted]	
	Performance was better…	
	6. With a close friend one-on-one	
	7. With a stranger one-on-one	
	8. Listening to a speaker across the room	
	9. Listening to a TV with no one else talking	
	10. Listening to TV with one or more people talking	
	11. Listening at a meeting with one speaker	
	12. Listening at a meeting with several speakers	
	13. Listening at a family gathering	
	14. Listening to the radio in the car	
	[redacted]	
	[redacted]	
	[redacted]	
	18. Listening to sounds at a distance	
	19. Listening at a house of worship	
	20. Listening at a movie theater	
	21. Listening to recorded music	
	22. Performance was less frustrating	
	23. Quiet sounds were more audible	

Figure 1: Shows results of chi squared testing on hypothesis #1

*Yellow Highlighting~ significant preference for user's own aids

[redacted]

Hypothesis #2
Power Zoom vs. own Aids

	Speech was more...	
	1. Distinct	
	2. Pleasant	
	3. Natural	
	4.Comfortably Loud	
	[redacted]	
	Performance was better...	
	6. With a close friend one-on-one	
	7. With a stranger one-on-one	
	8. Listening to a speaker across the room	
	9. Listening to a TV with no one else talking	
	10. Listening to TV with one or more people talking	
	11. Listening at a meeting with one speaker	
	12. Listening at a meeting with several speakers	
	13. Listening at a family gathering	
	14. Listening to the radio in the car	
	15. Listening to a passenger in the car	
	16. Listening in an "elegant" restaurant	
	17. Listening in a family restaurant	
	18. Listening to sounds at a distance	
	19. Listening at a house of worship	
	20. Listening at a movie theater	
	21. Listening to recorded music	
	[redacted]	
	23. Quiet sounds were more audible	

Figure 2: Shows results of chi-squared testing on hypothesis #2

*Yellow Highlighting ~ significant preference for the PZ

[redacted]

Hypothesis #3
Directional vs. Omni Including Own

	Speech was more…	
	1. Distinct	
	2. Pleasant	
	3. Natural	
	4.Comfortably Loud	
	5.Uncomfortably Loud	
	Performance was better…	
	6. With a close friend one-on-one	
	7. With a stranger one-on-one	
	8. Listening to a speaker across the room	
	9. Listening to a TV with no one else talking	
	10. Listening to TV with one or more people talking	
	11. Listening at a meeting with one speaker	
	12. Listening at a meeting with several speakers	
	13. Listening at a family gathering	
	14. Listening to the radio in the car	
	15. Listening to a passenger in the car	
	16. Listening in an "elegant" restaurant	
	17. Listening in a family restaurant	
	18. Listening to sounds at a distance	
	19. Listening at a house of worship	
	20. Listening at a movie theater	
	21. Listening to recorded music	
	22. Performance was less frustrating	
	23. Quiet sounds were more audible	

Figure3: Shows results of chi-squared testing on hypothesis #3

*Yellow Highlighting~significant preference for directional microphone

Hypothesis #4
Power Zoom only Omni vs. Directional

	Speech was more…	
	1. Distinct	
	2. Pleasant	
	3. Natural	
	4.Comfortably Loud	
	5.Uncomfortably Loud	
	Performance was better…	
	6. With a close friend one-on-one	
	7. With a stranger one-on-one	
	8. Listening to a speaker across the room	
	9. Listening to a TV with no one else talking	
	10. Listening to TV with one or more people talking	
	11. Listening at a meeting with one speaker	
	12. Listening at a meeting with several speakers	
	13. Listening at a family gathering	
	14. Listening to the radio in the car	
	15. Listening to a passenger in the car	
	16. Listening in an "elegant" restaurant	
	17. Listening in a family restaurant	
	18. Listening to sounds at a distance	
	19. Listening at a house of worship	
	20. Listening at a movie theater	
	21. Listening to recorded music	
	22. Performance was less frustrating	
	23. Quiet sounds were more audible	

Figure 4: Shows results of chi-squared testing on hypothesis #4

***Yellow Highlighting~ significant preference for directional microphon**

Discussion

The ability of a directional microphone to improve the signal -to- noise ratio in difficult listening situations has been well documented (Lentz, 1972; Sung et al, 1975; Madison and Hawkins, 1983; Hawkins and Yacullo, 1984). The effect of applying this technology to the severe to profound hearing-impaired population is one that is just beginning to be explored. It was the objective of this study to determine if severely hearing impaired patients preferred hearing aids with a directional microphone, and, if there was a preference, in what types of listening situations the directional option was successfully used.

Hypothesis #1

In hypothesis 1 each option was analyzed separately, in an attempt to see if there was a preference for any of the Power Zoom's memory settings, the user's aid, or if all the options were preferred equally. Results showed that users thought using their own aids were the least frustrating. This result could be related to adaptation issues. Thirteen of the subjects were used to a much simpler aid than the Power Zoom. Perhaps getting used to the remote control caused some frustration. There was also a significant preference for the users own aid in question #2, which referred to how "pleasant" speech was. This may also be an adjustment issue. The subjects had had their previous aids for a long time and were used to the sound quality that they produced.

In future projects, we could determine if these are truly adaptation issues by having the subjects use the PZ hearing aid for a longer period of time. We would expect a decreasing preference for the old hearing aid as the time the PZ was worn increased

This analysis also revealed a significant preference for memory setting three in questions 15,16,and 17. All of these questions referred to difficult listening situations. This result goes along with previous findings that directional microphones improve performance in difficult listening situations. There were, however, many difficult situations where there were no significant preferences for the directional microphone setting. Most of these questions involved listening to speech at a distance rather than listening to speech in noise. It may also be the case that the subjects did not experience some of these situations during the trial period. We may see a stronger preference develop as the subject uses the PZ aids longer, and gets more experience with difficult listening situations.

Memory three adjusts the frequency response as well as engaging the directional microphone. This suggests that the subjects prefer change in frequency response and not just the directional microphone when listening in noise.

Hypothesis #2

The option for the PZ hearing aid, programs 1,2 and 3 were combined and analyzed as one option. The PZ hearing aid was then compared to the subjects own aids. The preference for the PZ hearing aid increased, as shown in figure 2. There were 15 items where the PZ was preferred, and only one question where the subjects' own aids were preferred. This may suggest that the users prefer the versatility that comes with using the Power Zoom, or that there are various other aspects of the PZ that the subjects found desirable.

Hypothesis #3

In hypothesis three, the directional settings were compared to all omnidirectional settings. This means that the users own aid and memory one of the Power Zoom were grouped together, and compared against memories two and three of the Power Zoom.

When program 2 and program 3 are combined, the preference for directional microphones becomes less than the preference for the PZ alone. This would indicate that the frequency response adjustment was an important factor. Adding the directional microphone without the frequency response adjustment decreased the preference.

It has been suggested that the preference for directional microphones is affected by how often the person communicates in noise (Mueller, Grimes and Erdman et al, 1983). According to this study a strong preference does not develop unless the person spends more than half the day in noise. If the subject communicates in noise only two times a week, for a total of one hour, it would not be expected that a strong preference for the directional microphone would develop. Choosing a population that often communicated in noisy situations may increase the preference for the directional microphones

Hypothesis #4

In hypothesis four the comparison was between only those subjects who preferred the Power Zoom were considered. The two directional settings were compared to the omnidirectional setting. Results showed a preference for the directional microphone in

two of the difficult listening situations. Again, there were several difficult situations where there was no preference for the directional microphone.

Conclusion

This survey indicted that:

- There was a subjective preference for Power Zoom setting #3 when compared to all other categories. This validates hypothesis #1
- There was a subjective preference for the Power Zoom in comparison to the subjects' own aids. This validates hypothesis #2.
- There was a subjective preference for the directional microphone setting when compared to the omnidirectional setting in a limited number of the difficult listening situations. This validates hypothesis #3.
- There was a preference in at least one of the difficult listening situations for those subjects who preferred only the Power Zoom. This validates hypothesis #4.

Suggestions for further research

These results should be interpreted with caution, due to several factors. The subjects did not use the PZ hearing aid for very long, and may not have experienced some of the situations asked about. A possible way to eliminate this flaw would be to poll each subject on which difficult listening situations they encounter and develop a more individualized questionnaire.

These results did show that the users had a preference for the directional microphone in some of the noisy situations. It would be interesting to see if users with a lesser degree of hearing loss had a preference for the directional microphone in more of the noisy situations. One way to determine this would be to do a similar study with the Phonak Micro Zoom, and have the subjects fill out the Washington University

Questionnaire. This may let us know if the degree of hearing loss truly has an influence on how much benefit is subjectively perceived when using the directional microphone in noisy situations.

Lastly, adjustment issues may have influenced the results of the questionnaire. The users were not only getting used to using a directional microphone for the first time, they were also getting used to a brand new hearing aid. One possible way to combat this would be to give the subjects the Power Zoom for a period pf time without activating the directional microphone option. Then, when the users are accustomed to this new hearing aid, activate the directional microphone carry out the study.

As mentioned above, it did seem that the users preferred the directional microphone in some settings. It is apparent that the implementation of a directional microphone for use in the severe to profound population is an area that holds promise and warrants further study.

References

Ricketts, T., & Mueller, G. (1999). Making sense of directional microphone hearing aids. *American Journal of Audiology*, 8(2), 117-127.

Sung S.G., Sung R.J., & Angelli A.(1975). Directional microphone in hearing aids: effects on speech discrimination in noise. *Arch Otolaryng*, 101: 316-319.

Valente M., Fabry, D. A., & Potts, L. (1995). Recognition of speech in noise with hearing aids using dual microphones. *Journal of the American Academy of Audiology*, 6, 440-449.

Madison, T. & Hawkins, D (1983). The signal -to-noise ratio advantage of directional microphones. *Hearing Instruments*, 34(2), 18,45.

Hawkins, D. & Yacullo, W. (1984). Signal-to-noise ratio advantage of binaural hearing aids and directional microphones under different levels of reverberation. *Journal of Speech and Hearing, 49*, 278-285.

. Wouters J. Litiere L. van Wieringen A. (1999) Speech intelligibility in noisy environments with one- and two-microphone hearing aids. *Audiology. 38(2), 91-8*

Preves DA., Sammeth CA., & Wynne MK.(1999). Field trial evaluations of a switched directional/omnidirectional in-the-ear hearing instrument. *Journal of the American Academy of Audiology. 10(5), 273-84.*

Dillon H. & Storey L. (1998). The National Acoustic Laboratories' procedure for selecting the saturation sound pressure level of hearing aids: theoretical derivation. *Ear & Hearing. 19(4), 255-66.*

Kuk, F. (1996) Real world consumer satisfaction with a user-controlled, multiple microphone communication system. *Phonak Focus 22,* 2-6.

Mueller, G. Grimes, A. & Erdman, S. (1983) Subjective ratings of directional amplification. *Hearing Instruments* 34(2) 14-16,46-48.

Staab, W. & Lybarger, S. Characteristics and use of hearing aids. In Katz, J, Ed. Handbook of Clinical Audiology, 4th edition Baltimore: Williams and Wilkins, 1994.