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Evaluating the directional effects of acoustic horn style hearing aids using the QuickSIN procedure

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Evaluating the Directional Effects of Acoustic Horn Style Hearing Aids Using the Quick SIN Procedure

by

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ABSTRACT

Acoustic horns are historical devices that served to enhance hearing in those with a slight to mild hearing loss. The two devices used in this study were the London Dome and the Cupped Hand. To evaluate the directionality of these devices the Quick SIN (Speech in Noise) method was used. The Quick SIN is an adaptive test used to measure signal-to-noise ratio loss. It has been found that this test is an effective measure of the directionality of hearing aids. The same principles were employed to evaluate the directional effects of both the London Dome, Cupped Hand and unaided conditions. The evidence of this study proved that both devices enhanced the directional properties of the ear. Though both devices provided benefit, the London Dome provided more and the subjects preferred this device to the Cupped Hand and unaided conditions.

INTRODUCTION

People with hearing loss often visit an audiologist with the objective of achieving optimal hearing performance through amplification. Their most common complaint is "I can't understand speech in noisy environments." Through improvements in microphone technology, strides have been made to magnify the success of hearing aids. Microphone designs have strengthened the ability of hearing aids to perform well in noise, but the performance is nowhere near perfection. Duel and directional microphone designs aid a great deal in improving speech recognition in noise, but cannot tackle the lofty task of creating a perfect listening experience. It may be useful, therefore to include a demonstration during a hearing aid consultation session that would help foster realistic expectations for the patient.

Quick SIN Test

The Quick Speech In Noise (Quick-SIN) test was used in this study (Etymotic Research, 2001). It is an adaptive test used to measure signal to noise ratio loss. Both the speech signal and the noise can be modified to change the signal to noise ratio until a threshold of intelligibility is reached (50% performance). It can be applied in the clinical setting in three ways; diagnosing signal to noise ratio loss (SNR), demonstrating aided audibility in noise, and assessing directional-microphone benefit (Taylor, 2003). This test measure maybe helpful in allowing the audiologist to demonstrate the directional effects of the hearing aids to the patient. The test may also be helpful in selecting patients who would benefit from directionality and be predictive about patient preferences.

This study was designed to evaluate the Quick SIN's ability to evaluate directional effects of hearing aids. Previous studies have shown that speech perception tests can predict patients real world preferences when the differences between hearing aids is significant (Walden, 1998). The problem Walden (1998) encountered was that the test error tended to be large in ration to the difference between aids. Table 1 the scores obtained from a single list are within 2.7 dB of the patients "true" score with a 95% confidence level. As the number of lists presented increases, this number (in dB) decreases creating an even smaller margin. The SNR loss is a very useful measurement, that cannot be predicted from the audiogram (Killion & Niquette, 2000). One possible use of the test would be to measure the SNR loss of patients and recommend directional microphones for those with significant losses. The present study will ask (1) Do patients show reliable results on repeated measurements? (2) Are the results predictive of the subject's perception? And (3) What is the rage of SNR loss measured for normal ears under clinical conditions?

Historical Hearing Devices

Central Institute for the Deaf maintains a hearing aid museum. Data has been collected on some of the historic hearing devices to quantify their gain characteristics. The two devices selected for this study were the *Cupped Hand* and the *London Dome.* Previous studies have shown that both provide a significant amount of gain in the mid frequency region. The frequency response of the *Cupped Hand* is shown in Figure 1 and the frequency response of the *London Dome* is shown in Figure 2. A recent study reveal that the *Cupped Hand* and *London Dome* provided approximately 5 and 16 dB,

Table 1 Confidence intervals for number of lists

Number of lists=	1	2	3	4	5	6	7	8	9
95%C.I.±	2.7	1.9	1.6	1.4	1.2	1.1	1.0	1.0	0.9
80%C.I.±	2.2	1.6	1.3	1.1	1.0	0.9	0.8	0.8	0.7

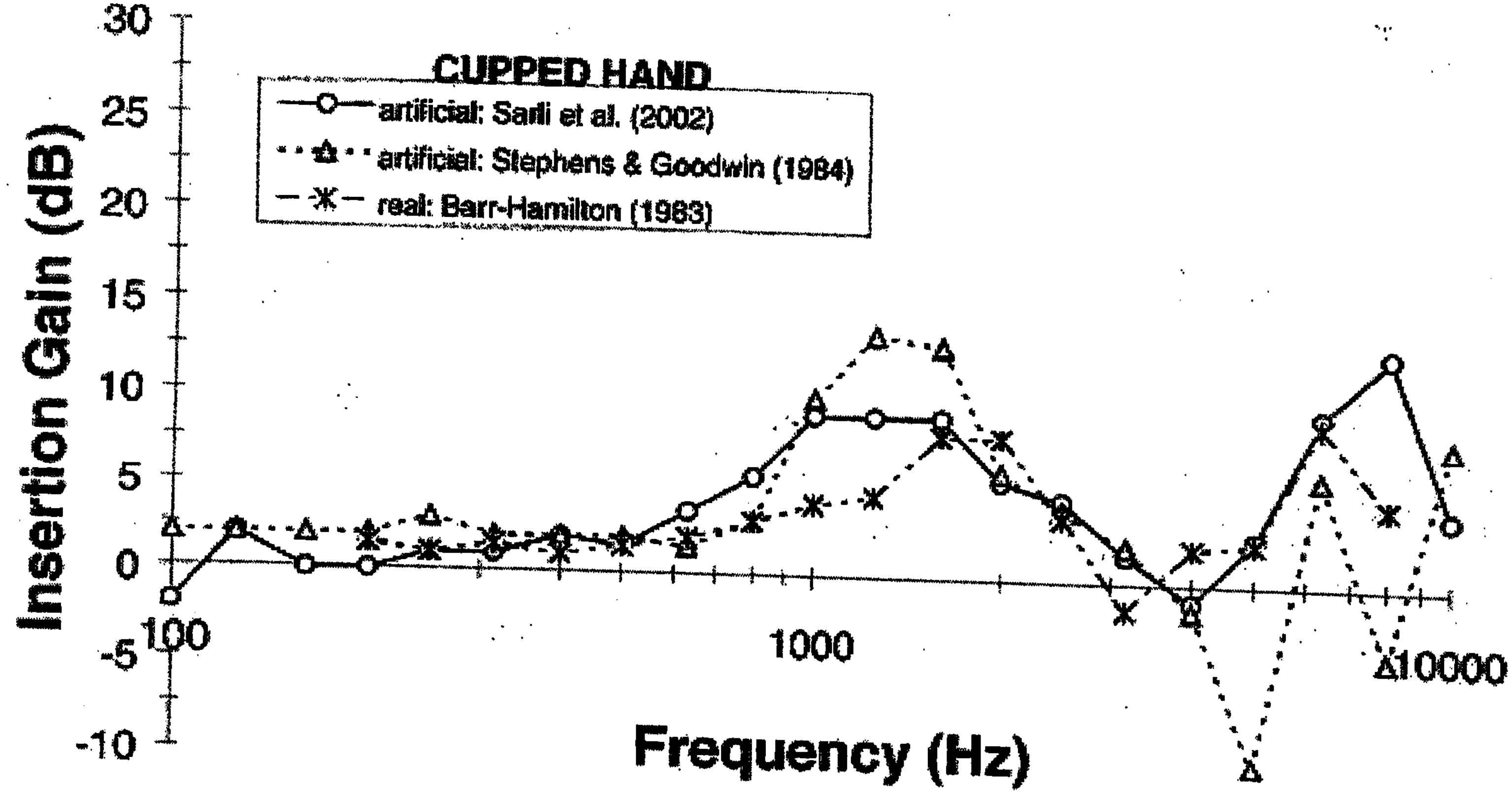

Figure 1 Insertion gain and frequency response of Cupped Hand

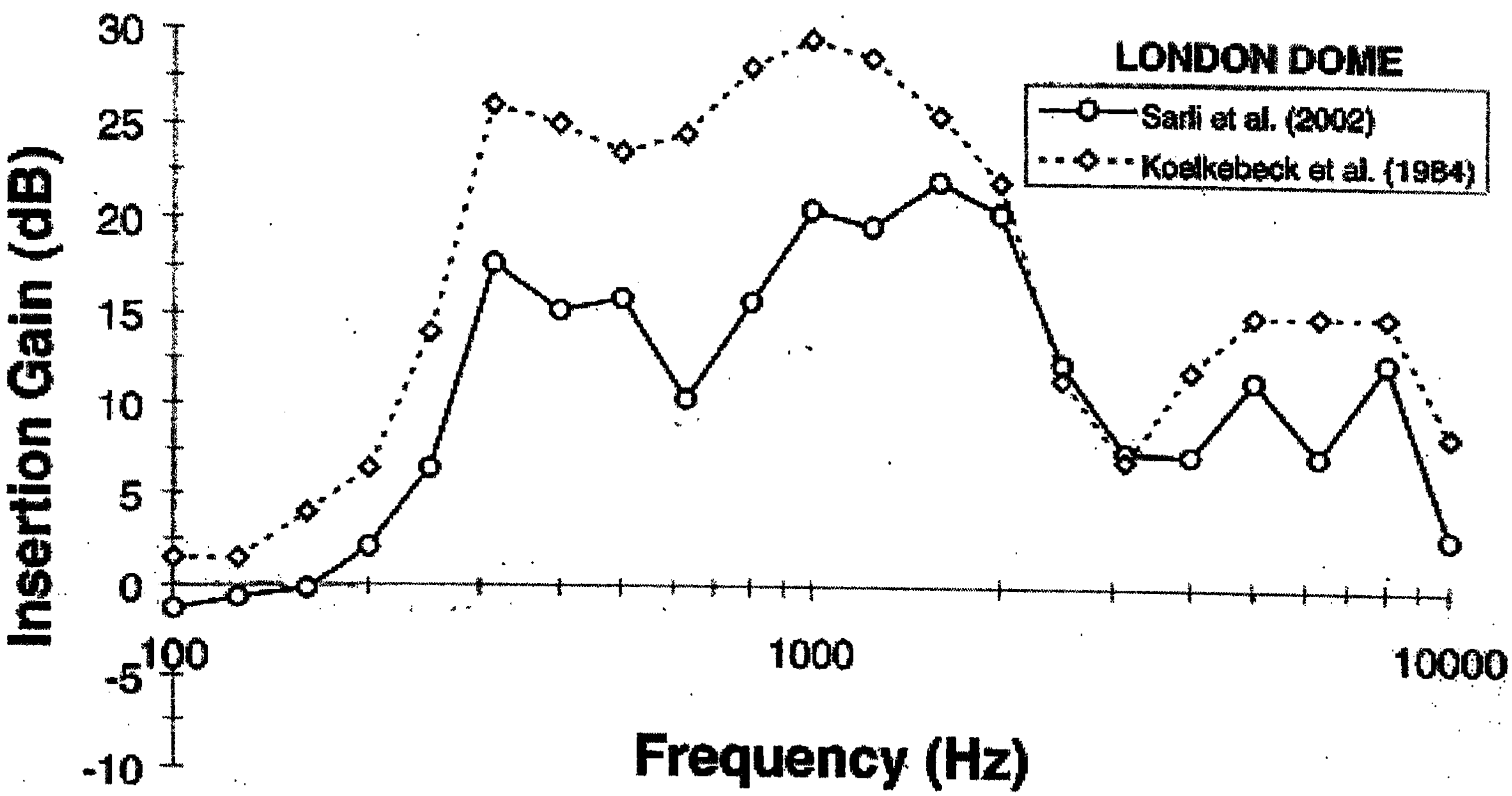

Figure 2 Insertion gain and frequency response of the London Dome

respectively, of average insertion gain in the frequency region of 300-3000 Hz (Sarli et al, 2002). These devices would best benefit a person with a slight to mild hearing loss.

A secondary purpose of this study is to examine the directional effects of acoustic horns using the Quick-SIN method. This was done in part to add information about the historical devices in the CID museum. The questions were (1) Do acoustic horns enhance the directional properties of the ear? and (2) Does the style of horn affect its directional properties?

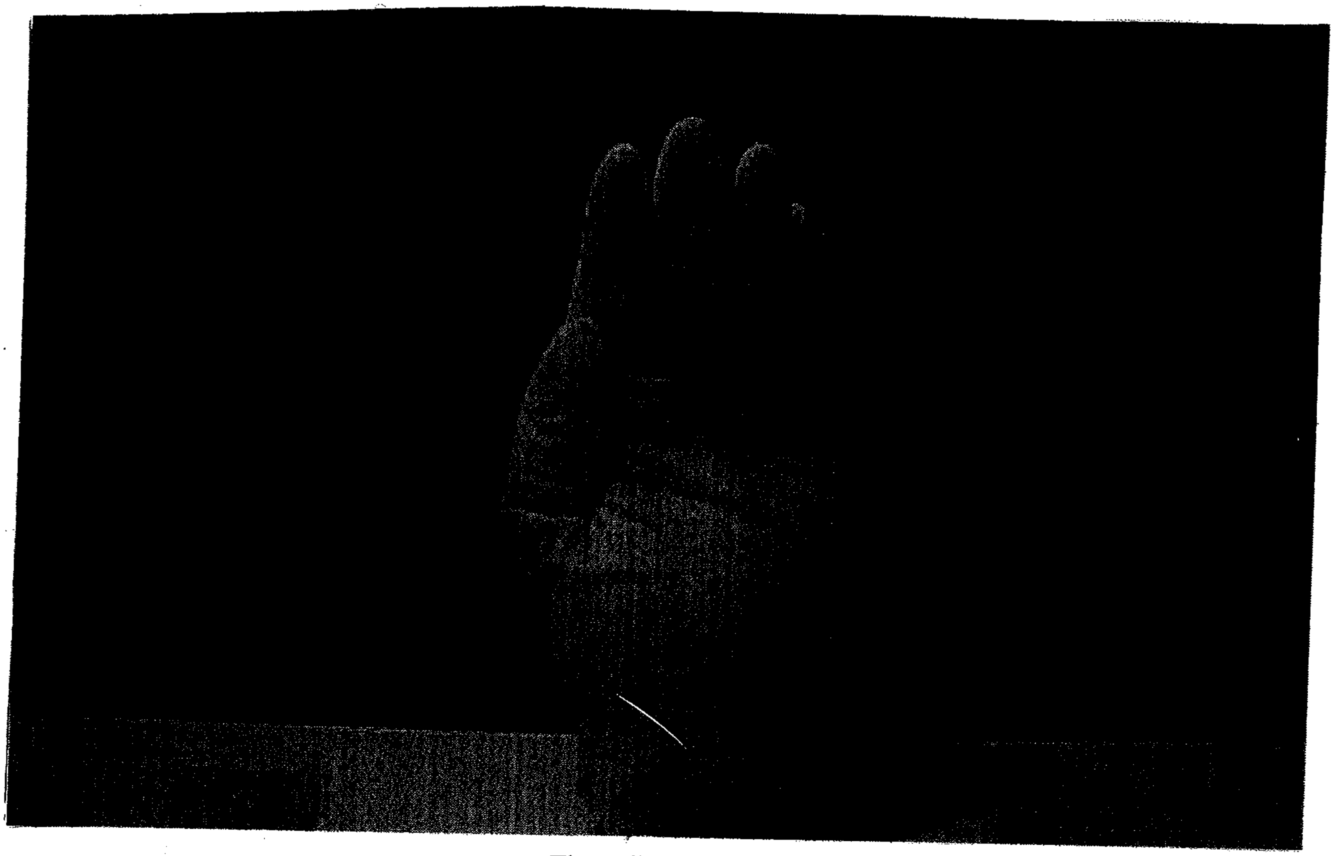

Figure 1-*Cupped Hand*

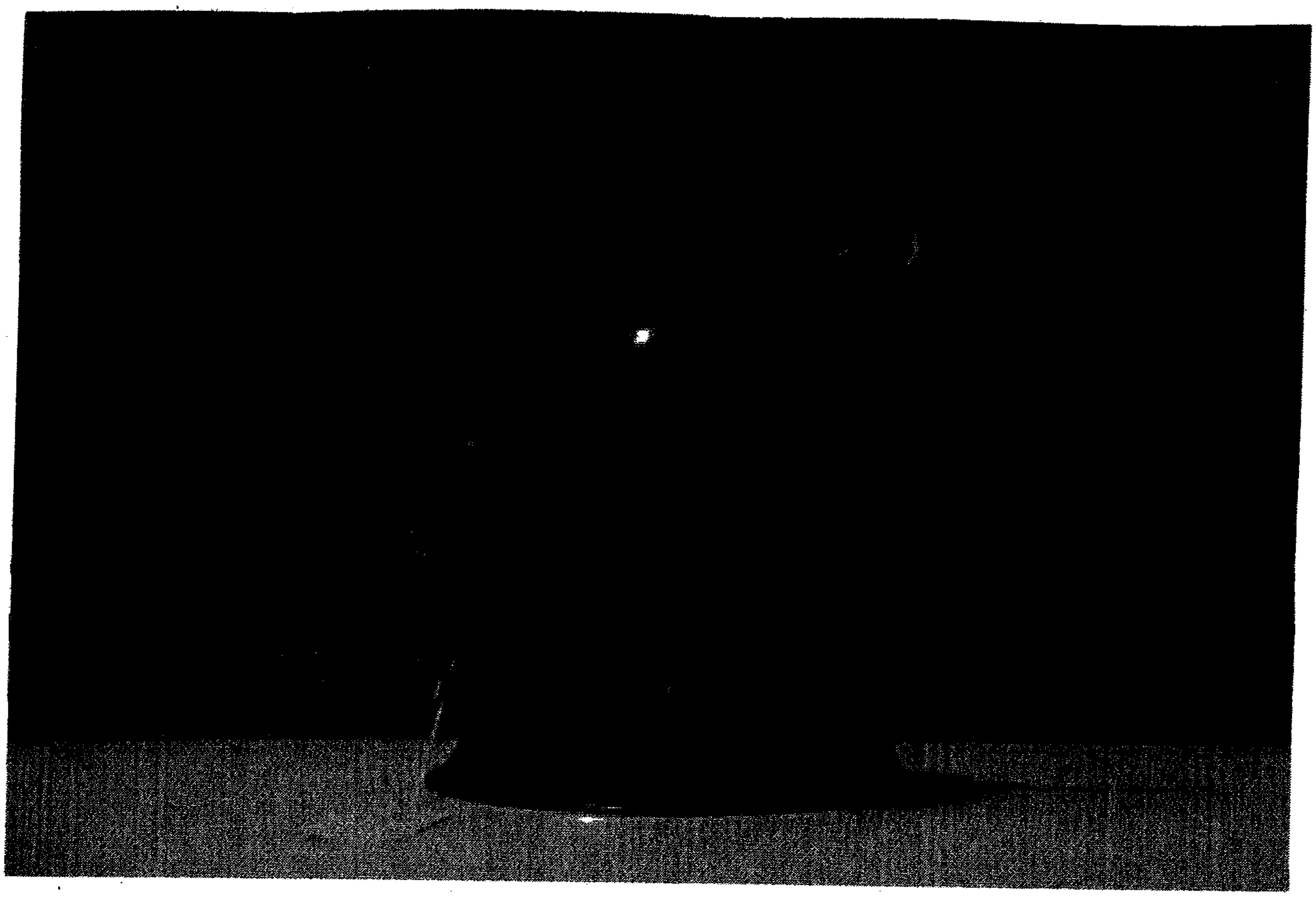

Figure 2-*London Dome*

PROCEDURES

Subjects

Fifteen subjects age 21-30 years old participated in this study. There were one male and 14 females, and all subjects had normal hearing thresholds at 250, 500, 1000, 2000, 4000, and 8000 Hz. The majority of the subjects were graduate students at Central Institute for the Deaf. Only one subject was not a student.

Hearing Devices

The three listening conditions used were unaided, *Cupped Hand*, and *London Dome*. The unaided condition served as a reference point to judge the effect of the two hearing devices. The *Cupped Hand* was an artificial hand constructed by following the protocol of a prior study (Carraway, 2001). First, a latex surgical glove was filled with Crayola Model Magic molding clay. The constructed hand was then molded to fit the dimensions of a large man's hand- 0.24m long (base of palm to the tip of the middle finger) and 0.10m wide across the palm (Carraway, 2001). A picture of the constructed artificial Cupped hand can be seen in Figure 1. The third listening condition involved the use of the *London Dome*. F.C. Rein designed this device in 1850. The *London Dome* is a metal, bell shaped horn that is 0.24m high, 0.21m wide, 0.20m deep, and weighs 0.90 kg (Carraway, 2001). It is held by the listener using a handle on the side of the device and placed at the peripheral end of the external auditory meatus (See Figure 2).

Test Room and Materials

The test room was set up as recommended by the Etymotic Research Company (Etymotic Research, 2001). The subject was first positioned in the booth so that speech was presented through a front speaker at a 45-degree angle and noise from a rear speaker at a 135-degree angle (See Figure 3). To achieve these angles the room was first measure in length from corner to corner (116.5 in), The distance is then divided in half (54.25 in). The precise spot lies 54.25 inches perpendicular to the mid point. This spot was then mark to ensure that both angles where kept constant.

The Quick SIN Test is a keyword sentence test. The sentences in each list are presented simultaneously with four-talker babble. Each sentence contains five key words that are used to calculate the SNR loss. The loudspeakers were calibrated using tract one on the compact disc containing test materials. The signal and noise were then simultaneously presented via two channels. The signal was set at 50dB and the noise was initially set at 35dB. Following the completion of a sentence, the noise is then increased in five dB steps until the list was complete. This created a more adverse listening situation as testing progressed. The number of key words that the listener correctly repeated were recorded and a tally of correct responses were obtained from the six sentences. This number was then subtracted from a reference of 25.5dB to find the SNR. Table 2 illustrates the degrees of SNR loss (Etymotic Research, 2001).

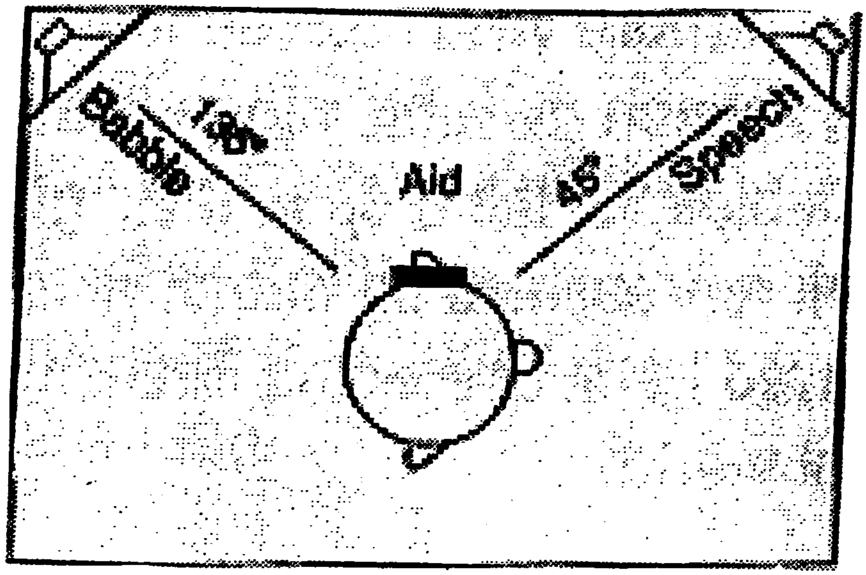

Figure 3 Schematic drawing of test room layout

Table 2 Degrees of SNR loss

SNR Loss	Degree of SNR Loss	Expected Improvement with Directional Mic
0-2 dB	Normal/near normal	May hear better than normals hear in noise
2-7 dB	Mild SNR loss	May hear almost as well as normals hear in noise
7-15 dB	Moderate SNR loss	Directional microphone help. Consider array mic
>15 dB	Severe SNR loss	Maximum SNR improvement is needed. Consider FM

RESULTS

The measurements made in this study indicate the signal-to-noise ratio at the threshold of intelligibility (SNR). The SNR's for each subject across conditions are shown in Table 3. Figure 3 shows the mean performance (in SNR) across listening conditions. A two-factor Analysis of Variance (ANOVA) indicated a significant difference among the three listening conditions ($F=37.39$, $DF=2.00$, $P<0.0001$). The unaided condition needed significantly better signal-to-noise ratios to reach threshold than both aided conditions. Although both aided conditions helped the listeners, the data revealed that the *London Dome* (SNR=-2.6) enhanced performance more than the *Cupped Hand* (SNR=.43).

This study required the subject to listen in each of the conditions twice. To ensure that there was no learning effect from the first presentation to the second, the data was analyzed further. The ANOVA was used to compare the first and second presentation with the devices. Data showed that the presentation order did not, in fact, significantly alter the subjects' performance ($F=0.03$, $DF=1.00$, $P=0.85$) and there was no interaction between the two presentations ($F=0.30$, $DF=2.00$, $P=0.73$). Figure 4 shows subject performance with first and second presentation (with standard deviations) and Figure 5 displays subject performance with first and second presentation as a function of listening conditions (with standard deviations). A supplemental Pearson Product-Moment Correlation was performed between Test 1 and Test 2 that combined all conditions. The data revealed that there was no relation from one list to another. The value was 7,390.6.

Subjects were asked which of the three listening conditions provided the most benefit and why. The data revealed that 93% of subjects (14 out of 15) preferred the

Table 3 SNR scores across conditions

Subject	Unaided-1	Unaided-2	Unaided Average	Cupped Hand-1	Cupped Hand-2	Cupped Hand-Avg	London Dome-1	London Dome-2	London Dome-Avg
1	5.5	3.5	4.5	-1.5	-0.5	-1	-2.5	-1.5	-2
2	5.5	1.5	3.5	-1.5	-2.5	-2	-5.5	-3.5	-4.5
3	2.5	2.5	2.5	-0.5	-6.5	-3.5	-7.5	-1.5	-4.5
4	0.5	7.5	4	-3.5	-3.5	-3.5	-3.5	-1.5	-2.5
5	1.5	2.5	2	0.5	-0.5	0	-5.5	-3.5	-4.5
6	5.5	3.5	4.5	2.5	2.5	2.5	-0.5	-1.5	-1
7	5.5	3.5	4.5	1.5	-0.5	0.5	0.5	0.5	0.5
8	5.5	-0.5	2.5	-1.5	1.5	0	-5.5	-3.5	-4.5
9	3.5	1.5	2.5	-2.5	-5.5	-4	-5.5	-4.5	-5
10	3.5	5.5	4.5	0.5	1.5	1	1.5	1.5	1.5
11	1.5	3.5	2.5	5.5	0.5	3	-1.5	-0.5	-1
12	0.5	3.5	2	0.5	4.5	2.5	-4.5	-4.5	-4.5
13	3.5	6.5	5	3.5	5.5	4.5	-4.5	-6.5	-5.5
14	7.5	10.5	9	-0.5	-1.5	-1	-3.5	-3.5	-3.5
15	5.5	6.5	6	7.5	7.5	7.5	3.5	-1.5	1

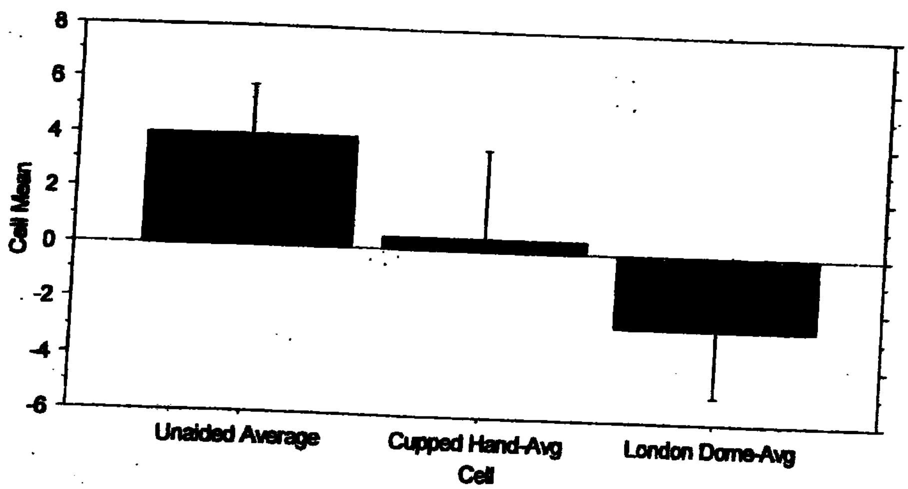

Figure 3 Mean performance across listening conditions

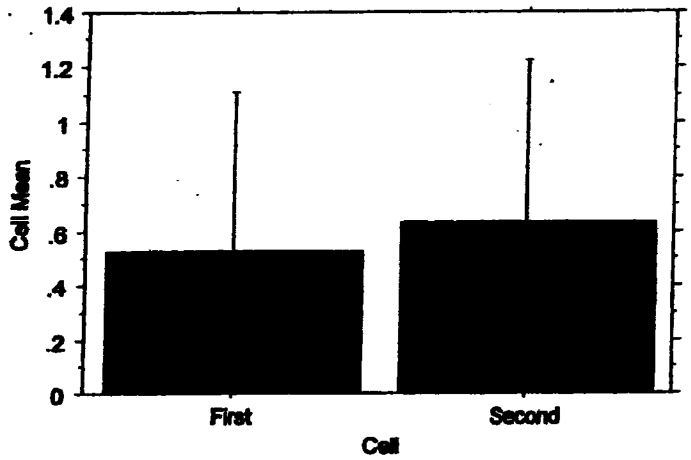

Figure 4 Performance during 1st and 2nd presentation

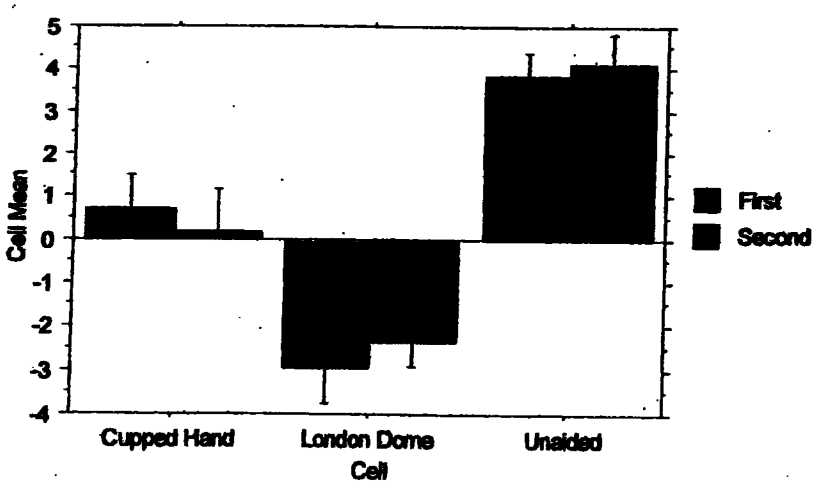

Figure 5 Mean performance across listening conditions

London Dome to both unaided and *Cupped Hand* conditions. Eighty-six percent (13 out of 15) of the subjects agreed that the London Dome " separated" the sentence form the noises better than the other two conditions. Listeners also noted that while the *London Dome* helped more, it was heavy and created an echo while listening.

The data was able to predict the subject preferences. All subjects performed better with *London Dome*. On average 80 % of the subjects performed better with the *Cupped Hand* as compared to 100% improvement with the *London Dome*. This improvement was measured using the 95% confidence interval (C.I.) in Table 1 (1.9dB for two lists).

Of the fifteen subjects, 13 showed a SNR loss. Although all were normal hearing, the SNR loss calculation was altered to create more adverse listening conditions. The data revealed that the *Cupped Hand* reduced the SNR loss in all but one of the subjects. The *London Dome* reduced the SNR loss for all fifteen subjects.

DISCUSSION

Limitations of Study

Only subjects with normal hearing were included in this investigation. This limitation was placed, in part, because the evaluation was use to measure the true performance of each device within a homogeneous group of subjects with regard to SNR loss. Further study may indicate that the aided benefit interacts with the degree of SNR loss.

Age was a controlled factor in this investigation. The listeners in this study ranged from age 21-30. It has been documented that there is a decline in speech recognition as age increases (Gordon-Salant & Fitzgibons, 1995 and Helfer & Wilber, 1990). The finding in this study may not be indicative of those for an older population of adults. That is, the devices may not provide the same amount of benefit with age.

The practical use of both devices is limited. Both would best benefit those with no more that a mild hearing loss. The *London Dome's* "bulkiness" also limits its practical use. Although the technology is different from modern hearing aids, the directional effect of the *London Dome* (6.5dB), is similar to that measured with directional microphones in audiometric test rooms. Many of our observations about the test procedure, therefore, may also apply to modern hearing aids with directional microphones.

Sometimes the subjects' performance or opinion can be influenced by his knowledge or expectations of the condition s to the experiment. In the current study, there was no way to present the three aided conditions in a blinded manner.

<u>Observations about Quick SIN</u>

The Quick SIN can demonstrate the improved directionality based on group data. The *London Dome* showed a 6.5dB average improvement in the SNR loss compared to the unaided condition and 3.5dB compared the *Cupped Hand.* The ANOVA test indicated this was a significant improvement, and the average improvements for the *London Dome* were greater than the values for significant differences shown in Table 1. The reduced SNR loss corresponded to a 93% subjective preference of the *London Dome.*

Individual differences were also predictive of subject preference. Of the 14 subjects who preferred the *London Dome* to the *Cupped Hand,* 13 had reduced SNR loss using the *London Dome*. One subject's SNR remained the same, but also chose the *London Dome*. Only one subject preferred the *Cupped Hand.* This subject's SNR increased with the use of the *London Dome*.

The data indicates that the differences in SNR values need to be greater than in Table 1 to shown a significant difference between conditions. The test-retest standard deviations were 3.9dB. The 95 % confidence interval would be significantly wider that indicated by Killion (2000).

The SNR calculation was altered to make certain that it accurately calculated the SNR for a normal hearing subject. The original calculation used 25dB as the highest SNR plus 2.5dB. The 2.5dB is the half of the step size of the audiometer (5dB). This yields a total of 27.5 dB. An additional 2dB is then subtracted along with the total number of word correct in a sentence (27.5-(total words correct)-2dB). Since the subjects were normal hearing the total number of word correct were subtracted by 20.5dB. This number was derived from the highest SNR used.

Compared to the data in Table 2, "normal" should not be a SNR loss of 0 to 2 dB. The data reveal the "normal" subject may have a SNR loss much greater the 2dB. Of the 15 subjects with the average unaided condition, only one subject was within this norm. Fourteen of the participants had a SNR loss greater than 2dB.

<u>Observations About Devices</u>

This investigation found that the subjects performed better with the *London Dome.* There are several possibilities why this happened. The larger size of the London Dome allowed the collection of more sound and captured and funneled more to the ear than the Cupped Hand. The impedance differences of metal versus clay played a role in the improvement. More sound was reflected then funneled by the metal of the London Dome. The head shadow effect also had an impact on the speech recognition of the listener. A study reported 23% reduction in word recognition between direct and indirect listening (Nordlund and Fritzell, 1963). The effects of head shadow are most noticeable in those who only wear one hearing aid (much like the participants in this study). Body baffle results from low frequency emphasis created by the body. It provided a boost in low frequencies and reduces higher frequencies important for speech. The amplification occurred around 500Hz and the attenuation near 2000 Hz (Katz, 2002).

The unaided condition did provide the listener some benefit. The physical characteristics of the pinna are much like that of both the *Cupped Hand* and the *London Dome.* Its purpose is to collect sound and direct it into the ear. During the collection, modifications of spectral composition of sound are made. The resonant frequency of the pinna is between 2-7kHz (Katz, 2002)

SUMMARY

The three conditions compared in this study were the *London Dome, Cupped Hand,* and unaided. The *London Dome* proved to provide the most directional benefit. It significantly decreased the SNR. The *Cupped Hand* then provided the listener with significantly greater directional benefits over the unaided condition. All three conditions were significantly different from each other and there was no learning effect between the lists presented.

Patients preferred the *London Dome* in this study. This is probably due to the fact that it provided them with the most directional benefit. Although the *London Dome* was favored, patients commented on its weight and lack of aesthetic appeal.

This study provides a glimpse into the history of amplification. It paired the use of older amplification devices with new methods of testing. The information derived from this study shows the effectiveness of amplification devices of the past and can provide insight into the technology of the future.

ACKNOWLEDGEMENTS

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