SIGNAL-TO-NOISE-RATIO COMPARISON OF A DIRECTIONAL MICROPHONE ON THREE HEARING AID SIZES

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INTRODUCTION

As today's instruments become smaller, the possible location of the microphones and/or receiver may become more restricted compared to a more traditional sized instrument. With these changes, a concern may be the effect of microphone placement on directional performance. As the angular deviation of two microphones on the horizontal plane increases, the directivity index decreases as shown in Figure 1. The deviation in microphone alignment needed to be approximately 30^0 for the directivity index to decrease by 1 dB. Beyond an angular deviation of 35^0, the directivity index decreases more rapidly (Kuk et al, 2007). For some manufacturers, additional processing within the instrument beyond the microphone stage has been implemented in order to offset the deviation in the microphone angle from the horizontal plane of new micro sized or nano sized instruments. Therefore, the purpose of this study was to compare the performance of a more traditional-sized mini BTE to the performance of new micro sized and nano sized receiver-in-canal (RIC) instruments where the microphone placement may be different than in the traditional BTE.

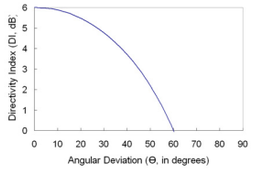

Figure 1: Theoretical relationship between directivity index (y-axis) and angular deviation of microphone alignment (x-axis) from the horizontal plane

Objective

To measure microphone angle and evaluate the SNR performance of a directional microphone in three different hearing aid sizes: a mini BTE (IN-9), a micro BTE (IN-m) and nano-size receiver in the canal (PA-115) instrument.

KEY INTEO FEATURES

The hearing instruments in this study all utilize Integrated Signal Processing (ISP) to achieve their desired functions. The readers are referred to Kuk (2006 – ISP supplement) for a detailed description of the various features. This section will cover a brief review of the key features that were examined in this study.

The instruments, shown in Figure 2, included:

- a receiver in the canal instrument (PA-115)
- a micro BTE (IN-m)
- a traditional mini BTE (IN-9)

Figure 2: Hearing aids used in study with open fit option: PA-115, IN-m, IN-9

1. ***High definition Locator*** – A 15-channel, fully adaptive dual-microphone system that can switch its polar pattern in each of its 15 channels from an omni directional mode to a bi-directional mode and any polar patterns in between. In addition, it has a speech preservation mechanism that maintains the omni directional mode when speech is presented.
2. ***Classic noise reduction*** – A 15-channel noise reduction algorithm that uses a patented "level-distribution function" analysis to differentiate between speech and noise inputs. Once noise is identified, gain in the specific channel is reduced depending on the input level, signal-to-noise ratio measured in that channel, as well as the importance of that channel to overall speech intelligibility.
3. ***Speech enhancer*** - The Speech Enhancer is another "noise reduction" algorithm that calculates the Speech Intelligibility Index (SII, ANSI-1997) of any noisy environment and adjusts its settings so that the SII is maximized without reaching discomfort. The goal is not only to improve comfort in noise but also to provide the best possible speech intelligibility for the patient while considering the input (speech spectrum **and** noise spectrum) and the wearers' hearing loss.

METHOD

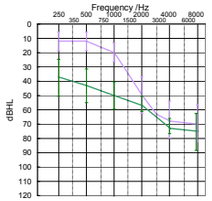

Figure 3: average audiogram for closed mold group in green and average audiogram for open fittings in purple

Subjects

Two groups of hearing impaired listeners.

- Group 1 (N=10): hearing loss greater than 30 dB HL at 500 Hz used a closed mold
- Group 2 (N=9): hearing loss better than 30 dB HL at 500 Hz used an open fit option
- 13 males and 6 females
- All subjects had previous hearing aid experience
- All participants were native English speakers

Hearing Aid Test Conditions

Each instrument was tested under six different microphone options:
1. omni directional with no noise reduction: (omni alone)
2. omni directional with classic noise reduction: (omni + NR)
3. omni directional with the Speech Enhancer: (omni + SE)
4. adaptive directional microphone (Locator) with no noise reduction: (Loc alone)
5. adaptive directional microphone (Locator) with classic noise reduction: (Loc + NR)
6. adaptive directional microphone (Locator) with the Speech Enhancer: (Loc + SE)

Evaluation Set-Up

The HINT (Hearing In Noise Test) was modified so that the speech-shaped noise was continuous and its level was fixed at 75 dB SPL-C. The speech stimulus was presented from the front loudspeaker at 0ºazimuth, while the noise stimulus was delivered from three loudspeakers at 90º, 180º, and 270º, each one meter from the subject.
The hearing aid test order and microphone options were tested in a counterbalanced fashion to minimize order effect.
To determine the angle formed by the microphones relative to the horizontal plane, an angle linear ruler with an attached level meter was used. The subject was instructed to sit in the test chair in a comfortable position and to hold their head in a typical position as if they were having a conversation with someone. The opening of the hinge between both sides of the ruler was positioned over the back microphone of the instrument. The bottom of the ruler was level to the horizontal plane. The line of the top ruler was then positioned to align with the front microphone opening.
Each subject was seen on two, two-hour visits where the IN-9 was tested with either the IN-m or the PA-115.

RESULTS

Microphone Angle

A bar graph of the average microphone angle (right and left averaged together) was shown in Figure 4.

- The average microphone angle for the IN-9 was 13 degrees, 29 degrees for the IN-m and 32 degrees for the PA-115.
- A repeated-measures ANOVA indicated that the microphone angle difference was significant between the IN-9 and the IN-m and PA-115 ($p<0.001$) but the angle difference between the IN-m and the PA-115 was not significant ($p>0.8$).

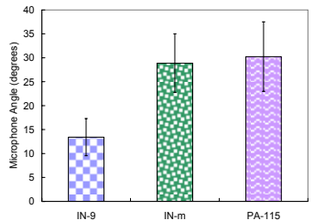

Figure 4: Average microphone angles for IN-9, IN-m, and PA-115; right and left ears averaged together

RESULTS (cont.)

Absolute performance in noise

The average absolute SNR performance on the HINT using a closed mold fitting was shown in Figure 5 and an open fitting in Figure 6. Some observations were:

- In order to obtain 50% correct on the HINT, the omni directional settings required a higher signal-to-noise ratio than with the Locator microphone settings:
  - omni directional
    - ≥4 dB with a closed mold
    - ≥2 dB with an open fit.
  - Locator microphone
    - ≤1 dB with a closed mold
    - ≤1 dB with an open fit
- Best signal-to-noise ratio performance for all three hearing aid sizes was obtained with the Locator microphone plus Speech Enhancer.
- Performance was similar across hearing aid models for each test condition. A repeated-measures ANOVA indicated that hearing aid size was not significant. In other words, performance between the three hearing aid sizes was essentially the same; the microphone angle did not make a difference.
  - p=0.21 with a closed mold
  - p=0.41 with an open fit
- On average, the signal-to-noise ratio required for 50% correct on the HINT decreased for all three hearing aid models as additional processing was added.

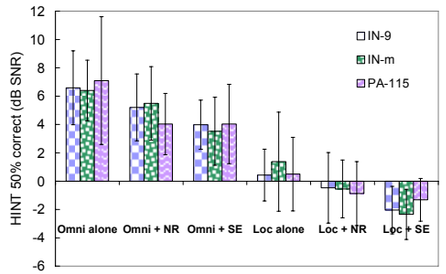

Figure 5: Average closed mold absolute performance on HINT for each hearing aid model

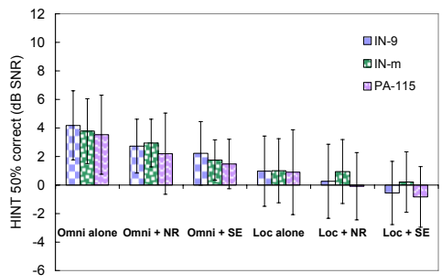

Figure 6: Average open fit absolute performance on HINT for each hearing aid model

RESULTS (cont.)

Feature Benefits

The benefit of additional hearing aid features was calculated for each instrument by subtracting the performance of each hearing aid test condition from the omni directional performance with no noise reduction. The results obtained with a closed mold were shown in Figure 7 and with the open fit in Figure 8. Some observations from these performance differences were:

Locator Benefit:

- Directional benefit alone (Loc alone) for all three hearing aid sizes:
  - 6 dB with a closed mold
  - 3 dB with an open fit.
- A repeated-measures ANOVA indicated that directional benefit was significant ($p<0.001$) in all three hearing aid sizes for Loc alone, Loc + NR, and Loc +SE (closed mold and open fit).

Speech Enhancer Benefit

- With the addition of the Speech Enhancer to the directional mic (Loc + SE) benefit improved:
  - 8.5 dB with a closed mold and
  - 3.5-4 dB with an open fit.
- When adding the Speech Enhancer to an omni directional mic (omni + SE), the benefit was
  - 3 dB with a closed mold
  - 2 dB with an open fit.
- A repeated-measures ANOVA indicated that benefit with the Speech Enhancer was significant ($p<0.001$) for Loc + SE and omni + SE.

Noise Reduction Benefit

- The benefit with classic noise reduction was not significant in an open fit and was only significant ($p<0.001$) in a closed mold for the IN-9 and the PA-115.

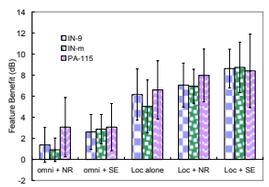

Figure 7: Average Closed Mold Feature Benefit

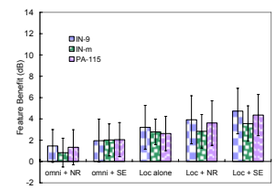

Figure 8: Average Open Fit Feature Benefit

CONCLUSIONS

This study compared the difference in microphone angle and the performance of hearing in noise between three different sizes of hearing instruments: a traditional mini BTE (IN-9), a micro sized BTE (IN-m) and a nano sized receiver in the canal (PA-115). Measurements of the microphone placement revealed a significant difference between the angle of the IN-9 and the IN-m and the IN-9 and the PA-115. However, there was not a significant difference between the microphone angle of the IN-m and the PA-115. The performance in noise evaluation revealed no significant difference in absolute performance between all three instruments regardless of hearing aid test condition. The directional benefit of 6 dB in a closed mold and 3 dB in an open fit was measured for all three models. The similarity among absolute performance and benefit would indicate that the microphone placement did not adversely affect performance in noise.

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