OPENNESS OF FIT AND BENEFIT FROM ADAPTIVE FEATURES

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Introduction

Openness of the coupling between the hearing aid and ear modifies the acoustic properties of a hearing aid fitting. An open-canal hearing aid fitting offers inherent benefits related to comfort and reduction of perceived occlusion for the patient (Jespersen et al., 2006). Contrasting these benefits, the open-canal hearing aid fitting inherently limits attainable low-frequency levels in the ear. There is also a greater contribution of direct unamplified sound that enters the ear when compared to more occluding hearing aid fittings.

Traditionally the open-canal fitting is reserved for patients with mild-to-normal, low-frequency hearing. In contrast, a review of manufacturers' recommended fitting ranges shows that candidacy may extend to patients with low-frequency thresholds reaching 40 dB HL. Because individuals with moderate low-frequency hearing loss may be regarded as poor candidates for open-canal fittings it is of interest to document how they benefit from hearing aid fittings that range in openness of coupling to the ear.

Previous work has shown that increasing vent diameter systematically decreases measured directivity index (DI) (Ricketts, 2000). Extending this observation to behavioral data, several studies have shown reduced directional benefit with increased vent diameter (Kuk et al., 2004; Galster et al., 2012). A second signal processing strategy, digital noise reduction (DNR), has been shown to improve acceptance of background noise (Ricketts & Hornsby, 2005). The plausible interaction between openness of hearing aid fit and benefit from digital noise reduction has not been investigated. It is reasonable to assume that decreased low-frequency levels and increased contribution of direct unamplified sound, associated with increasing openness of fit, may decrease the benefits of digital noise reduction.

The present study aimed to document the comparative benefits of digital noise reduction and directional microphones with increasing openness of fit. A sample of participants with low-frequency thresholds approaching moderate severity were recruited with the expectation that this sample would be sensitive to changes in low-frequency audibility and the changes in contribution of direct, unamplified sound that occur as openness of fit increases.

Methods

Participants

- 10 participants (6 female, 4 male) with mild to moderately-severe sensorineural hearing losses
- Ages ranged from 32-81 years (mean = 64 years)
- Both new and experienced users of hearing instruments were included
- All study participants were fit bilaterally and were seen for a minimum of 2 laboratory sessions

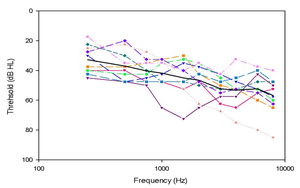

Figure 1: Air conduction thresholds are shown for each of 10 participants. The black solid line shows mean hearing thresholds across participants.

Hearing Aid Selection and Programming

Starkey Wi Series i110 Receiver in the Canal (RIC) hearing aids with three different earmold configurations and a 50 dB peak gain receiver.

- Open silicon dome
- Silicone custom earmold with 2-3mm vent
- Silicone custom earmold, fully occluding

Four memories were programmed for each device. Within each vent condition, per-memory frequency response was matched.

- Omnidirectional mode (DNR disabled)
- Omnidirectional mode with DNR enabled
- Directional mode (DNR disabled)
- Directional mode with DNR enabled

Digital Noise Reduction

A modified version of Starkey's proprietary noise reduction (DNR; Voice iQ2) was used. Modification to the existing algorithm includes removal of a level dependency that affects the amount gain reduction applied as input level increases. In this revised algorithm gain reduction attempts to reach 15dB in all non-speech segments.

Methods (continued)

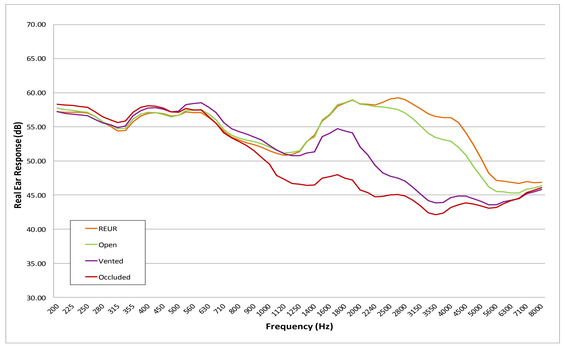

Figure 2. The mean real-ear occluded response is shown as a function of frequency for fully occluded, vented and open-canal fitting conditions across participants. The group mean real-ear unaided response is also shown.

Measures of the Real Ear Occluded Response (REOR) assessed the occluding characteristics of each earmold configuration

- Measures of the REOR were obtained for each vent condition using an Audioscan Verifit and the ISTS at 65 dBSPL

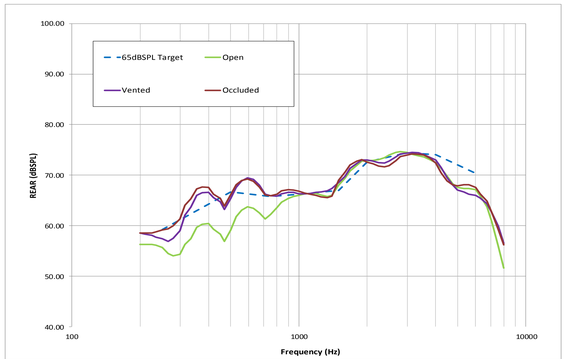

Figure 3. Mean real-ear aided response for all three vent conditions (Open, Vented & Occluded) at 65 dBSPL input in omnidirectional mode with noise reduction turned off. The blue dashed line shows mean DSL v5.0 prescriptive targets for a 65 dBSPL input.

DSL v5.0 adult fitting formula was used for the fitting of each device-mold set

- Real Ear Aided Response (REAR) were performed using the Audioscan Verifit with the International Speech Test Signal (ISTS) at 55, 65 and 75 dBSPL
- Match to prescribed targets for the occluded and vented earmold conditions was fair with a deviation of +/-10 from target
- Match to prescribed targets for the open-canal fitting was consistently below the prescribed target by 5 dB

Test Materials

The Connected Speech Test (CST; Cox, 1987) was administered using a pair of passages (20 sentence) presented at 65 dBA from 0^0 azimuth. The masker was an uncorrelated speech shaped noise presented from seven speakers at 62 dBA.

A modified Acceptable Noise Level (mANL; Nabelek et al., 1991) test was administered for each condition using the Arizona travel log as the speech stimulus in the presence of steady state, uncorrelated speech shaped noise from seven speakers. The mANL scores were based on the average of two runs.

In both behavioral tasks, competing noise was presented continuously with a 30 second period for algorithm adaptation prior to speech presentation.

Results

CST

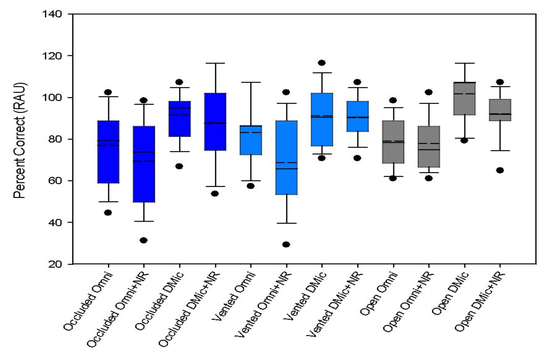

Figure 4: Connected Speech Test (CST) performance in percent correct across participants (N=10) within vent condition (3) across memories. The boxes represent the interquartile range with the mean shown in the dashed line and median in the solid line inside each box. The error bars extend to the maximum and minimum when within 1.5 times the interquartile range. Data beyond this range are shown with individual symbols (black dots).

- RMANOVA analysis for the main effect of venting did not reveal a significant difference ($F(2,9)= 2.154$, p=0.145). Suggesting that changes to openness of a hearing aid fitting did not affect performance.
- RMANOVA analysis for the main effect of memory revealed a significant difference ($F(3,9)= 20.524$, p<0.001). Suggesting that changes in signal processing improved performance.
- The pairwise comparison (Tukey Test) reveals a significant difference for all directional vs. omnidirectional conditions suggesting positive effect of directionality. Similar conditions with noise reduction showed no significant effect (Table 1).

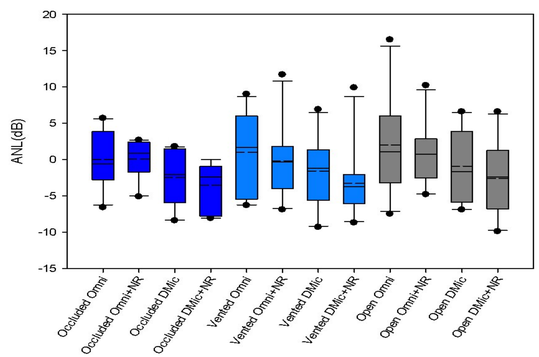

Figure 5: Modified Acceptable Noise Level Test (mANL) score in dB SNR among participants (N=10) within vent condition (3) across memories. A lower signal-to-noise ration (SNR) value equals better performance. The boxes represent the interquartile range with the mean shown in the dashed line and median in the solid line inside each box. The error bars extend to the maximum and minimum when within 1.5 times the interquartile range. Data beyond this range are shown with individual symbols (black dots).

mANL

- RMANOVA analysis for the main effect of venting did not reveal a significant difference ($F(2,9)= 1.341$, p=0.287). Suggesting that changes to openness of a hearing aid fitting did not affect performance.
- RMANOVA analysis for the main effect of memory revealed a significant difference ($F(3,9)= 19.312$, p<0.001). Suggesting that changes in signal processing improved performance.
- The pairwise comparison (Tukey Test) reveals a significant difference for all directional vs. omnidirectional conditions suggesting positive effect of directionality. Similar conditions with noise reduction showed no significant effect (Table 1).

Results

MEMORIES	CST	ANL
DMic vs. Omni+NR	<0.001**	<0.001**
DMic vs. Omni	<0.001**	<0.001**
DMic vs. DMic+NR	0.414	0.568
DMic+NR vs. Omni+NR	<0.001**	<0.001**
DMic+NR vs. Omni	0.019*	0.021*
Omni vs. Omni+NR	0.093	0.090

Table 1: Summary of post hoc Tukey pairwise comparison between treatment conditions for CST and mANL results. Shows p values for each memory test combination. * Indicate significance at the 0.05 level and ** indicates significance at the 0.001 level.

Discussion

The outcomes of the present study demonstrate that a sample of participants with mild-to-moderate, low-frequency, sloping to moderately-severe hearing loss demonstrate statistically equivalent performance when increasing openness of a hearing aid fitting from fully occluded to an open-canal hearing aid fitting.

Specifically, the magnitude of benefit received from directional microphones, as measured with the CST, and benefit received from DNR, as measured with a modified ANL, did not vary with increased openness of fitting. The first observation, specific to directional microphones, is in contrast with previous work that has shown decreased directivity and thus decreased performance with increased vent diameter. The second observation of unchanged benefit from DNR had not—to the awareness of the authors—been previously documented.

As illustrated by the follow-up analyses the majority of significant effects were driven by the inclusion of directional microphones in the test condition. It appears that of the examined features directional microphones are most likely to affect an improvement to speech recognition in noise as well as improved acceptance of background noise.

The selection of a participant sample with thresholds approaching moderate low-frequency hearing loss was done as a contrast to previous studies investigating openness of hearing aid fit that focused on participant samples with normal-to-mild, low-frequency hearing loss. This difference may underlie some of the disagreement between our findings and previous work. Within the constraints of this study design, these observations suggest that the candidacy for open-canal hearing aid fittings may be reasonably extended to patients with moderate low-frequency hearing loss

References

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