Clinical Topics in Hearing Aid Research

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Introduction

Several years ago, Dr. Stevens and I sat down to discuss a collaborative writing project. Although we both have a background in research, Dr. Stevens’ day-to-day routine involves the successful ownership of a private audiology practice that focuses on the dispensing of hearing aids; mine concerns the research of hearing aid technology and outcomes. I had a project in mind, but it needed a healthy dose of clinical insight.

This project, and the resulting blog and book, were born from our observation that the average clinician faces many challenges if they wish to follow the hearing aid research literature. Most clinicians spend their workday seeing patients, managing reimbursement, completing documentation, or attending to the myriad needs of running a successful business. With these demands alone, one would be challenged to stay abreast of relevant scientific publications, particularly when membership or subscription is required to access many of our journals.

Even if one were to gain access to all of our hearing-related scientific publications, the task of sifting through this material for clinical insights is a daunting one. For this reason, Dr. Stevens and I set out to review and summarize research articles that offer valuable clinical insight into selecting and fitting hearing aids. Drawing from past and current literature, we created a collection of article reviews that summarize the authors’ findings in an accessible manner, describing experimental design and outcomes, and closing each review with commentary on the clinical relevance of their findings.

This book is a topic-driven review of research; some topics consist of three or four consecutive reviews; others are covered with a single review. Our recommendation is that you begin by scanning the Table of Contents for topics that you find interesting. We sincerely hope that you find this book to be a valuable resource with information that is easily applied to your clinical practice.
Physical Characteristics of Hearing Aids
A Comparison of Receiver-in-Canal (RIC) and Receiver-in-the-Aid (RITA) Hearing Aids


Open-fit behind-the-ear hearing instruments are favored by audiologists and patients alike because of their small size and discreet appearance, as well as their ability to minimize occlusion. The performance of open-fit instruments with the receiver in the aid (RITA) and receiver in canal (RIC) has been compared to unaided conditions and to traditional, custom-molded instruments. However, few studies have examined the effect of receiver location on performance by comparing RITA and RIC instruments to each other. In the current paper, Alworth and her associates (2010) were interested in the effect of receiver location on:

- occlusion;
- maximum gain before feedback;
- speech perception in quiet and noise;
- subjective performance and listener preferences.

Theoretically, RIC instruments should outperform RITA instruments for a number of reasons. Delivery of sound through the thin tube on a RITA instrument can cause peaks in the frequency response, resulting in upward spread of masking (Hoen & Fabry, 2007). Such masking effects are of particular concern for typical open-fit hearing aid users with high-frequency hearing loss. RIC instruments are also capable of a broader bandwidth than RITA aids
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(Kuk & Baekgaard, 2008) and may present lowered feedback risk because of the distance between the microphone and receiver (Ross & Cirmo, 1980), and increased maximum gain before feedback (Hallenbeck & Groth, 2008; Hoen & Fabry, 2007).

The authors recruited twenty-five subjects with mild-to-moderate, high-frequency, sensorineural hearing loss to participate in the study. Fifteen had no prior experience with open-canal hearing instruments, whereas ten had some prior experience. Each subject was fitted bilaterally with RIC and RITA instruments with identical signal-processing characteristics, programmed to match NAL-NAL1 targets. Directional microphones and digital-noise-reduction features were deactivated. Subjects used one instrument type (RIC or RITA) for six weeks before testing and then wore the other type for six weeks before being tested again. The instrument style was counterbalanced among the subjects.

Probe microphone measures were conducted to evaluate occlusion and maximum gain before feedback. Speech perception was evaluated with the Connected Speech Test (CST) (Cox et al., 1987), the Hearing in Noise Test (HINT) (Nilsson, et al., 1994), the High Frequency Word List (HFWL) (Pascoe, 1975), and the Acceptable Noise Level (ANL) test (Nabelek et al., 2004). Subjective responses were evaluated with the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995), overall listener preferences for quiet and noise, and satisfaction ratings for five criteria: sound quality, appearance, retention and comfort, speech clarity, and ease of use and care.

Real-Ear Occluded Response (REOR) measurements showed minimal occlusion for both types of instruments in this study. Although there was more occlusion overall for RIC instruments, the difference between RIC and RITA hearing instruments was not significant. Overall maximum gain before feedback did not differ between RIC and RITA instruments. However, when analyzed by frequency, the authors found significantly greater maximum gain in the 4000–6000Hz range for RIC hearing instruments.

On the four speech tests, there were no significant differences between RITA versus RIC instruments. Furthermore, there were no significant improvements for aided listening over unaided, except for experienced users with RIC instruments on the Connected Speech Test (CST). It appears that amplification did not significantly improve scores in quiet conditions, for either instrument type,
because of ceiling effects. The high unaided speech scores indicated that the subjects in this study, because of their audiometric configurations, already had broad enough access to high-frequency speech cues, even in the unaided conditions. Aided performance in noise was significantly poorer than unaided on the HINT test, but no other significant differences were found for aided versus unaided conditions. This finding was in agreement with previous studies that also found degraded HINT scores for aided versus unaided conditions (Klemp & Dhar, 2008; Valente & Mispagel, 2008).

APHAB responses indicated better aided performance for both instrument types than for unaided conditions on all APHAB categories except aversiveness, in which aided performance was worse than unaided. There were no significant differences between RIC and RITA instruments. However, satisfaction ratings were significantly higher for RIC hearing instruments. New users reported more satisfaction with the appearance of RIC instruments; experienced users indicated more satisfaction with appearance, retention, comfort, and speech clarity. Overall listener preferences were similar, with 80% of experienced users and 74% of new users preferring RIC instruments over RITA instruments.

The findings of Alworth and colleagues (2010) are useful for clinicians and their open-fit hearing aid candidates. Because they provided significantly more high-frequency gain before feedback than RITA instruments, RIC instruments may be more appropriate for patients with significant high-frequency hearing loss. Indeed, this result may suggest that RIC instruments should be the preferred recommendation for open-fit candidates. The results of this study also underscore the importance of using subjective measures with hearing aid patients. Objective speech discrimination testing did not yield significant performance differences between RIC and RITA instruments, but participants showed significant preference for RIC instruments.

Further information is needed to compare performance in noise with RIC and RITA instruments. In this study and others, some objective scores and subjective ratings were poorer for aided conditions than unaided conditions. It is important to note that in the current study, all noise and speech was presented at a 0° azimuth angle, with directional microphones disabled. In real-life environments, it is likely that users would have directional microphones and would participate in conversations with various noise sources surrounding them. Previous work has shown
significant improvements with directionality in open-fit instruments (Valente & Mispagel, 2008; Klemp & Dhar, 2008). Future work comparing directional RIC and RITA instruments, in a variety of listening environments, would be helpful for clinical decision making.

Although the performance effects and preference ratings reported here support recommendation of RIC instruments, clinicians should still consider other factors when discussing options with individual patients. For instance, small ear canals may preclude the use of RIC instruments because of retention, comfort, or occlusion concerns. Patients with excessive cerumen may prefer RITA instruments because of easier maintenance and care, or those with cosmetic concerns may prefer the smaller size of RIC instruments. Every patient’s individual characteristics and concerns must be considered, but the potential benefits of RIC instruments warrant further examination and may indicate that this receiver configuration should be recommended over slim-tube fittings.

References


Comparing Localization Ability with BTE and CIC Hearing Aids


Localization of external sound sources is achieved in a number of ways. In addition to visual cues, listeners use binaural time and intensity differences to localize sounds on a horizontal plane (Woodworth, 1938). Monaural spectral cues provide additional information about vertical location and help differentiate sound sources that are in front of or behind the listener (Blauert, 1997). There is ample evidence that localization of sound sources may be an important first step in the perception of speech in complex listening environments (Arbogast et al., 2002; Bregman, 1990; Freyman et al., 2001). Several studies have shown that hearing aid users demonstrate poorer aided localization than when unaided (Byrne et al., 1992; Keidser et al., 2006; Noble & Byrne, 1990; Vanden Bogaert et al., 2006). This is thought to be due to disruption of binaural time and intensity cues by bilateral hearing aids. Therefore, monaural localization cues are valuable to hearing aid wearers and may have particularly important implications for their ability to understand speech in noisy situations.

Two factors known to reduce the availability of monaural spectral cues are of particular relevance to hearing aid users: reduced audible bandwidth (Blauert, 1997; Butler, 1986; Middlebrooks, 1992) and sensorineural hearing loss (Byrne & Noble, 1998; Byrne et al., 1992; 1997; Noble et al., 1994; Rakerd et al., 1998). These factors reduce spectral cue localization because of decreased audibility of high frequencies. Sensorineural hearing loss is accompanied by decreased frequency resolution, which can itself impair spectral cue
localization (Jin et al., 2002). Additionally, hearing aid users lose pinna-related spectral cues, particularly with behind-the-ear (BTE) models in which the microphone is placed above the pinna. Completely-in-the-canal (CIC) instruments are thought to preserve pinna-related spectral localization cues because of microphone placement at the ear canal entrance.

The purpose current study was to contrast spatial localization abilities in users with CIC and BTE hearing aids and normal hearing listeners. Two measures of localization were analyzed:

- Lateral localization (horizontal localization: left/right with reference to midline)
- Polar localization (encompassing up/down and front/back dimensions)

The authors recruited eleven subjects with mild-to-moderate sensorineural hearing loss and four subjects with normal hearing. Hearing-impaired subjects were fitted with CIC and BTE instruments. All hearing instruments had 1.5 mm vents and both CIC and BTE instruments had bandwidth out to approximately 6800Hz. Directional microphones, noise-reduction processing, and environment classification features were disabled. Hearing aids were programmed to match CAMEQ gain targets (Moore et al., 1999) and fittings were verified with real-ear measurements. Prior to localization testing, additional probe microphone measurements were conducted to determine aided audibility of the speech stimuli to be used in the test sessions.

Hearing-impaired subjects were tested with both CIC and BTE hearing instruments after a period of “accommodation” or acclimatization to each type of instrument. The experiment was therefore conducted in six phases:

1. Localization testing (both hearing aids)
2. Accommodation period (4–6 weeks, hearing aid A)
3. Localization testing (hearing aid A)
4. Accommodation period (4–6 weeks, hearing aid B)
5. Localization testing (hearing aid B)
6. Localization testing (unaided)

Subjects with normal hearing were tested under two conditions. In one condition, the speech was a broadband stimulus (up to
40,000Hz) and in the other it was low-pass filtered at 6800Hz to approximate the bandwidth of the hearing instruments worn by the hearing-impaired subjects.

Listeners were presented with monosyllabic words at an average level of 65dB SPL for hearing-impaired listeners and 55dB SPL for normal hearing listeners. Subjects were asked to “point their nose” toward the perceived location of the speech. Testing was completed in an anechoic chamber and head orientation was monitored with an electromagnetic tracking system.

The results indicated that for lateral localization errors, there was no difference between CICs and BTEs, no significant difference between aided and unaided results, nor was there a significant effect of accommodation. Performance for normal hearing subjects was more accurate than that of the hearing-impaired subjects. There was a great deal of variability among hearing-impaired subjects; those with poorer low-frequency thresholds had increased lateral localization errors. Previous studies have shown that aided lateral localization is usually worse than unaided and the authors surmised that the performance of the subjects in this study could have been related to their relatively good low-frequency hearing thresholds or the availability of airborne sound through the hearing aid vents.

Analysis of polar angle localization errors yielded similar results. There was no significant effect of hearing aid use, hearing aid style, or accommodation. Performance was substantially better for normal hearing subjects, regardless of bandwidth condition, though errors were slightly greater for the limited bandwidth condition. Although vertical localization in particular was expected to be related to the availability of high-frequency cues, no significant correlational was found for unaided individual performance and high-frequency pure-tone thresholds, or aided results and high-frequency aided sensation level.

Performance with CIC instruments yielded significantly fewer front/back reversals than performance with BTEs and results for both hearing aid types showed significant improvement after accommodation periods. Unaided responses were more accurate than either aided condition and subjects with normal hearing did better than hearing-impaired subjects in any condition. The front/back reversal rate was not correlated with high-frequency audiometric thresholds or aided sensation levels,
nor was the benefit of CICs over BTEs correlated with high-frequency sensation level. Previous research shows that front/back localization is primarily related to conchal resonance, which occurs around 4000–5000Hz (Hebrank & Wright, 1974). CIC microphone placement should allow for preservation of these cues, whereas BTE configurations would not. Interestingly, unaided performance in the current study was still better than aided, despite the likelihood that cues in the 4000–5000Hz range would have been inaudible for these subjects without their hearing aids.

The results of this study indicate that hearing-impaired listeners are likely to experience some decreased sound localization ability relative to normal hearing listeners, regardless of hearing aid style. The degree to which localization ability is affected may be related to audiometric thresholds, venting, directionality, compressions settings, and other variables. Though lateral and vertical localization was not affected by hearing aid microphone location in this study, CIC instruments afforded better front/back localization than BTE devices. It is possible that new hearing aid technology will allow for enhanced spectral cue availability. For instance, improvements in feedback control allow more stable high-frequency gain and new, deep-fitting CIC instruments may increase the availability of ear canal and pinna-related spectral cues.

The decrease in front/back localization errors following accommodation periods in this study underscores the importance of acclimatization to new hearing aids. Improvement in localization ability over time is not necessarily something that would warrant adjustments to hearing aid settings, but it should be discussed with new hearing aid users with reference to their expectations during the trial period and thereafter.

Though sound source localization is important for speech perception in complex listening environments, it should be noted that the hearing instruments in this study were programmed without directionality. For many hearing aid users, directional microphones will improve the ability to understand primary speech stimuli in front of the listener so binaural and monaural localization cues may be of decreased significance in some circumstances.
References


