Localization with M&RIE improves with experience

Charlotte Jespersen, MA; Isabel Schindwolf, MSc

ABSTRACT

Receiver-in-the-ear (RIE) hearing aids are the most popular style of hearing aid today. Unfortunately, the location of the microphones on the devices deprives users of natural cues for spatial hearing. ReSound ONE preserves these cues with the M&RIE receiver module. It places a microphone in the user's ear canal along with the receiver and allows sound to be collected in the most natural location. Localization performance was evaluated at the initial fitting and repeated after 4 and 8 months of wear time as part of a two-year study following adult users of ReSound ONE fit with M&RIE receivers. This article presents long-term benefit results in localization performance with the M&RIE.

INTRODUCTION

The primary benefit of hearing aids is that users experience better audibility of sounds in their environment. This helps them be more aware of sounds around them and improves their ability to hear speech. Compared to older technology, today's hearing aids use varying compression strategies, wider frequency bandwidth, and high input dynamic range to provide superior audio quality. Hearing aid designers are challenged to develop ways to enrich the listening experience even further. At ReSound, hearing aid development is driven by the Organic Hearing philosophy: we are inspired by the natural way we hear and how we use our hearing in daily life. The shape of our ears and their physical position on the head provide filtering of sound entering the ear that is unique to each individual ear. The brain uses this information to provide spatial perception. While spatial perception is not required for listeners to experience better audibility with hearing aids, it can enhance how users are able to listen when wearing their hearing aids. People with hearing loss may not realize how their hearing difficulties are impacted by degraded spatial perception, or how hearing aids may help or hinder this ability. Good spatial perception contributes to the listening experience in at least three important ways.[1] One can be thought of as "survival". In today's world, this can refer to safety-related events such as knowing which direction an oncoming vehicle is approaching from, but it can also be extended to other important sounds, such as knowing from which direction someone is calling or being able to locate the source of an unusual noise in the surroundings. Spatial perception is also important for less utilitarian reasons. For example, the appreciation of the sound environment as being outside of one's head depends on spatial perception. Finally, spatial perception contributes to our ability to sift out and focus on the sounds we want when in noisy situations.

The way that the torso, head and pinna transform the sound delivered to a listener's ear is an important contributor to localization of sound, especially in determining whether sound arises from in front or in back, as well as elevation of the sound source relative to the listener. These spectral cues are generally disrupted by wearing hearing aids. In fact, for hearing aid wearers, aided localization may be worse than unaided localization provided the sound is audible.[2,3] Today's most popular hearing aid style, the Receiver-in-the-Ear (RIE), picks up sound via microphones located on the device, which is worn behind the ear. Placing the microphones behind the ear precludes the natural way of picking up sounds within the ear canal and thereby the spatial hearing cues that may potentially be used by the brain to help orient to the environment, shift attention and focus on sounds of interest. In addition, the shaping of sound by each person's anatomy is unique, which can contribute to externalization of sound and natural sound quality.

The ReSound ONE fit with the M&RIE receiver module preserves individual spectral cues by placing a microphone in the ear canal.[4,5] This microphone placement has been shown to improve localization as measured by a significant reduction in front-back confusions relative to traditional RIE microphone placement.[6] There is evidence that listeners can adapt to changes in spectral cues,[7,8] with further improvements in front-back localization over time.[6]

The purpose of this study was to test whether localization benefit with ReSound ONE fit with M&RIE was affected by experience in wearing the hearing aids over time.

Figure 1. The ReSound ONE can be fit with the M&RIE receiver, which contains both a receiver and microphone in the tiny module. The M&RIE allows sound to be collected in the ear canal, as nature intended.

Methods

Participants

Ten adults with bilateral mild-to-moderate sloping sensorineural hearing loss participated in the study. The median age was 61 years (1st quartile: 55 years and 3rd quartile: 67 years). Five participants were current users of RIE hearing aids with a median experience of 5 years (1st quartile: 4 years and 3rd quartile: 7 years) and five participants were inexperienced with amplification at the beginning of experiment. The average audiogram is shown in Figure 2.

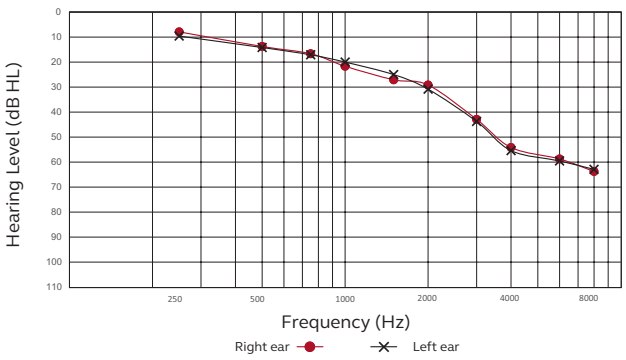

Figure 2. Average hearing thresholds of the participants (N=10).

Hearing aids and fitting

The participants are part of a 2-year study that aims to document real-life benefit and device performance and quality over time of the ReSound ONE RIE hearing aids. Participants were fitted with ReSound ONE hearing aids, M&RIE receivers and domes. Eight people were fitted with open domes, one was fitted with closed domes and one with tulip domes. Gain was prescribed using the proprietary fitting rationale and fine-tuned as needed.

At the first visit participants were also fitted with the hearing aids and SureFit 3 standard receivers and domes. This RIE hearing aid fitting with traditional microphone placement in the body of the hearing aid served as the benchmark in the localization testing. Fittings with standard receivers have Spatial Sense as a default feature. Spatial Sense is designed to approximate the average spectral filtering effect of the adult pinna and to assist in horizontal localization by maintaining interaural level difference cues. This is accomplished by combining a binaural compression algorithm with a pinna compensation algorithm that applies a front-facing directional mode in the higher frequencies.[2] Other advanced features except for feedback cancellation were turned off to prevent them from interfering with the white noise target signal.

Test Conditions

The part of the long-term study focusing on localization was evaluated over 3 visits: at the initial fitting, after 4 months and again after 8 months of hearing aid usage of the ReSound ONE hearing aids fitted with M&RIE receivers.

At the first visit, the participants performed the localization test for three different conditions: unaided, with the standard receivers and traditional microphone location on the hearing aids, and with the M&RIE receivers. The test order of the conditions was counterbalanced across participants.

The participants repeated the localization test after 4-months and 8-months of wearing the ReSound ONE hearing aids fitted with the M&RIE receivers.

Visit 1 At fitting	Visit 2 After 4 months usage	Visit 3 After 8 months usage
Unaided	-	-
M&RIE receiver	M&RIE receiver	M&RIE receiver
SureFit 3 standard receiver		

Table 1. Localization test conditions at visit 1, 2 and 3.

Procedures

Participants were seated in the middle of a twelve-loudspeaker setup. The loudspeakers were separated by 30° as illustrated in Figure 3. White noise bursts 250 ms in length were played randomly from one of the loudspeakers at a level that was audible to the participants. Participants responded by stating from which loudspeaker they perceived the stimulus was played. This procedure was repeated 5 times for each angle resulting in a total of 60 signals presentation per condition. Before starting the actual test, the participants performed an unaided training round.

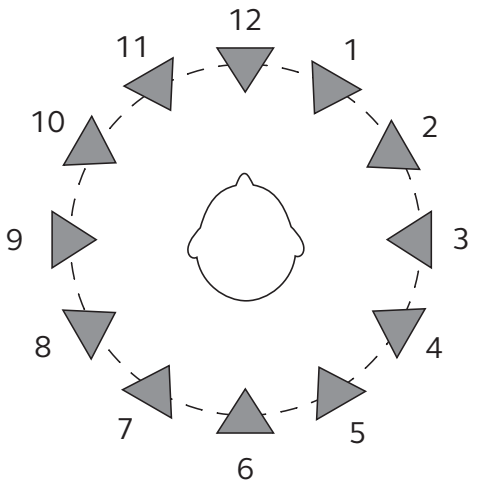

Figure 3. Illustration of localization test setup.

Results

The average front/back error was calculated for each test condition. This is the percentage of times, out of all tests, that the participants reported hearing the stimulus coming from in front of them when it actually came from behind them and vice versa. The results are shown in Figure 4. Statistical comparisons were made between the fittings with M&RIE and the SureFit 3 standard receiver at visit 1 and subsequently between the M&RIE at visit 1, and after 4 months and 8 months of adaptation to the M&RIE receiver. The Tukey Honestly Significant Difference test was used for the comparisons.

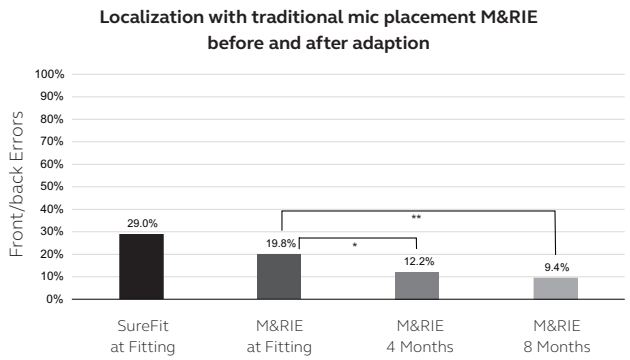

Figure 4. Mean percentage of front/back errors for the traditional mic placement with the SureFit 3 standard receivers vs. the M&RIE receiver at fitting as well as after 4 months and 8 months of adaptation for the ten participants. The asterisks show significant differences where * indicates p<.01 and ** indicates p<.001.

At the initial visit, localization performance was not significantly different with M&RIE than unaided (unaided result not shown in Figure 4), while localization performance was significantly worse than unaided for the participants wearing the SureFit 3 standard receivers who listened with traditional microphone placement. On average, the participants made fewer front/back localization errors with M&RIE than with the SureFit 3 standard receivers. However, these two conditions were found not to be significantly different from each other. The participants demonstrated a significant improvement in performance on the front/back localization task already after 4 months of wear time with the M&RIE receivers (p=0.009) compared to M&RIE at the fitting. The average front/back error decreased even further after using M&RIE for 8 months, although the result was not significantly different from that obtained after 4 months of usage.

As the participant group consisted of both experienced users of RIE hearing aids and inexperienced hearing aid users, it is of interest to see if there were differences between these two types of participants. The mean front/back error for the experienced and inexperienced participants is presented in Figure 5.

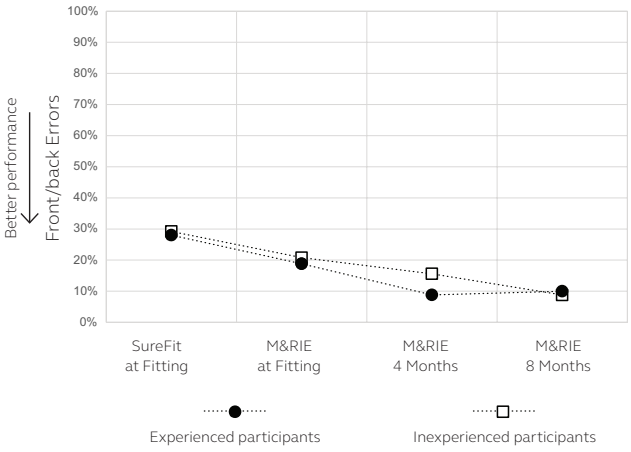

Figure 5. Mean front/back errors for the traditional mic placement with the SureFit 3 standard receivers vs. the M&RIE receiver at fitting as well as after 4 and 8 months of adaptation for experienced users of RIE hearing aids (N=5) and inexperienced participants (N=5).

The inexperienced participants made slightly fewer front/back errors after wearing ReSound ONE hearing aids fitted with M&RIE receivers for 4 months compared to the experienced participants although this difference was not significant (Figure 5). However, they did not improve further after having used the hearing aids fitted with M&RIE receivers for an additional 4 months (8 months altogether). After 8 months of adaptation, performance was identical for both groups.

When looking at the localization performance per participant (Figure 6) it becomes apparent that the progress of localization performance with hearing aids fitted with the M&RIE receivers is highly individual regardless of previous experience with hearing aids.

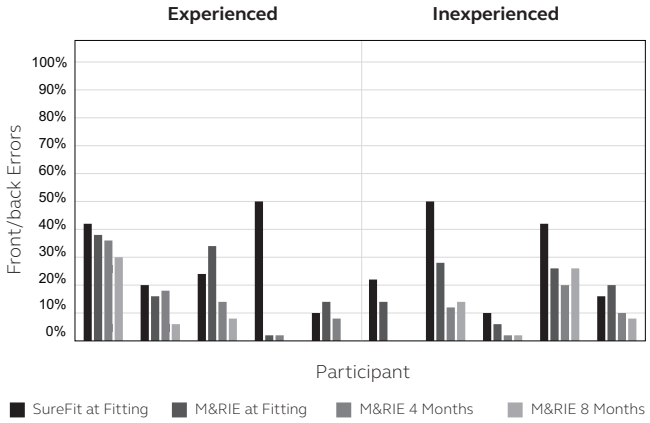

Figure 6. front/back errors for the traditional mic placement with the SureFit 3 standard receiver vs. the M&RIE receiver at fitting as well as after 4 and 8 months of adaptation for each participant (N=10).

Four participants - one experienced and three inexperienced users - showed large front/back error improvements with the M&RIE receivers already at the first fitting compared to with the SureFit 3 standard receivers with traditional microphone placement, while only one experienced user performed better with SureFit receivers. The other five participants performed similarly with both the M&RIE and SureFit 3 standard receivers at the fitting.

Almost all participants' front/back localization performance with the M&RIE receivers improved with wear time. Four participants reached 100% or nearly 100% correct front/back localization with the M&RIE receiver. As can be seen in Figure 6, participant 4 achieved this score already at fitting; participant 6 and 8 after 4 months' usage and participant 5 after 8 months' usage. The M&RIE localization performance of the experienced participant 3, who performed better at fitting with SureFit receivers, improved by 26 percentage points after an 8-month adaptation time. Yet, the localization performance of two M&RIE users, participants 7 and 9, declined slightly from 4-month to 8-month adaptation. Datalogging from the hearing aids revealed that these two participants had been wearing the hearing aids less than 6 hours per day as compared to an average of 11 hours per day for the other participants.

Discussion

Considering that M&RIE has been shown to provide benefit in localization immediately after fitting, this study sought to find out whether localization benefit with the M&RIE receiver improves with wear time. The results show an average increase in localization benefit with the M&RIE receiver when participants were retested after 4 months. This group level increase in benefit did not differ depending on experience with amplification. In other words, people who already were hearing aid users as well as people who were new to hearing aids showed improvement over time wearing ReSound ONE with M&RIE. Furthermore, average localization performance with the M&RIE was better than with the traditional microphone placement on the RIE hearing aid. Even the one experienced user of RIE hearing aids who initially did better on the localization task with the standard receiver showed greatly improved performance with M&RIE after 4 months of wear time. The two participants with slightly worse results with M&RIE after 8-months of adaptation compared to 4 months of adaptation did not wear the hearing aids as many hours per day as other participants, which might have affected their results.

In this study as well as in earlier research,[6] front/back localization for sound in the horizontal plane is used as a proxy for overall localization ability. However, it should be noted that this is not the only contributor and certainly gives an incomplete impression of localization ability in the real world. People continually move their heads in real listening situations, and this helps in localizing sound sources regardless of whether you are wearing hearing aids or not. People with good vision also augment sound localization with input from this domain. In the auditory realm, additional information is relevant. Lateral localization depends on differences in timing and level of sound reaching one ear versus the other. It is thus important for hearing aids to minimize disruptions to these cues as well. Many candidates for ReSound ONE with M&RIE will have open fittings that allow good audibility of direct low frequency sound, thereby preserving access to between-ear timing cues. Even for those with more occluding fittings, equal processing delays in the hearing aids ensure that ear specific differences are maintained. In addition, ReSound ONE applies Spatial Sense when the ear canal microphone of M&RIE is active to maintain natural sound level differences between the ears known as interaural level differences (ILD). Audibility of extended high frequency information may assist with localization in reverberant environments[10] and even extend to better externalization of sound.[11] The extended high frequency bandwidth of ReSound ONE exceeding 8 kHz may therefore also contribute to localization and spatial perception generally by making these cues accessible.

Front/back localization performance also may not do an adequate job of discriminating different hearing aid technology approaches to preserving localization. For example, digital directional hearing aid technology that approximates average pinna cues for sound in the horizontal plane has been shown in multiple investigations to improve front/back localization performance to varying degrees.[12] In the current study, performance on front/back localization was better when participants listened with M&RIE compared to the traditional microphone location and Spatial Sense (which incorporates a pinna compensation feature) but the differences between the two conditions could be even more far-reaching. Pinna compensation features such as Spatial Sense are not designed to restore elevation cues that help to tell whether sound comes from above or below. Therefore, potential localization benefits of microphone location in the ear relative to pinna compensation processing are not fully captured by evaluating only front/back localization. Because the M&RIE canal microphone location preserves individual pinna cues better than traditional BTE microphone location, more extensive benefit relative to localization can be expected. Such benefits might include up-down localization as well as externalization of sound.

Conclusions

For people with mild-to-moderate hearing losses, ReSound ONE fit with the M&RIE receiver assists in better front/back localization than when fit with receivers that use the traditional microphone placement on the hearing aids behind the ear. This confirms that the M&RIE receiver is a solution that first-time users as well as experienced hearing aid users can benefit from. Localization performance with ReSound ONE fit with M&RIE receivers improves as users gain experience in using the hearing aids, and this improvement continues through at least 4 months after the fitting.

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Worldwide Headquarters
GN Hearing A/S
Lautrupbjerg 7
DK-2750 Ballerup
Denmark
Tel.: +45 4575 1111
resound.com

CVR no. 55082715

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