Development and Implementation of Acuity Immersion Directionality

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Introduction

The primary goal of a hearing aid fitting is to restore audibility to the hearing aid wearer. Restoration of audibility allows hearing aid wearers to communicate more effectively and participate more meaningfully in everyday life. While the benefits of restored audibility are clear, traditional hearing aids have not accounted for the natural directivity of the human ear in their design and thus produce an output that differs from that produced by the unaided ear. Acuity Immersion Directionality recreates this natural directivity, allowing the hearing aid wearer to feel more connected to the world and immersed in their environment.

Traditional hearing aid systems employ an omnidirectional microphone pattern to give the patient access to sounds from all directions, providing situational awareness and allowing the patient to choose what sounds to attend to. These are critical functions of hearing and should be preserved (or restored) by the hearing aid, but to preserve them in a way that sounds natural, the directivity of the unaided ear must be accounted for — this is where the omnidirectional microphone pattern falls short in RIC and BTE hearing aids.

The unaided ear — in particular, the physical structure of the pinna — provides a natural directivity in the higher frequencies. This effect can be quantified in terms of the directivity index (DI); the DI for a directional system describes its response to sounds originating from the front (on-axis) relative to its response to a diffuse sound field (off-axis). A positive DI indicates that off-axis...
sound is attenuated relative to on-axis sound. We can observe in Figure 1 that the unaided ear is a directional system that attenuates off-axis sounds relative to on-axis sounds at frequencies above 2000 Hz. As a simple example, for the unaided ear, a 2000 Hz sound presented from the front will be louder than the same sound presented from the rear; a 500 Hz sound will have roughly the same loudness whether presented from the front or the rear.

The directional filtering by the pinna provides two advantages to normal hearing listeners. First, the difference in how sound is perceived from the front relative to the rear provides a cue to the listener that helps in determining the spatial origin of the sound. Second, the attenuation of off-axis sound provides an SNR benefit in situations where the listener is attending to a front-facing target in the presence of a rearward or diffuse noise source.

When a patient is fitted with a Behind-The-Ear (BTE) or Receiver-In-The-Canal (RIC) hearing aid, access to natural directivity is lost because incoming sound is not filtered by the pinna prior to entering the hearing aid microphones (Westermann and Topholm, 1985; Best et al., 2010). Acuity Immersion Directionality recreates natural directivity in a BTE/RIC hearing aid by employing a directional microphone pattern in the higher frequency channels and an omnidirectional microphone pattern in the lower frequency channels (Figure 2). This technique effectively restores some of the localization cues and SNR benefits normally provided by the pinna in the unaided ear to BTE and RIC users (Keidser et al., 2009; Kuk et al., 2013; Weile et al., 2013), providing a more natural and immersive experience.

### Acuity Immersion Directionality in Inspire

The Acuity Immersion Directionality feature can be controlled from the Inspire Directionality Details screen (Figure 3).

When selected, Acuity Immersion Directionality will configure the hearing aid to use a high-frequency directional microphone pattern in quiet and/or challenging environments according to the selected Directionality Mode. This behavior is summarized in the Table 1.

<table>
<thead>
<tr>
<th>Directional Mode</th>
<th>Quiet</th>
<th>Challenging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive</td>
<td>High-Frequency Directional</td>
<td>Broadband Directional with Null Steering</td>
</tr>
<tr>
<td>Dynamic</td>
<td>High-Frequency Directional</td>
<td>Broadband Directional</td>
</tr>
<tr>
<td>Fixed Directional</td>
<td>Broadband Directional</td>
<td>Broadband Directional</td>
</tr>
<tr>
<td>Fixed Omni</td>
<td>High-Frequency Directional</td>
<td>High-Frequency Directional</td>
</tr>
</tbody>
</table>

Table 1. Microphone pattern in quiet and challenging environments for each Directionality mode with Immersion Directionality enabled.

Note that the Fixed Directional mode is reserved for patients who benefit from broadband directionality in all environments; as such, Acuity Immersion Directionality does not apply to this Directionality Mode.

In the automatic switching modes (Adaptive and Dynamic), the high-frequency microphone pattern will be used in quiet environments where situational awareness and naturalness of sound are a priority. In more challenging environments, the hearing aid will automatically switch to a broadband directional microphone pattern so that the hearing aid wearer can focus on a signal of interest while the hearing aid suppresses noise from other directions. In the Fixed Omnidirectional mode, the high-frequency microphone pattern will be employed for all acoustical environments.

Providing situational awareness and allowing the patient to choose what sounds to attend to are critical functions of hearing and should be preserved (or restored) by the hearing aid, but to preserve them in a way that sounds natural, the DIRECTIVITY of the unaided ear must be accounted for.
Clinical Validation Study

A research study was completed to evaluate hearing aid wearers’ performance on a speech-in-noise task and satisfaction with the Acuity Immersion Directionality feature enabled. In the study, participants attended three laboratory sessions as well as used the hearing aids for approximately five weeks in real-world situations. Fourteen experienced hearing aid wearers participated in the clinical trial. During the study, participants wore pre-released micro RIC 312 or BTE 13 hearing aids.

The hearing aids were Best Fit to Starkey Hearing Technologies’ proprietary e-STAT targets during the initial session (Scheller & Rosenthal, 2012). Real-ear measurements were completed using the Audioscan Verifit system. To ensure audibility, the International Speech Test Signal (ISTS; Holube, Fredelake, Vlaming, & Kollmeier, 2010) stimulus was used for the Real Ear Aided Response (REAR) measurement and was presented at levels of 50, 65 and 75 dB SPL. An 85 dB SPL pure tone sweep was presented to verify comfort. Finally, directivity at the null in the high-frequency channels was measured to ensure that directionality was operating as expected.

Speech-in-Noise Testing

Participants completed the Hearing in Noise Test (HINT), which assessed the differences in speech understanding ability with three different microphone patterns: omnidirectional, high-frequency directional (Acuity Immersion Directionality feature), and broadband directional. The HINT is a standardized speech test that adaptively arrives at the signal-to-noise (SNR) ratio required for correct repetition of 50 percent of the sentences presented in a background of competing speech-shaped noise at a fixed level of 65 dB SPL (Nilsson, Soli & Sullivan, 1994). The speech level adapts based on each correct (or incorrect) response, resulting in a calculated HINT score. Speech is presented from a front loudspeaker with diffuse noise presented from seven other loudspeakers surrounding the participant.

Results (Figure 4) demonstrate both the high frequency and broadband directional microphone patterns provided a statistically significant improvement in speech understanding in noise over an omnidirectional microphone pattern. A two-way repeated measures ANOVA demonstrated there was a significant main effect of microphone pattern (p<0.001) and that there was no significant difference in results between styles of devices (p=0.101). Posthoc testing (Holm-Sidak method) demonstrated that participants performed significantly better using both high-frequency and broadband directional microphone patterns than omnidirectional (p<0.001) and that participants using broadband directional performed significantly better than when using high-frequency directional (p<0.001).

The results from the HINT are as expected. As the hearing aids switched from omnidirectional to high-frequency directional to broadband directional microphone patterns, off-axis sound sources were attenuated across a broader range of frequencies. Accordingly, a lower SNR was needed in the Acuity...
Immersion Directionality and fixed directional modes to achieve the same level of performance. This resulted in improved intelligibility of the speech.

**Overall Satisfaction**

Participants also completed multiple questionnaires during their time wearing the hearing aids in everyday listening environments with Acuity Immersion Directionality on. For ratings of overall satisfaction (Figure 5), participants used a five-point scale, ranging from very poor to very good. In quiet environments, 92% of participants rated their overall satisfaction as okay to very good. In noisy environments, 85% of participants rated their overall satisfaction as okay to very good.

**Conclusion**

Starkey Hearing Technologies’ Acuity Immersion Directionality feature restores some of the benefits of natural directivity to hearing aid wearers by recreating elements of the sound filtering provided by the pinna. This natural directivity provides for front-back localization cues and improved speech understanding in noise (relative to Omnidirectional). Studies performed with the Acuity Immersion Directionality feature demonstrated a significant benefit for speech recognition and was well accepted in terms of sound quality in quiet and noisy environments.

**References**


