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Letter to the Editor: Johnson, J.A., Xu, J., Cox, R.M. (2017). Impact of hearing aid technology on outcomes in daily life III: Localization, *Ear Hear*, XX, 00-00

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In recent years, clinicians have begun to discuss the sound localization abilities of hearing aid users more frequently. This is due in part to hearing aid manufacturers' attempts to remove binaural cue distortion and add pinna cue information in their products. These advancements create a need for, and interest in, binaural hearing research in clinical audiology. This means that for those who are experts in other clinical areas, guidance from the last century of binaural psychoacoustics research (e.g., Stecker and Gallun, 2012) would be of great benefit. The importance of connecting clinical research and binaural psychoacoustics is demonstrated by a recent study evaluating the effects of hearing aid technology on sound localization ability (Johnson et al., 2017). While examining the relationship of localization ability to hearing aid technology is timely and of great interest, we are concerned that the behavioral methods used to examine localization are not appropriate to test the important hypotheses proposed. As a result, we are concerned that the results are potentially misleading. Specifically, 1) the technique used to evaluate premium versus basic hearing aid technology on front-back confusions allowed listeners to move their heads, which we are concerned is a more potent cue than the pinna cue simulations present in the premium (but not basic) hearing aids, and, 2) the response method used for horizontal plane localization involved such large steps in horizontal angle that it is potentially insufficiently sensitive to the differences in localization that would have occurred on the basis of differences in, or even the introduction of, hearing aid technology.

Methodological issues

A critical decision when designing a localization study is whether or not to control for head movement. Allowing for head movement in the laboratory may better translate to real world settings, but it needs to be measured and controlled methodologically. Standard practice for free-field sound localization is to fix or control for head movement (Mills 1958, Wightman et al. 1987). This is essential when evaluating front-back confusions. For example, as you move your head from left to right, even small movements allow listeners to differentiate forward versus backward signals due to the opposing interaural time and level difference cues available at those two locations (forward signal becomes louder in left ear, backward signal becomes louder in right ear). Ibrahim et al. (2013) saw this in effect when they looked

at head motion $> 10^\circ$ compared to trials with smaller ($< 10^\circ$) head movements; greater head movements resulted in reduced front-back errors. Additionally, Brimijoin and Akeroyd (2014) show that self-motion reduces front-back confusions compared to source-motion, for the same degree angle movements. If the goal is to measure front-back confusions produced by different hearing aid technology, head movement must be fixed to eliminate monaural pinna cues and interaural time and level cues.

The second important design choice pertains to the size of the horizontal angles used for the presentation and response scales. To evaluate differences in azimuthal degree error across test conditions, the scale needs to be near the limits of the auditory system under test. Classic psychoacoustic papers evaluating minimal audible angle (MAA), such as Mills (1958), show thresholds as low as 1° for pure tones presented in front of a listener. With increased azimuthal angle, up to $\pm 45^\circ$, MAA remains under 10° across frequency. Using broadband stimuli, such as noise, MAA was around 1° to lateral positions up to 70° , and was under $\sim 5^\circ$ up to 100° azimuth (Perrott and Saberi, 1990). Thus, it is a substantial limitation to restrict localization response to 15° . Results from a limited azimuthal response scale are less likely to reflect small differences in localization. A more appropriate method to evaluate localization thresholds would be to track angular responses by using a laser pointer on an acoustic screen hiding the target speakers or through a response touchscreen allowing the listener to specify any 360° location.

Conclusions

Do premium hearing aids allow for better localization ability than basic hearing aid technology? In our opinion, Johnson et al.'s (2017) paper does not fully answer this question, and any behavioral results should be carefully interpreted. Measurements on KEMAR (Johnson et al., 2017; Figure 3) clearly show large level differences for front versus back signals. With a few minor changes to the methodology (fixing head movement, refining response scale), behavioral differences across premium and basic technology would be more likely to have been observed. The one significant finding that premium aids show fewer errors than basic technology in quiet, high frequency filtered condition (Johnson et al., 2017; Figure 6), is of such a small magnitude that to suggest that it would impact real-world localization appears to us to be an over-interpretation.

Further work on sound localization and modern hearing aids is still needed, especially those accomplished by clinical researchers using appropriate psychoacoustical methods. Going forward, it is important to combine these methods with strong clinical approaches such as those demonstrated by Johnson et al. (2017): valid self-report measures and acclimatization to the hearing aids being tested.

As many clinicians know, our patients rarely present themselves at a clinic because of difficulty with sound localization. However, by ensuring that hearing aids do not distort binaural cues, this cue information should be available to those who can use it for localization and potentially other auditory tasks. Sound localization and hearing aids will continue to be a topic of great interest in hearing aid research as manufacturers continue to adjust their premium product algorithms to address binaural cue distortion.

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