Can you hear me now?

Examining speech intelligibility differences between bilateral and unilateral telephone listening conditions

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Communicating on the telephone continues to be a point of difficulty for many hearing aid users. Data from MarkeTrak IX revealed that satisfaction while talking on the telephone is low when compared to satisfaction in other environments (Abrams & Kihm, 2015). There are various contributing factors that may explain the difficulty a hearing aid user experiences on the phone, such as lack of visual cues, improper positioning of the telephone relative to the hearing aid, ambient noise levels, monaural presentation of the telephone audio, poor sound quality of the telephone itself and the relatively narrow frequency bandwidth of the telephone (Picou & Ricketts, 2011).

Traditionally, there are two types of hearing aid memory environments that a hearing aid user can use to improve speech understanding on the phone: acoustic memories and telecoil memories. Within Inspire® X, Telephone and Autophone are two acoustic memories in which the hearing aid microphones act as the transducer for the telephone signal. If the hearing aid has a telecoil, the signal is transduced via electromagnetic induction, and the Telecoil and Autocoil memories are both options. Telephone memories can be activated manually by the hearing aid user (Telephone or Telecoil) or can be activated automatically when the magnetic field of the phone is detected by the hearing aid (Autophone or Autocoil).

It is important to consider the following factors when deciding which type of telephone memory to choose for a particular patient. First, natural telecoil noise [i.e., the noise floor of the telecoil] may be audible to individuals with good low-frequency hearing; this may negatively impact sound quality of the phone conversation. On the other hand, if the close placement of the telephone receiver to the hearing aid results in feedback, a telecoil memory may be appealing, as by default, the hearing aid microphones are turned off when the telecoil memory is in use. Telecoil memories can provide benefit in noisy environments as well because the transmission of the phone signal is magnetic and the hearing aid microphones are turned off. This prevents the hearing aid from picking up any noise in the hearing aid user’s environment.

According to MarkeTrak VIII, telephone listening was rated as a “Very Important” listening environment, and thus counseling of the patient is important when discussing the struggles the patient may face while conversing on the telephone (Kochkin, 2010). One possible solution to improving speech intelligibility over the phone is to leverage the benefits of binaural hearing. Improved speech understanding in a variety of environments with bilateral hearing aid use is well documented (McArdle, Kilion, Mennite, & Chisolm, 2012; Silman, Gelfand, & Silverman, 1984), and some studies have shown that the benefit of bilateral amplification also extends to telephone listening (Picou & Ricketts, 2011; Wolfe, Schafer, Mills, John, Hudson, & Anderson, 2015). Wolfe and colleagues (2015) examined speech recognition over the telephone in a hearing impaired pediatric population. Two conditions were analyzed: a unilateral telephone condition, and a bilateral telephone listening condition achieved with an ear-to-ear phone streaming feature. Results indicated that speech recognition performance was significantly better in the bilateral condition compared to the unilateral condition. Picou and
Ricketts (2011) measured unilateral and bilateral telephone speech recognition performance across multiple conditions using an adult hearing impaired population. A wireless transmitter routed the telephone signal to one or both hearing aids. Speech recognition performance was significantly better in the bilateral wireless routing condition compared to the unilateral condition.

Starkey Hearing Technologies’ newest line of hearing aids, Muse™, powered by the Synergy® platform, includes an ear-to-ear phone streaming feature. Utilizing 900sync™ Technology, the primary goal of ear-to-ear phone streaming is to improve a patient’s ability to communicate on a telephone by streaming the caller’s voice from one hearing aid directly to the other, allowing for bilateral amplification of the signal. The feature is available in all four telephone memory environments (Telecoil, Autocoil, Telephone and Autophone).

To ensure the feature was working as designed, a clinical validation study was completed as part of the product development process. The clinical validation of the ear-to-ear phone streaming feature consisted of field trial testing as well as a laboratory evaluation to determine if speech recognition performance improved with the use of ear-to-ear phone streaming compared to traditional unilateral phone listening.

Methods
The study consisted of 41 participants (23 males and 18 females) with an age range of 48 to 81 years (mean age of 69.6 years). On average, all participants had bilateral, symmetrical mild-to-severe sensorineural hearing loss (Figure 1). The majority of participants were previous users of amplification. The study was approximately six to eight weeks in duration and consisted of subjective and objective testing of Muse i2400 hearing aids.

All participants were fit with various styles of Muse products with venting appropriate for their hearing loss. In total, there were 27 participants fit with standard products and 14 participants fit with various custom styles. All hearing aids were fit to Starkey Hearing Technologies’ proprietary fitting formula, e-STAT (Scheller & Rosenthal, 2012). Real-ear verification was performed and fine-tuning adjustments were made in all memories based on participants’ subjective reports. Twenty-three of 41 participants were provided with an acoustic ear-to-ear phone memory and the remaining participants were provided with a telecoil ear-to-ear phone memory. The ear each participant used for phone listening was configured as their “send stream” ear (i.e., “phone ear”). The opposite ear was configured as their “receive stream” ear (i.e., “non-phone” ear). In this configuration, the telephone audio picked up from the “send stream” ear is sent to the “receive stream” ear, resulting in a bilateral signal. Over the course of 3, two-week field trials, participants were asked to use the ear-to-ear phone streaming memory as much as possible and to complete questionnaires regarding sound quality, speech understanding and overall satisfaction when using the feature. Participants rated sound quality and speech understanding while using the ear-to-ear phone streaming feature using a five-point Likert scale ranging from “Very Poor” to “Very Good.” Participants rated their overall satisfaction with the ear-to-ear phone streaming feature on a 10-point scale, where 1 indicates poor satisfaction and 10 indicates excellent satisfaction.

![Figure 1: Audiograms of all participants. Individual thresholds are plotted in grey. Red and blue solid lines represent the average right and left mean hearing thresholds, respectively.](image-url)
A laboratory evaluation of speech recognition was completed with all 41 participants, in which an unaided condition, a unilateral telephone condition and a bilateral (ear-to-ear) telephone condition were compared. Acoustic unilateral and acoustic bilateral telephone memories were programmed for each participant with the participant’s chosen “phone ear” remaining consistent between the two memories. To ensure audibility, adjustments to the telephone memories were made while each participant listened to a recorded telephone passage over the test phone in the unilateral telephone memory. Any adjustments made to the unilateral telephone memory were also applied to the ear-to-ear phone streaming memory. To simulate a real-world phone conversation, the Connected Speech Test (CST; Cox, Alexander, & Gilmore, 1987), which is rich in contextual cues, was used to assess speech intelligibility in a laboratory setting. The test is comprised of 24 passage pairs (e.g., Carrot/Grass) that are approximately equal in intelligibility. Key words in each sentence are scored, resulting in an overall percentage correct (Cox, Alexander, Gilmore, & Pusakulich, 1988). The speech signal was routed from a desktop computer to a Siemens OptiPoint 500 landline telephone using a Sandman Handset Audio Feeder.

Prior to administering the test, a trial run was completed using the unilateral acoustic telephone memory to determine the appropriate presentation level for approximately 50 percent correct performance. This level was then used as the presentation level for all of the experimental conditions. The minimum presentation level was 55dB SPL and the maximum presentation level was 75dB SPL. The participants were seated in a quiet clinical fitting room, and they were informed of the sentence topics prior to beginning each test condition, in accordance with the instructions for administration of the CST. The participant was instructed to hold the phone to the hearing aid, and proper placement was confirmed by the clinician before testing began. The hearing aid microphone for the opposite ear was attenuated by 40dB for the unilateral condition and was turned off for the bilateral condition. After each condition was complete, participants were asked to rate their listening effort on a scale from 1-7 (1=No effort; 7=Extreme effort) (Johnson, Xu, Cox, & Pendergraft, 2015).

Results

Subjective ratings obtained from field trial questionnaires indicated that a majority of participants rated sound quality and speech understanding as “OK” to “Very Good” with the ear-to-ear phone streaming feature (Figure 2).

Analysis of the speech intelligibility laboratory evaluation results revealed significant benefit with the ear-to-ear phone streaming feature when compared to both the unaided and unilateral conditions (Figure 3). A repeated measures analysis of variance (RM-ANOVA) revealed a significant effect of test condition on CST performance; F(2, 80)=5.209, Greenhouse-Geisser adjusted $\varepsilon=0.779$, p=0.008. Using Tukey’s Honestly Significant Differences, post-hoc testing revealed no significant difference between the unaided and unilateral conditions (p>0.05). The differences between the unaided and bilateral conditions and the unilateral and bilateral conditions were significant (p=0.015 and p=0.014, respectively).

Benefit with the ear-to-ear phone streaming feature was calculated by subtracting participants’ scores in the unilateral condition from their scores in the bilateral condition. As illustrated in Figure 4, there was a significant positive correlation between overall satisfaction with the ear-to-ear phone streaming feature and laboratory benefit ($r=0.48$; p=0.02), suggesting that participants’ satisfaction with the feature may be predicted by the speech intelligibility benefit they receive.

Finally, analysis of the participants’ listening effort ratings indicated a significant improvement in listening effort when comparing the unaided and bilateral telephone listening conditions (Figure 5). Listening effort data were analyzed using a RM-ANOVA and revealed a significant effect of condition
F[2, 80]=3.592, Greenhouse-Geisser adjusted ε=0.9198, p=0.032. Post-hoc testing, using Tukey’s Honestly Significant Differences, revealed no significant difference between the unilateral and bilateral conditions (p>0.05) and no significant difference between the unilateral and bilateral conditions or the unaided and unilateral conditions (p>0.05).

Figure 2: Subjective ratings of overall sound quality and speech understanding. The majority of participants rated sound quality and speech understanding as “OK” to “Very Good.”

Figure 3: CST performance across all three conditions. Box plots summarize CST performance (in percentage correct) for all participants (N=41) as a function of three listening conditions: unaided, unilateral telephone use, and bilateral telephone routing. Box-plot whiskers indicate the minimum and maximum values. The median value is the solid line, and the mean is the white, dashed line. Lower and upper boundaries indicate the 25th and 75th percentiles, respectively. Statistical analysis revealed no significant difference between the unaided and bilateral conditions (p=0.032) and no significant difference between the unilateral and bilateral conditions or the unaided and unilateral conditions (p>0.05).

Figure 4: Overall satisfaction with the ear-to-ear phone streaming feature versus benefit. There is a positive correlation between laboratory benefit and overall satisfaction ratings from the field (r=0.48; p=0.02).

Figure 5: Listening effort ratings across all three conditions. Statistical analysis revealed a significant difference between the unaided and bilateral condition (p=0.032) and no significant difference between the unilateral and bilateral conditions and the unaided and unilateral conditions (p>0.05).
Conclusion

The primary goal of this study was to demonstrate improved speech intelligibility when listening to a bilateral telephone signal compared to traditional unilateral phone listening. Analysis of data collected in the laboratory revealed a significant difference between the unaided and bilateral conditions and between the unilateral and bilateral conditions. These results demonstrate that bilateral presentation of the telephone signal, via 900sync Technology in Muse hearing aids, may result in improved sound quality and speech understanding, reduced listening effort and greater satisfaction for hearing aid users when communicating on the telephone.

References


