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ORIGINAL RESEARCH

Objective and perceptual comparisons of two bluetooth hearing aid assistive devices

Jackie L. Clark[a,b], Carmen Pustejovsky[c] and Sven Vanneste[a]

[a]University of Texas, Callier Center for Communication Disorders, Dallas, TX, USA; [b]University of the Witwatersrand, Johannesburg, South Africa; [c]Heard it Through the Grapevine; Grapevine, TX, USA

ABSTRACT

Purpose: With the advent of Bluetooth technology, many of the assistive listening devices for hearing have become manufacturer specific, with little objective information about the performance provided.
Method: Thirty native English-speaking adults (mean age 29.8) with normal hearing were tested pseudo-randomly with two major hearing aid manufacturers' proprietary Bluetooth connectivity devices paired to the accompanying manufacturer's specific hearing aids. Sentence recognition performance was objectively measured for each system with signals transmitted via a land-line to the same iPhone in two conditions.
Results: There was a significant effect of participant's performance according to listening condition. There was no significant effect between device manufacturers according to listening condition, but there was a significant effect in participant's perception of "*quality of sound*".
Conclusions: Despite differences in signal transmission for each devise, when worn by participants both the systems performed equally. In fact, participants expressed personal preferences for specific technology that was largely due to their perceived quality of sound while listening to recorded signals. While further research is necessary to investigate other measures of benefit for Bluetooth connectivity devices, preliminary data suggest that in order to ensure comfort and compatibility, not only should objective measures of the patient benefit be completed, but also assessing the patient's perception of benefit is equally important.

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➤ IMPLICATIONS FOR REHABILITATION

- All professionals who work with individuals with hearing loss, become aware of the differences in the multiple choices for assistive technology readily available for hearing loss.
- With the ever growing dispensing of Bluetooth connectivity devices coupled to hearing aids, there is an increased burden to determine whether performance differences could exist between manufacturers.
- There is a growing need to investigate other measures of benefit for Bluetooth hearing aid connectivity devices that not only include objective measures, but also patient perception of benefit.

Background

Telephone usage is important to people of all ages and is by far one of the most common technologies used across populations, and people with hearing loss are no exception.[1] Various market surveys have repeatedly shown that individuals with hearing loss continue to have residual difficulties when using hearing aids. In particular, patients tend to site communication on a telephone as one of the top reasons that they choose not to use hearing aids.[2] There are multiple factors that contribute to these residual difficulties including auditory status, environmental factors, health factors, psychosocial and cognitive factors and situational/lifestyle needs. In fact, since hearing impairment implies challenges in communication, finding a way to successfully use the telephone is of paramount importance. As successful telephone use continues to be one of the most common residual difficulties amongst people with hearing loss, it is no surprise that a great deal of commercial endeavors have recently focused on improving telecommunication assistive devices coupled to a hearing aid.

Various methods in assistive listening devices used over the past years to ease the telecommunication challenges faced by hearing-impaired individuals include telecoils residing inside the body of hearing aids, neckloops and Bluetooth technology. One of the early solutions that are sensitive to electromagnetic signals, the telecoil, is a tiny coil of wire around a core permanently residing within the body of a hearing aid. Despite providing an improved signal-to-noise ratio (SNR) when properly placed and oriented within a hearing aid, telecoils can be susceptible to interference and degradation of speech signals[3] from several everyday appliances (e.g., computers, digital cell phones, power lines and fluorescent lights). When the telecoils are even slightly misaligned, the signal may be received in neither or only one of the set of hearing aids. Generic neckloops are body-worn devices that convert and send an electromagnetic signal to the telecoil residing in hearing aids. While this technology does have the potential of providing a binaural advantage it requires the use of a larger telecoil, which is susceptible to interference. A newer solution, Bluetooth technology, has recently been embraced by the hearing aid industry as an effective means of overcoming phone communication challenges with less interference. Bluetooth technology allows a wireless binaural signal

CONTACT Jackie L. Clark, PhD jclark@utdallas.edu University of Texas at Dallas, Callier Center, 1966 Inwood Road, Dallas, TX 75235, USA

transmission from an equipped telecommunications device, such as cell phone, to a receiver device that is either body worn around the neck or in the pocket directed to the patient's hearing aids.[4] Hearing aid manufacturers have produced proprietary wireless Bluetooth assistive listening devices that interface exclusively with each manufacturer's hearing aids without engaging the less reliable telecoil technology. As such, the wearer reaps the benefits of smaller hearing aids while yielding a binaural advantage and eliminating telecoil interference problems.

Recent comparisons of the three telecommunications devices described earlier, when used by experienced hearing aids users listening on a cell phone showed significant improvement with binaural Bluetooth transmission over the other two devices [3,4] Audiologists make recommendations to solve patient communication challenges resulting from hearing loss. Such decisions frequently begin with hearing aids and often times extend into various assistive listening devices specific to the patient's needs. It is important for all professionals who work with individuals with hearing loss, to be aware that there are now multiple choices for assistive technology readily available. Since the newest line of assistive technologies have become manufacturer specific, hearing aid recommendations are often made in light of objective evidence that details ability of listeners in all listening environments. Certainly, Bluetooth assistive listening devices influence hearing aid recommendations. Not only do hearing aid manufacturers claim to offer the best sound quality while providing the wearer superior ability to participate in everyday listening situations when wearing hearing aids, but also when wearing the wireless devices for telecommunication devices specific to the manufacturer. Of course, each manufacturer boasts exceptional quality and wearer's ability to hear in every situation, but because of the proprietary information surrounding all of the products, it is not possible to methodically investigate the formulas and algorithms that control the products electronics.

As previously mentioned, there is evidence of significant improvement in listening performance of hearing aid users when interacting with Bluetooth technology than with telecoils in hearing aids and neckloops. However, there is no documented evidence that commercially available Bluetooth assistive listening devices will provide comparable sound quality and performance between manufacturers. This study investigated whether listeners perform comparably when using two different manufacturers' unique proprietary Bluetooth assistive listening devices coupled with each manufacturers' premium receiver in the ear (RITE) hearing aid while in the presence of an auditorily friendly and hostile environment.

Materials and methods

Participants

Due to the very nature of a compromised auditory system, individuals with hearing loss have unpredictably wide ranging abilities of understanding speech in quiet and noise. For consistency in the performance found in healthy auditory systems, it was determined to recruit normal hearing participants in this study. A total of thirty native English-speaking normal hearing adults (defined as symmetrical behavioral pure tone average 25 dB or better) between the ages of 19 and 50 (mean age 29.8; 22 females) were recruited. Participants exhibited no evidence of middle ear pathology (as indicated by normal tympanograms and participant self-report). In addition, participants reported no additional medical history that would interfere with performing the required tasks. In accordance with ethical guidelines, all participants provided informed written consent after the procedures were explained.

Hearing aid fitting

All participants were binaurally fitted with premium level RITE hearing aids from two manufacturers (Manufacturer A and Manufacturer B) with their accompanying dedicated and proprietary Bluetooth assistive listening device. These specific manufacturers were chosen because they are considered industry leaders who produce equally high quality and reliable products, but with some programming differences. Both sets of products (i.e., RITE hearing aids and Bluetooth devices) are digitally programmable through proprietary computer software unique and created by each manufacturer for their line of products. A wireless interface was used during programming of all hearing aids for each participant's unique individual thresholds according to manufacturer specifications. Once paired, both Bluetooth devices automatically connect to the specified hearing aids as well as other devices (e.g., cellphones, landlines, etc.). While both manufacturers' instruments have been programmed with a "first fit" formula, they potentially could allow for volume adjustment when paired with telephone but differ in two ways:

Manufacturer A hearing aids reportedly provide a wide frequency range of audibility in order to increase speech understanding, with microphones that can be attenuated/muted permanently through the programming software. The programming software also allows the audiologist to adjust a wide range of attack and release times as well as compression ratios for the programmable hearing aids.

Manufacturer B hearing aids reportedly deliver greater linear input without distortion and thus fewer artifacts in noisy environments while getting access to more soft level, it can be muted at will by the patient with a button on the device. The programming software allows the audiologist to adjust only the compression ratios for the programmable hearing aids.

Both hearing aids external omni-directional microphones were activated with no attenuation allowing the target speech signal to be mixed with noise from the listener's environment during presentation. Real ear verification system (Audioscan Verefit and KEMAR) confirmed comparable amplification (within 5 dB) for frequencies 500–6000 Hz across participants. The external microphones on the hearing aids were set to default/start-up gain (no added attenuation) when the Bluetooth device was in use. Volume control was disabled on all hearing aids so that the participants were unable to change the volume while using the devices. In an effort to reduce the perception of "hollow" or "echo-like" sounds (occlusion effect) for the participants while wearing the hearing aids, standard size 6 mm open domes with standard receivers from each manufacturer were used.

Testing conditions

All testing was conducted utilizing two professional offices (one office occupied by the participant and researcher; one office occupied by the signal controller) in which environmental noise was rigorously controlled at less than 40 dBA (OSHA, 2007). While wearing each manufacturer's systems consecutively, all participants listened to the CID Everyday Sentences at 65 dBA in two conditions, quiet (no competing background noise) and five speaker multi-talker babble.

In the signal controller office, three of 10 lists, each list with 10 sentences with a total of 50 target words, from the CID Everyday Sentence Test were pseudo-randomly chosen and presented in their entirety at 65 dB A: in the quiet condition, and two separate lists in the noise condition. In order to simulate the typical distance of a talker from a phone, the standard analogue landline phone transmitter was held 2 inches away from the loudspeaker in which the target signal was emitted.

In the room occupied by the participant, a presentation of the recorded competing background noise was accomplished with participants seated 1 m from a loudspeaker. A 65 dB A level was chosen as more commonly found in restaurants, shopping malls and other everyday listening environments. Each participant was instructed to ignore the multi-talker babble background noise coming from the loud speaker (when it was present) and repeat the target speech sentence signals transmitted to their Bluetooth device and RITE hearing instruments via iPhone. Participant's performance scores were calculated as a percentage of total words correct (from a base of 50 target words), the one quiet and two averaged noise list scores were compared for statistical purposes. Since all hearing aids were set to the same amount of amplification as a result of all having normal hearing, it was possible to maintain consistency of SNR across all participants.

Procedures

All participants were first familiarized with each of the Bluetooth devices prior to proceeding with testing. Choice of order of manufacturer system for use was also based on pseudorandom selection. Once both listening conditions were completed with one manufacturer's system, the participants were then fit with the other manufacturer's equipment to undertake the same test battery as detailed above. After testing was complete for both manufacturers' systems, participants were asked to subjectively rate on a 5-point Likert scale (5 = very good, 4 = good, 3 = average, 2 = poor, and 1 = very poor) as given in the following:

- How would you rate the volume level of system A?
- How would you rate the volume level of system B?
- How would you rate the sound quality of system A?
- How would you rate the sound quality of system B?
- How would you rate the speech-to-noise level of system A?
- How would you rate the speech-to-noise level of system B?

Results

As mentioned previously, participant's performance while listening to two unique Bluetooth enabled systems were objectively measured with a percent score correct from their responses words presented in a quiet and noisy condition. Group average scores (and standard deviation) were then computed. As seen in Figure 1, a repeated measures ANOVA with condition (Quiet versus Noise) × manufacturer (A versus B) as within-subjects variables yielded a significant main effect for condition between quiet and noise conditions ($F(1,29) = 261.44$, $p < 0.001$) indicating, not surprisingly, that the performance improved during the quiet condition in comparison to the noise condition. A comparison between manufacturer systems showed no significant effect ($F(1,29) = (0).23$, $p = 0.64$). In addition, no interaction effect was obtained between the condition and the manufacturers, indicating that the differences were not statistically significant between manufacturers in either condition. In fact, group performances in the quiet condition while utilizing Manufacturer A system was 97.1% correct (SD = 3.99) compared to performance utilizing Manufacturer B system of 95.93% correct (SD = 6.82). Group performances in the multi-talker babble noise condition when utilizing Manufacturer A was 54.87% correct (SD = 17.88) and 53.93% correct (SD = 20.42) for Manufacturer B.

A repeated measure ANOVA was completed for average subjective personal preferences for overall characteristics by manufacturer according to "*speech-to-noise level*", "*volume*" and "*sound quality*" in one model. In general, the participants perception of "*speech-to-noise level*" characteristic for both manufacturer's system's ranked significantly lower (poorer) than the other two characteristics of sound quality and volume ($F(2,58) = 33.37$, $p < 0.001$). As seen in Figure 2, however, no significant difference could be obtained between "*speech-to-noise level*" ($F(1,29) = 0.50$, $p = 0.49$), "*volume*" ($F(1,29) = 0.01$, $p = 0.94$) and "*sound quality*" ($F(1,29) = 1.36$, $p = 0.25$) between Manufacturer A in comparison to Manufacturer B. When comparing the average, calculating the mean score over "*speech-to-noise level*", "*volume*" and "*sound quality*", over the two manufacturers no significant effect could be obtained ($F(1,29) = 0.01$, $p = 0.94$).

In addition to analyzing group averaged data, a closer examination of individual participant's preference was undertaken by disregarding numeric scores, but rather identify which manufacturer's system scored better according to the specific characteristics for each participant. For example, if a participant scored Manufacturer A as 4.0 and Manufacturer B as 2.0 for volume, the participant would show Manufacturer A as a preference since Manufacturer A scored higher than Manufacturer B. In the instance where a

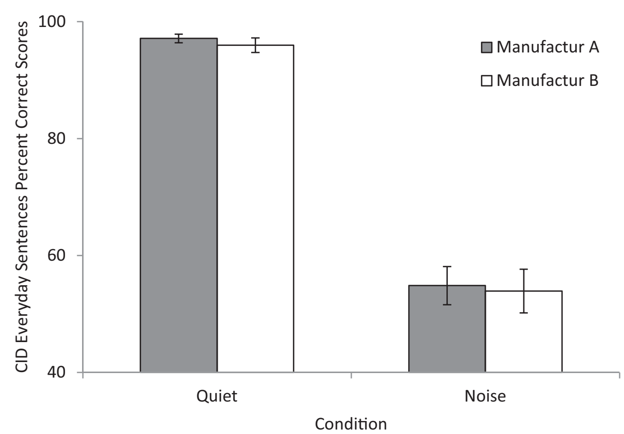

Figure 1. Group mean (and standard deviation) CID Everyday Sentence performance (% correct scores and standard deviation) for each condition (Quiet and in presence of background noise) according to manufacturer.

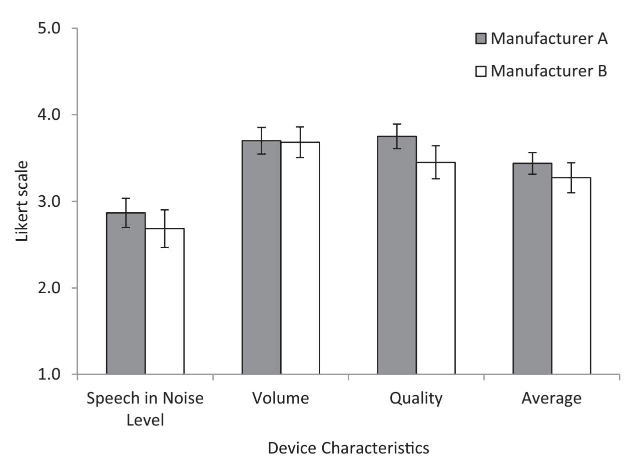

Figure 2. Group mean (and standard deviation) subjective ratings of device characteristics for each manufacturer. Device characteristics included: *"volume", "sound quality", and "speech-to-noise".*

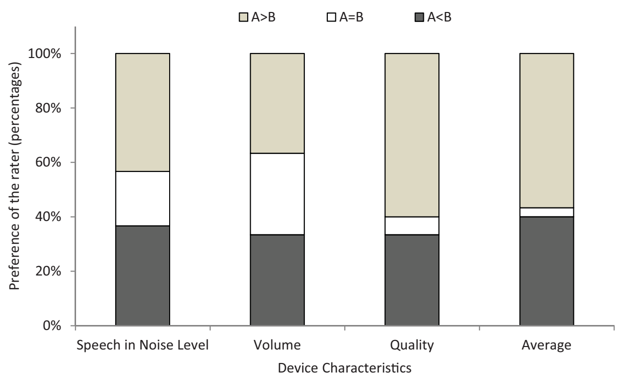

Figure 3. Individual subjective preference for manufacturer system according to device characteristics (*"volume", "sound quality", "speech-to-noise"*).

participant scored Manufacturer A and B as equivalent, an indicator of "*no preference*" was shown in the data. As seen in Figure 3, after conducting an analysis of variance, there were no equivocal differences in preference for "*volume*" for the systems ($\chi^2(1) = 0.04$, $p = 0.84$). It would stand to reason that the participants found volume setting comfortable and appropriate due to programming of the hearing aids regardless of manufacturer. When analyzing the characteristics of "*sound quality*" and "*speech-to-noise level*" there was specific manufacturer preference. A McNemar test revealed a significant effect of manufacturer according to "*sound quality*" scores, with participants preferring Manufacturer A ($\chi^2(1) = 2.29$, $p = 0.013$). There was a trend towards a significant effect of manufacturer according to "*speech-to-noise level*" ($\chi^2(1) = 0.17$, $p = 0.68$). When comparing the average preference, based on the mean score over "*speech-to-noise level*", "*volume*" and "*sound quality*", for the two manufacturers revealed a no significant effect ($\chi^2(1) = 0.86$, $p = 0.86$).

Discussion

Various market surveys have repeatedly shown that individuals with hearing loss resist wearing hearing aids when they are called for. Some of the multiple factors that contribute to hesitancy in pursuit – and eventual successful use of amplification include auditory status, perception of handicapping condition, environmental factors, presence of co-morbid health status; psychological and cognitive status and situational/lifestyle needs.[2,5] Some individuals cite the importance of ease in communicating on a telephone as a critical determination of pursuing hearing aids. With increased proliferation of Bluetooth assistive listening devices to be dedicated and paired to specific hearing aids, there is an increased burden to determine whether the performance differences could exist between manufacturers. Both objective and subjective measures have an important place in clinical decision-making to ascertain amount of benefit from hearing aids as well as any accessory associated with the instruments, such Bluetooth devices.

This study utilized a unique model to investigate an objective measure of performance for normal hearing listeners using premium level RITE hearing aids and Bluetooth devices paired to a cell phone while in both controlled friendly as well as hostile listening environment. The objective measures of participant's listening performance revealed that very few participant performance differences existed between the two manufacturers.

Inarguably, one goal of evidence-based practice is to provide services that reflect the needs and choices of patients served. This study reinforces the necessity and validity of also gathering subjective feedback about a patient's personal preference and opinions specific to the preferred assistive listening device. Despite objectively measured performance, the participants expressed their own personal preferences for the assistive listening device. More specifically, when participants were asked about preferences according to specific characteristic traits ("*volume*", "*sound quality*", and "*speech-to-noise*") for each manufacturer, there was no significant manufacturer preference expressed for "*volume*". It is possible that the limitation of amplification, due to the participant's normal hearing status, is reflected with no perceived differences between manufacturers for "*volume*". However, there was a significant preference for Manufacturer A when participants considered "*sound quality*" of the incoming signal. In addition, though not significant, there was positive trend noted for preference for Manufacturer A when participants considered "*speech-to-noise*" of the incoming signal. Both "*sound quality*" and "*speech-in-noise*" are more clearly an indicator of participant personal perception and preferences for specific manufacturers. While this study indicated a group performance and preference averages (though, not significantly different), it became necessary to look closer at individual perceptions.

Summary and conclusions

Even after being fit with amplification, the common challenge of hearing aid wearers is to understand phone conversations. It is important for all professionals who work with individuals who have hearing loss, to be aware that there are now multiple choices for assistive technology readily available. Despite recent technological advancements in assistive listening devices for wireless binaural signal transmissions, there has never been verified that all these Bluetooth assistive devices are created equally. The results of this investigation showed that despite differences in proprietary method of signal transmission from the device to the hearing aid, participants performed equally when utilizing manufacturer A as well as B systems. However, after being queried about preferences for Manufacturers, participants indicated a preference of better "*sound quality*" for one manufacturer. While further research is called for to investigate other measures of benefit for Bluetooth assistive listening devices, preliminary data suggests that those measures of benefit must not only include objective measures, but also patient perception of benefit.

Disclosure statement

The authors report no conflicts of interest

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