Music Streaming with Halo 2: Fitting Tips for Patient Success

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Stream Boost versus Music memory

Although the traditional goal of amplification has focused on the audibility of acoustically presented speech, many hearing aid wearers listen to a variety of other important signals on a daily basis. Given that audibility and sound quality of many different signal types are important for hearing impaired patients, Starkey Hearing Technologies has introduced two features in the past several years to improve the listener's experience of signals other than acoustic speech: Stream Boost and the Music memory.

Despite sharing the goal of improving signals other than acoustic speech, these two features differ in many ways. Perhaps the most obvious difference is that Stream Boost is intended to improve the sound quality of non-acoustic, streamed signals (i.e., signals streamed from accessories such as SurfLink Media 2, SurfLink Mobile 2, SurfLink Remote Microphone 2, SurfLink Mini Mobile, and Apple® devices when paired with Halo™ and Halo 2 hearing aids), while the Music memory is intended to improve the sound quality of music presented in the acoustic environment.

The differing goals of these features impacted their design and functionality. Stream Boost (which is synonymous with the Streaming memory) was designed to improve the sound quality of non-acoustic, streamed inputs by mitigating the effects of acoustic leakage, or the loss of amplified information out of the ear, on the hearing aid response. Acoustic leakage occurs in any hearing aid fitting that does not achieve a complete hermetic seal. With a typical acoustic sound source, some sound can enter the ear canal via the hearing aid or earmold vent to replace the amplified information that leaked out of the ear

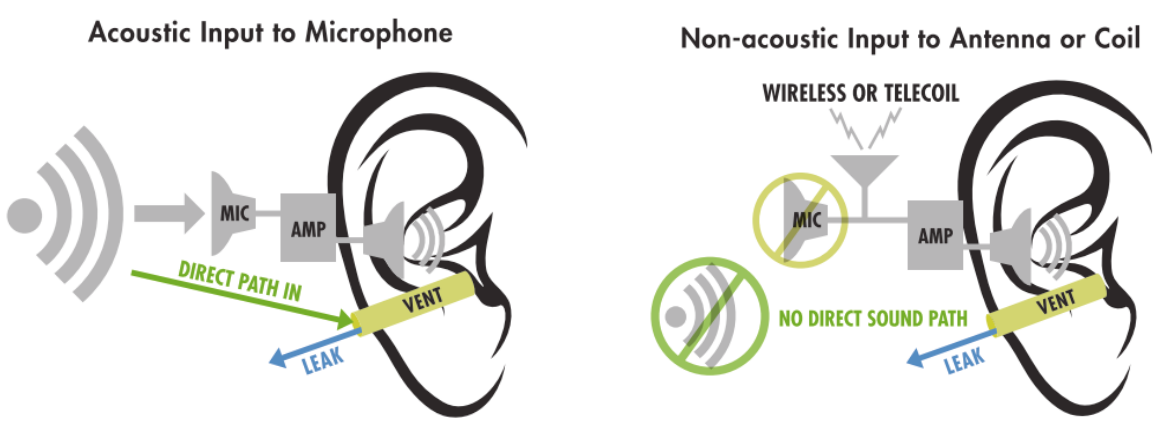

Figure 1: On the left, an acoustic sound source provides a signal to the hearing aid microphones. This signal is amplified and processed by the hearing aid and presented to the patient via the receiver. In addition to the amplified sound, some sound enters the ear through the vent (the direct path). This direct path sound, as illustrated in green, compensates for some of the acoustic leakage. A streaming input signal is illustrated on the right. This signal provides an input to the hearing aid via wireless communication, and the amplified and processed signal is presented to the patient via the receiver. However, in this case, there is no direct path sound, but acoustic leakage still occurs. Even with identical inputs between the two scenarios, the effects of leakage will be most pronounced in the streaming example, as there is no direct path to replace some of the "leaked" low-frequency content. Illustration taken from Pederson & Gruhlke (2016).

(Dillon, 2012; Pederson & Gruhlke, 2016). However, when an input is presented non-acoustically, there is no direct-path sound present to enter the hearing aid wearer's ear canal through the vent. In the case of a streamed audio signal, for example, the hearing aid picks up the signal directly via the wireless antenna housed in the hearing aid. Thus, for non-acoustic signals, there is a loss of amplified information out of the ear with no direct path into the ear canal to compensate. This loss is most severe for fittings with large vents or open fittings. Without the acoustic sound source, the hearing aid must attempt to replace the lost low frequency content on its own; Stream Boost compensates for acoustic leakage by boosting low- and mid-frequency gain when needed to provide better sound quality for streamed inputs to the hearing aid. Figure 1 illustrates the effects of acoustic leakage and the lack of a direct path.

The Music memory, by contrast, is designed to provide the best possible sound quality for the wide bandwidth and dynamic range found with acoustic music listening. To accomplish this goal, the Music memory aims to provide enough amplification to ensure audibility for soft music, while avoiding distortion with loud music.

This goal was accomplished by the implementation of a twin compressor. The twin compressor allows the hearing aid to provide audibility of soft music signals while allowing for the amplification of moderate to loud music signals (excluding those reaching MPO) to be linear. This helps the patient hear not only soft music, but also a full contrast between soft and loud, thus allowing the hearing aid wearer to enjoy a full dynamic range (Scheller & Fitz, 2016).

Streaming Music with Halo 2

Many hearing aid users utilize streaming as a means of enjoying their favorite music. In particular, Halo 2 hearing aids and the TruLink® mobile application are designed to maximize streaming flexibility for the patient, as patients are able to stream music, phone calls, and other audio directly from their Apple device to their Halo 2 hearing aids. The clinician is then left to ask, "Should my patients stream music using the Stream Boost memory or the Music memory?" Although Starkey Hearing Technologies took care to validate and refine the new Music memory for acoustic music listening, the question still remained how it would compare to Stream Boost as a memory for streamed music.

This question is especially important as the TruLink app gives patients the ability to change the default memory for streaming audio to the dedicated Music memory, *Normal, or any other professionally or custom-made memory. Patients even have the flexibility to create a different default memory setting for streaming phone calls from other streaming audio, such as music, since what is best for music is not necessarily best for speech (Scheller & Fitz, 2016).

Because Halo 2 and the TruLink app offer this flexibility, Starkey Hearing Technologies set out to understand if patients would prefer listening to streaming music in Stream Boost or the Music memory, with the goal of being able to provide evidence-based fitting tips to clinicians. During the clinical trials for the Halo 2 RIC 312 hearing aid, a two-alternative forced-choice experiment was conducted, where the participants made blind preference judgments between Stream Boost and the Music memory. Real-ear measures in Stream Boost and the Music memory were made to help provide further insight into why a preference, if any, might exist.

Clinical Trial Participants

A total of 19 hearing impaired participants were recruited from the Twin Cities metropolitan area. All participants had sensorineural hearing loss and ranged in age from 24 to 77 years, with an average age of approximately 63 years. There were 15 males and four females in the study. Fourteen of these participants were previous users of amplification.

All participants were fit with Starkey Halo 2 i2400 RIC 312 hearing aids and had the TruLink mobile app installed onto their personal smartphones. Participants without a personal smartphone were provided one for their use during the study. Hearing aid matrix selections were made as appropriate for the participants' individual hearing losses. Seven participants were fit with custom Absolute Power 70-gain receivers (AP70) with a medium vent, and the remaining 12 participants were fit with stock 50-gain receivers and Comfort Fit open earbuds. Participants were fit to Starkey Hearing Technologies' proprietary fitting formula, eSTAT, for use during the study. Real-ear measurements were performed to verify audibility.

Participants were seen for three sessions over a four- to six-week period. The forced-choice experiment was conducted at each participant's final session. Due to time and scheduling constraints during the clinical trial, two participants were unable to complete the forced-choice experiment (final n=17). Figure 2 displays the individual audiograms (in dark grey) and mean audiograms (red and blue for right and left, respectively) for all 17 participants completing the experiment, subdivided by fitting matrix group.

Experimental Procedure

The paired comparison experiment was conducted during the final session of the Starkey Halo 2 RIC 312 clinical validation. Prior to the final session, each participant had worn the devices for a period of approximately four weeks and had reported back on their general observations and impressions.

At the third session, before participants began the forced-choice experiment, Streaming and Music memories were enabled at Best Fit for all participants, and Music Adaptation (an option in Environment Manager in the Inspire® fitting software) was set to "off" for the Streaming memory (note: this feature defaults to "off" for the Music memory, so no change was necessary). Memory and TruLink indicators were deactivated (to keep the participants blind during the experiment).

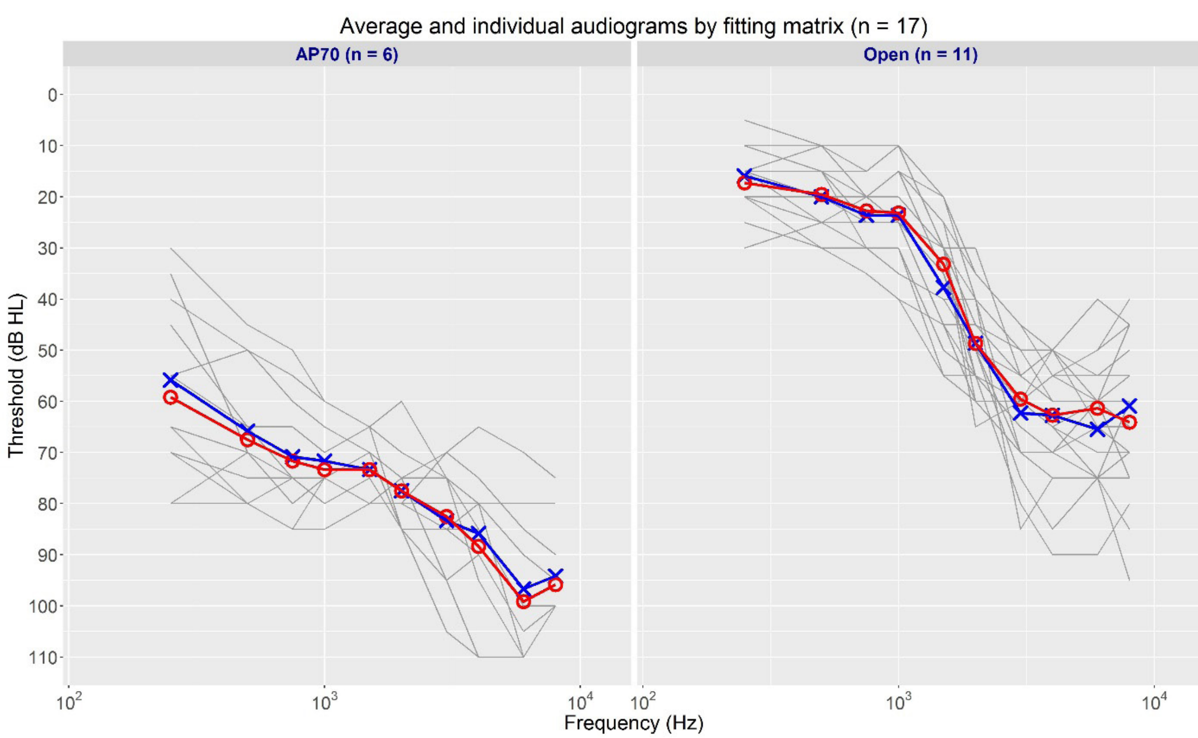

Figure 2: Mean (red/blue) and individual (grey) audiograms for the participants included in the study. On average, AP70 participants had a moderately severe-to-profound sensorineural hearing loss, while open fit participants had normal hearing sloping to a moderately severe sensorineural hearing loss.

To complete the paired comparison experiment, participants were seated in a sound-treated booth and their hearing aids were paired to a Starkey-owned iPhone® 5S with the TruLink mobile app installed. During the testing, participants made comparisons in a two-alternative forced-choice task between the Streaming memory and the Music memory for two different song samples. The samples, taken from Beethoven's *Egmont Overture* and Frank Sinatra's *World On a String*, were each 30 seconds long and were streamed from the Starkey-owned iPhone to the participant's hearing aids. Ten A/B comparisons were made for each song sample for a total of 20 comparisons per participant. The researcher controlled the song playback and the hearing aid memory setting from inside the booth using iPhone. While the clips were streaming, the hearing aid microphones were muted to help reduce the impact of any environmental noise on the participant's judgement.

For each comparison, the participant was presented with the song sample twice, one time in each memory, and was asked to select his or her preferred memory for listening. The order of the songs was counterbalanced across all participants; all 10 trials for each song sample were completed as a single test block. Within each of the two blocks, the order of presentation for the memories was randomized and counterbalanced.

Following the paired comparison testing, the hearing aid microphones were unmuted, and real-ear measurements were made in the Streaming and Music memories with each participant. Real-ear measurements were conducted using an Audioscan Verifit 2 with International Speech Test Signal (ISTS) (Holube, Fredelake, Vlaming, & Kollmeier, 2010) presented at 50, 65, and 75 dB SPL, and a pure tone sweep at 85 dB SPL to measure maximum power output (MPO). ISTS was selected as the input stimulus for measurements as its development was well documented (Holube, Fredelake, Vlaming, & Kollmeier, 2010), it is readily available on the Verifit 2 system, and it has a known frequency spectrum. Probe tubes were measured to ensure an insertion depth of approximately 28 mm for each participant.

Results

An exact binomial test revealed no significant preference for either the Streaming or Music memory (with both songs combined) for the open fit participants ($p > 0.05$), while the AP70 participants did show a statistically significant preference for the Streaming memory ($p < 0.0001$). A Chi-squared test indicated there was not a significant preference for either Stream Boost or the Music memory between the two song samples for either the AP70 ($\chi^2 = 0$, = 1, = 1.0) or open fit participants ($\chi2 = 0.295$, = 1, = 0.59). See Figure 3.

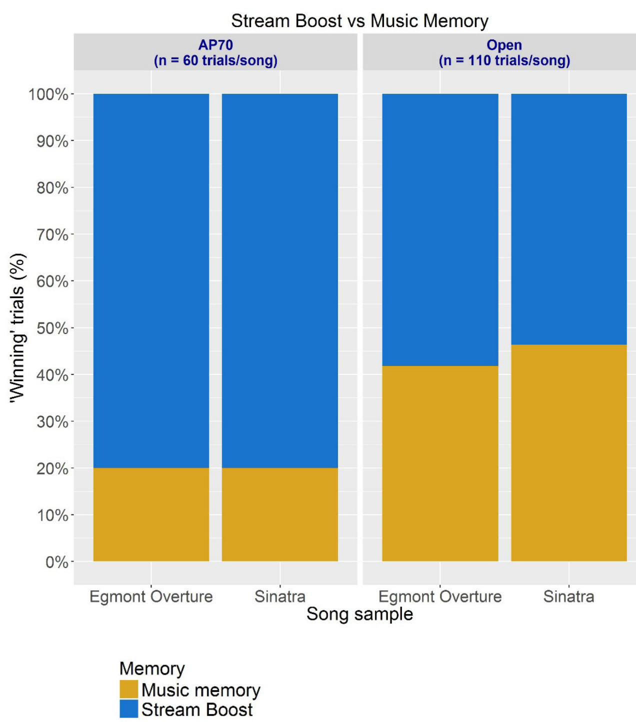

Figure 3: Results for each matrix group for the forced-choice task. Results are presented as a proportion for which each memory was selected out of all trials. For the AP70 group, there were a total of 60 trials for each song (ten trials for each of six participants), and for the open group, there were 110 trials for each song. For the open group, Stream Boost and the Music memory were selected nearly equally often (p > 0.05). However, for the AP70 group, Stream Boost was selected on 80% of all trials for both songs (p < 0.0001).

By coincidence, AP70 participants had exactly the same number of total selections (as a group) for each memory for the Beethoven and Sinatra song samples. For this reason, the test statistic is 0 and p-value is 1.

Insights from Real-Ear Measures

Real-ear measurements collected during the study were examined to determine whether there was a relationship between the hearing aid output and each participant's subjective memory preference. The difference of the real-ear SPL (RESPL) measured in the Streaming memory minus the RESPL measured in the Music memory was calculated. Further, only participants with a strong preference (determined prior to the analysis to be 70 percent of trials or more) for a memory were included. Only two participants were deemed to be indifferent using this metric (n = 15). This was done to aid in determining what, if any, differences in frequency response may have been contributed to subjective preference.

For the open fit participants, there was not an apparent relationship between RESPL and subjective preference. For all but one participant in the open fit group, the Music memory provided equivalent or higher output than the Streaming memory, particularly in the low frequencies, and yet the participants were roughly split on subjective preference.

The AP70 fittings showed a clearer relationship between RESPL and preference, however. Low frequency output was greater in the Streaming memory than in the Music memory for all but one AP70 participant, and these participants preferred the Streaming memory. The one AP70 participant who did have higher low frequency on-ear output in the Music memory preferred that memory. This relationship is illustrated in Figure 4.

Discussion of Results

The present study included two subsets of participants: one with more severe hearing losses who were fit with AP70 receivers, and one with less severe hearing losses fit with Comfort Fit open earbuds. While the AP70 receivers were all made with a medium vent (approximately 1.6 mm in diameter), the AP70 molds were expected to be more occluding than the open earbuds.

For participants with a more occluded fitting, real-ear results indicate that Stream Boost is likely to provide more low frequency gain for streamed signals than the dedicated Music memory. In contrast, open fittings may receive more low frequency output from either Stream Boost or the Music memory. Differences in the patients' hearing thresholds and in the degree of acoustic leakage account for these differences between the Stream Boost memory and the Music memory for open fittings.

For occluded fittings, participants in this study showed a strong likelihood to select Stream Boost for streaming music (c.f., Figure 3), and this appears to be based on low-frequency output (c.f., Figure 4). The song sample used did not appear to have an effect on this selection (c.f., Figure 3). Open fit participants did not exhibit a statistically significant preference for one memory over the other for either song sample, which is consistent with the greater degree of variability in the measured low-frequency output for these fittings.

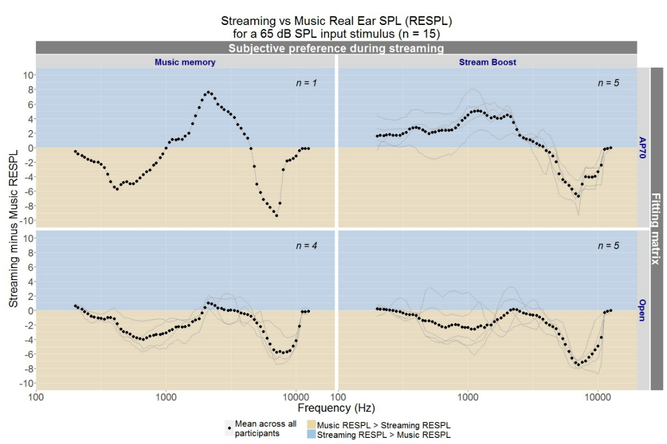

Figure 4: The difference between the Streaming memory RESPL and Music memory RESPL, grouped by fitting matrix and subjective preference during the forced-choice task. Individual participants are shown in grey lines, and the group mean for each of the four panels is given in black dots. Background shading aids the reader in determining whether the Music memory (tan) or Streaming memory (blue) had higher on-ear output. One can observe that, among the AP70 group, there appears to have been a strong association between low frequency RESPL and subjective preference, while results are somewhat mixed for the open fit group.

Conclusion and Clinical Recommendations

The present study demonstrated that patients with an occluded fitting have a preference for increased low frequency output when listening to streamed music. Starkey Hearing Technologies provides this increased low-frequency content via Stream Boost, which is available on all Made for iPhone products. Patients wearing Halo or Halo 2 products can listen to their streamed music in the Stream Boost memory simply by leaving streaming settings within the TruLink mobile app at default. The switch to Stream Boost will occur automatically when streaming begins, and the hearing aids will automatically switch back to the previously selected memory when streaming ends.

Patients with open fittings may not prefer Stream Boost over the Music memory while streaming music signals. Because Starkey Hearing Technologies recognizes that preferences vary widely from one person to the next, the TruLink mobile app allows the user to disable Stream Boost and enable another memory for streaming audio. One simply must go to the information icon next to the memory name on the menu and enable auto-streaming for their preferred memory while streaming. Patients in open fittings should be encouraged, at the professional's discretion, to experiment with streaming in Stream Boost, the Music memory, or other memory environments.

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