Validation of a Hearing Aid Program Designed for Music Listening

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Introduction

With a primary goal of improving speech intelligibility, amplification in modern hearing aids is specifically designed to increase audibility for soft sounds, such as speech, while keeping loud sounds tolerable. However, there are non-speech situations that are important for many hearing aid users. One of these is music listening, in which sound quality, rather than speech intelligibility is of greatest importance.

A survey completed by Cohen, Bailey, and Nilsson in 2002 found that music is judged to be very important even among older adults. Over 60% of respondents, ages 69-100, rated music importance as a 4 or 5 on a five-point scale. Leek, Molis, Kubli, and Tufts (2008) found that, although nearly 80% of participants reported they wore their hearing aids while listening to music, nearly 40% reported that hearing aid use did not improve or was even detrimental to their enjoyment of music.

Improving sound quality for music listening has proven to be a difficult task for clinicians fitting hearing aids. Music and speech differ significantly in many dimensions, including frequency range, crest factor, and overall intensity (Chasin & Russo, 2004). Previous research has suggested that linear gain, increasing the input and output dynamic range, as well as improving the low frequency response may improve music listening satisfaction (Chasin, & Hockley, 2014; Madsen, & Moore, 2014; Madsen, Stone, McKinney, Fitz, & Moore, 2015).

A research study was completed to evaluate a new Music program, consisting of a distinct compression architecture and fitting formula, designed to improve sound quality while listening to music. This new compression architecture and fitting formula have two main objectives: 1) restore audibility for soft music and 2) restore desired loudness for loud music. For low-level music, gain is shaped according to the hearing loss in order to restore audibility for soft music inputs. For loud music, an additional kneepoint is introduced to achieve flat-linear insertion gain at high input levels and to restore loudness for loud music inputs. An input limit of 110 dB SPL allows this loud music to be processed without input saturation. Advanced signal processing features such as automatic adaptive directional microphones, digital noise reduction, feedback suppression, and frequency lowering are designed for improving comfort and audibility in specific listening situations, but can have a deleterious effect on the sound quality of music. Therefore, settings for advanced signal processing features were customized for the Music program.

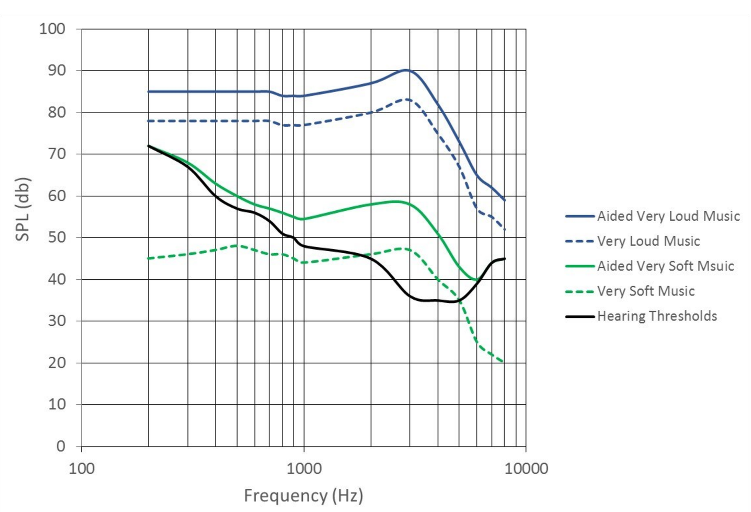

Figure 1. Representation of the fitting goals of the new Music program.

Methods

Participants and Hearing Aids

- 58 individuals with bilaterally symmetrical, mild to severe sensorineural hearing loss were recruited from the Minneapolis, MN metropolitan area (see figure 2*).*
- Participant ages ranged from 47 to 82 years (mean 69.6 years, standard deviation 8.08 years); there were 24 females and 34 males in the study.
- All but 2 participants were experienced users of amplification. One participant was a current monaural hearing aid user.

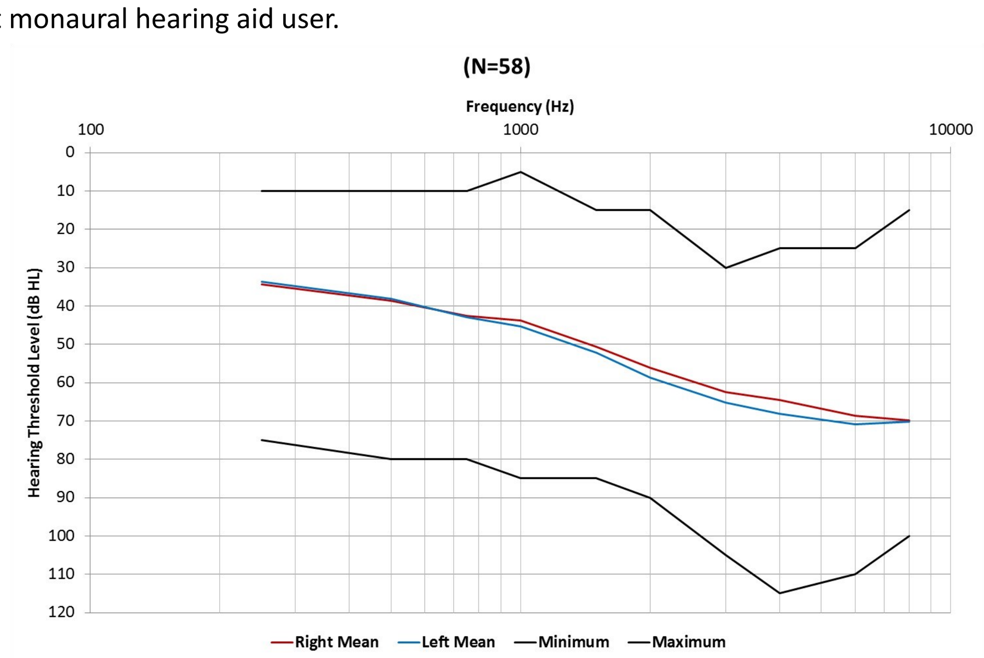

Figure 2. Participant thresholds (dB HL) are shown as a function of frequency (Hz). Red and blue solid lines represent the average right and left hearing thresholds, respectively. Black lines indicate the minimum and maximum thresholds across participants.

Methods, continued

- Participants were compensated for their participation and for their mileage to and from the test facility.
- Starkey Muse i2400 hearing aids were used for all participants.
- Participants were fit with a hearing aid style appropriate to their hearing loss:
  - 8 Behind-the-ear (BTE) with #13 tubing and vented ear mold
  - 11 BTE with thin tube and open ear bud
  - 10 Receiver-in-canal (RIC) with open ear bud
  - 10 RIC with custom vented ear mold
  - 19 vented custom style (6 in-the-ear, 6 in-the-canal, 7 completely-in-canal)
- All hearing aids were fit to Starkey Hearing Technologies' proprietary fitting formula, e-STAT (Scheller & Rosenthal, 2012). Real-ear probe microphone measurements were performed using the Audioscan Verifit hearing aid analyzer in the program used for every day listening (Normal). Minor adjustments were made to gain settings as requested by the participant for his/her comfort.
- Real-ear measurements in the Normal program were obtained using the International Speech Test Signal (ISTS) at 50 dB SPL, 65 dB SPL, and 75 dB SPL, and a pure-tone sweep at 85 dB SPL to set appropriate maximum output (Holube, Fredelake, Vlaming, & Kollmeier, 2010).
- Music listening is a very subjective experience and there are no independently verified prescriptive targets for music. Therefore, initial fitting of the Music program included playing a classical music sample for participants and adjusting the program to their personal preference.

Laboratory Testing

Participants were seated in a sound-treated booth with a speaker at 0 degrees azimuth, approximately 1 meter away. They completed a forced-choice comparison task in which they compared their Normal and Music programs, while listening to three music samples.

Music samples:

- Classical: Brandenburg Concerto No. 4, J.S. Bach
- Female Vocals: Don't Know Why, Norah Jones
- Jazz: The Way You Look Tonight, The Dave Brubeck Quartet

The music samples were presented at 68 dB SPL, and participants compared the Normal program to the Music program 6 times for each music sample. Song order was randomized for each participant. Participants used a custom software and a touch screen to make the comparison choices. This allowed them to quickly and easily switch between the two programs while blinding the participants to the program settings.

Field Testing

Hearing aids were programmed with both a Normal program designed for speech inputs and a Music program. They were asked to listen to music using both programs and make comparisons. Participants filled out questionnaires every two weeks, focusing on sound quality, artifacts, and music listening. Adjustments were made to their hearing aids as needed. Participants requested minimal adjustments to their Music program, on average +/- 2 dB, as seen in figure 3.

Results

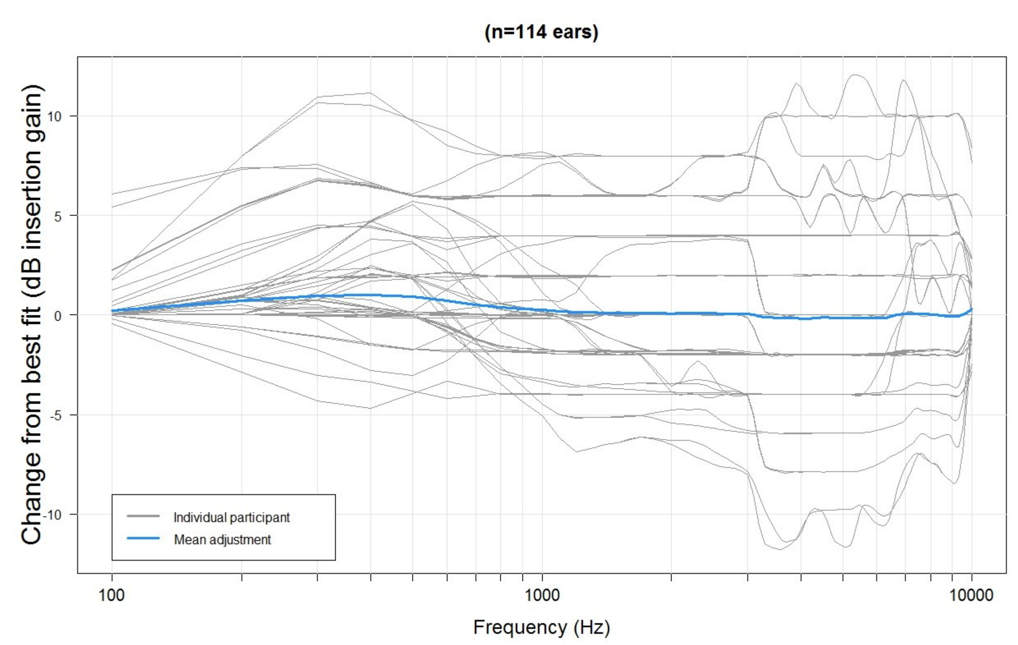

Figure 3. Gain changes (dB) made from baseline settings for soft gain shown as a function of frequency (Hz). Individual participant data shown in gray lines with the mean adjustment shown in blue. 70 of the ears required no adjustments from initial fit.

Results, continued

Laboratory Data

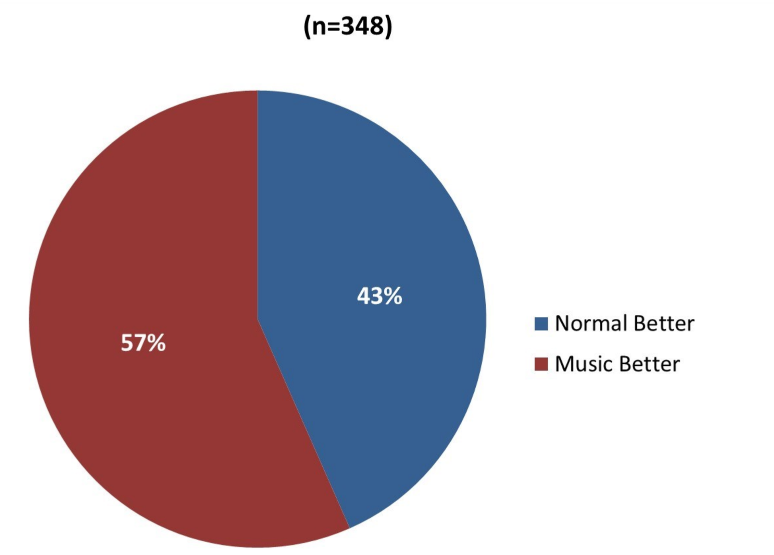

Figure 4. Responses for music listening preference based on the laboratory forced-choice comparison task for "Brandenburg Concerto No. 4,"the classical music sample. Analysis using the Exact Binomial test indicated a statistically significant preference for the Music program (p=0.012)

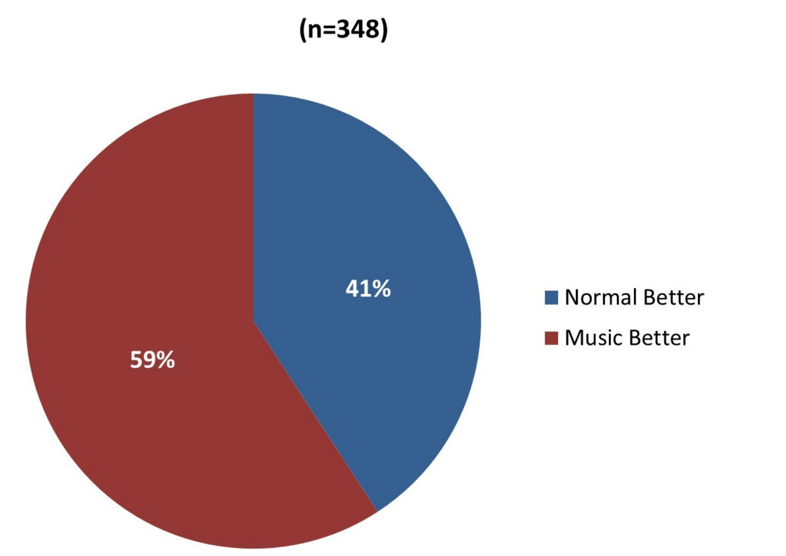

Figure 5. Responses for music listening preference based on the laboratory forced-choice comparison task for "The Way You Look Tonight," the jazz music sample. Analysis using the Exact Binomial test indicated a statistically significant preference for the Music program (p<0.001)

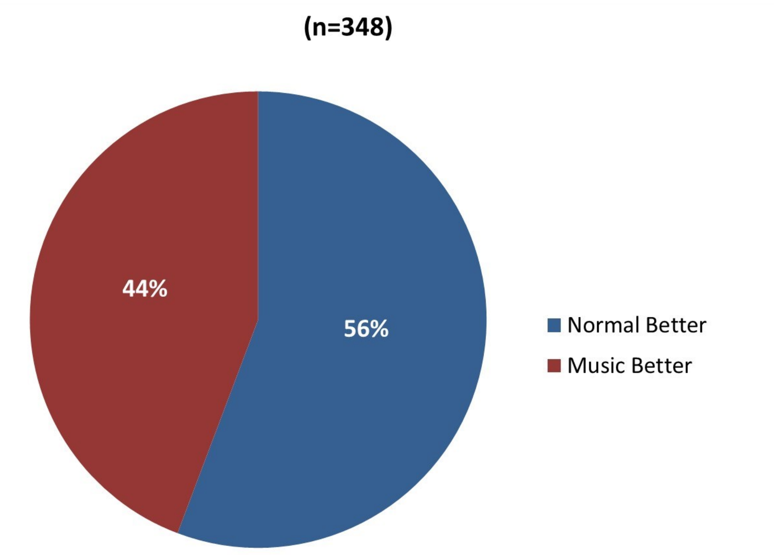

Figure 6. Responses for music listening preference based on the laboratory forced-choice comparison task for "Don't Know Why," the female vocal music sample. Analysis using the Exact Binomial test indicated a statistically significant preference for the Normal program (p=0.028)

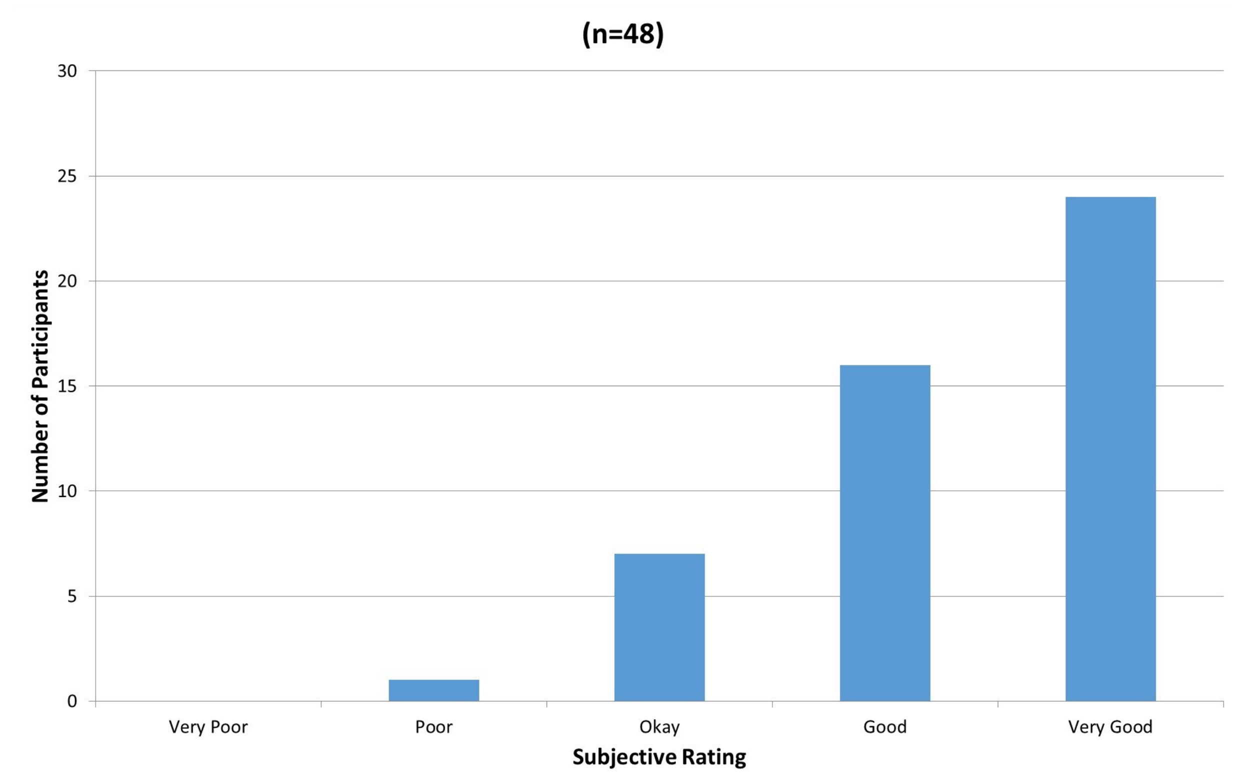

Figure 7. Responses for subjective sound quality rating while using the Music program. Ten participants did not respond, as they did not use the Music program sufficiently during the field trial.

Results, continued

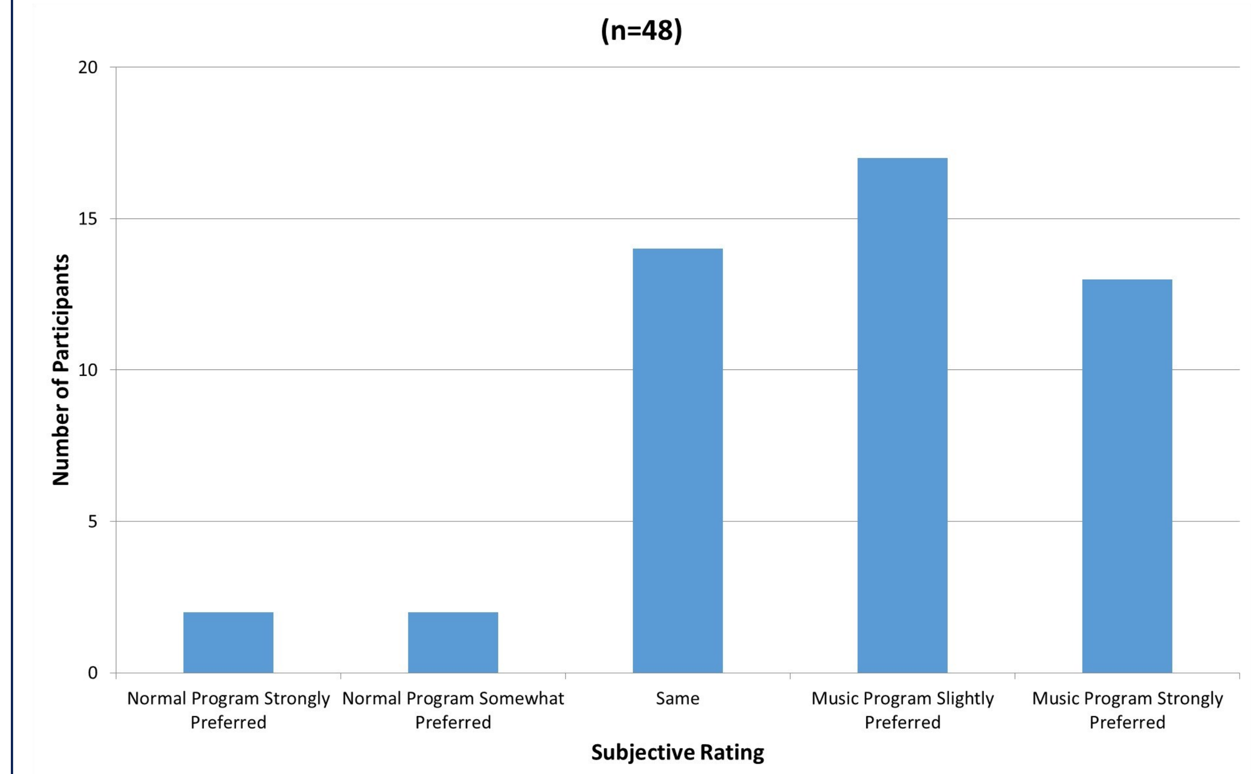

Figure 8. Preference between the Normal and Music programs are shown, based on field trial experience. Ten participants did not respond, as they did not use the Music program sufficiently during the field trial. These data indicate preference for the Music program during music listening.

Summary

- This research study aimed to demonstrate whether a new hearing aid program designed for music listening improved listener satisfaction, when compared to typical hearing aid processing.
- This research study demonstrated the ease of fitting the new Music program. Participants requested minimal gain adjustments, less than 2 dB on average, to the Music program. This demonstrates the success in the initial fitting algorithm.
- Data from the forced-choice comparison demonstrates a significant preference for the Music program over the Normal program. Individual song sample data shows this preference is reversed for "Don't Know Why," which is the only song sample used containing lyrics. The forced-choice comparisons were completed in a sound treated room, typical of an audiometric testing booth. Generally, optimal environments for music listening are more reverberant than a sound-treated booth; therefore these results may not generalize to typical music listening environments.
- Subjective data from the field demonstrated that participants were very satisfied with the sound quality of the Music program, with 40 of 48 participants rating sound quality as good or very good. In addition, among participants who indicated a preference, the new Music program was preferred nearly 8:1 over the Normal program. However, as participants were informed that the new program was designed for music listening, preferences while listening in the field may have been biased.

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Acknowledgments

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