Electroacoustic correlates of subjective sound quality for hearing aid processed music

J. M. Vaisberg, P. Folkeard, E. Macpherson, V. Parsa, & S. Scollie
National Centre for Audiology, Western University, London, ON, Canada
Contact: jvaisber@uwo.ca

INTRODUCTION

Hearing aid design largely reflects speech acoustics – not music.[1]

Hearing aids may not amplify music as effectively as speech.

Manufacturers often include dedicated music programs, although their programs' efficacies are not always fully understood.

Listeners are often dissatisfied with hearing aid music SQ.[2]

Objective 1: Compare SQ of hearing aid processed music across a range of hearing aid models, music programs, and music genres
(a version of the sound quality assessment has been published [3])

Objective 2: Identify electroacoustic parameters associated with relative good and poor-SQ market-level hearing aids

METHODS: Sound Quality

Participants: Adult hearing aid users (n = 26, ages 20-84, μ= 71). Air conduction thresholds ranged from 35-40 dBHL in the low frequencies to 65-70 dBHL in the high frequencies .

Hearing aids: Five leading manufacturers' hearing aids (2017), individually programmed to each participants' thresholds. Participants listened to music clips processed through the music program and "first fit" (universal) program of each hearing aid.

Stimuli: Samples from five genres: classical, jazz, folk, pop, and favourite (chosen by participant). Randomized presentation by generating recordings on a Bruel & Kjaer Head & Torso 4128C simulator. Stimuli were delivered to hearing aids mounted on the head & torso simulator at levels ranging from 60-78 dB SPL and played back via Etymotic Research 2 insert headphones.

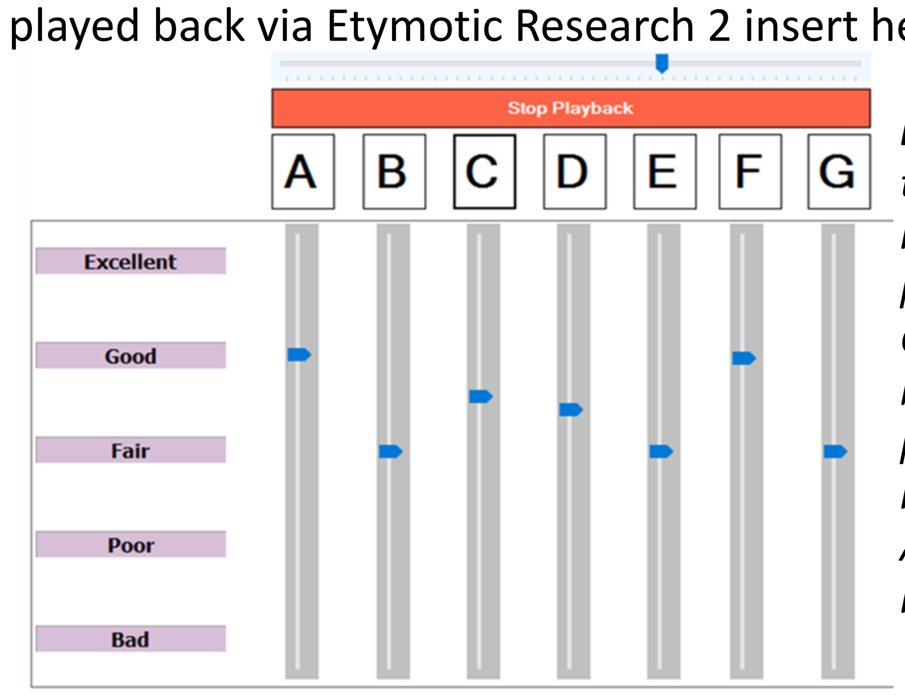

Figure 1: Software used to gather sound quality ratings of hearing aid processed samples. Clicking on each lettered button played the processed sample randomly assigned to it. Adjusting the slider indicated quality ratings.

Sound quality ratings: Obtained using the "multiple stimulus test with hidden references and anchors" (MUSHRA) task.[3]

RESULTS: Sound Quality

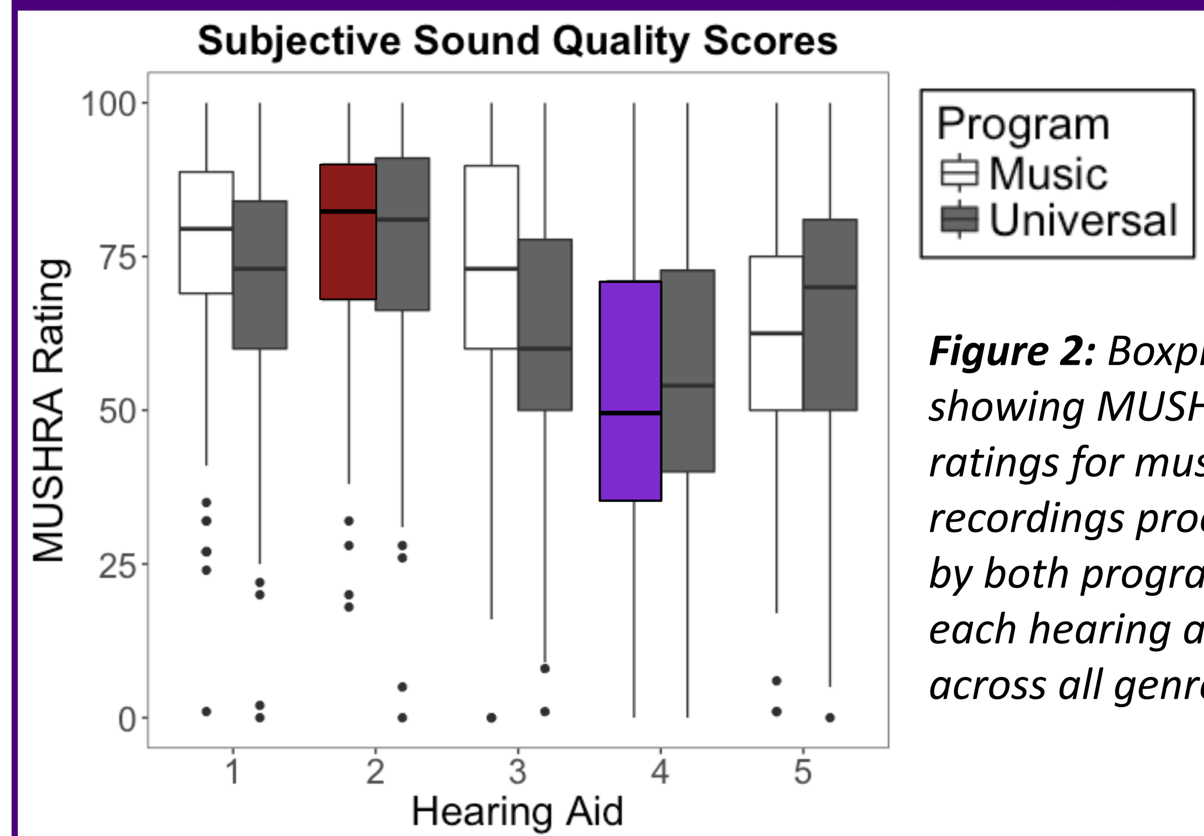

Figure 2: Boxplots showing MUSHRA ratings for music recordings processed by both programs for each hearing aid across all genres.

A repeated measures ANOVA revealed that hearing aid model was a significant factor ($F_{(3.2,79.5)} = 19.7$, $p < 0.001$). HA-2 and HA-4 were rated the highest and poorest, respectively

Within the music program, HA-1 and -2 were rated significantly higher than HA-4 and -5, and HA-3 higher than HA-4.
Within the universal program, HA-2 was rated significantly higher than HA-3, -4, and -5, and HA-1 higher than HA-4.

There was a significant interaction of program by hearing aid ($F_{(4,100)} = 8.3$, $p < 0.001$). The music program significantly improved SQ for HA-1 and HA-3.

METHODS: Electroacoustics

Electroacoustic measurements (related to SQ) were performed on HA-2 and -4 to determine if the measurements can be used to predict relative good- or poor-SQ market-level hearing aids:

Limits of Audibility[5]: The upper and lower limits of audibility, measured by calculating the intersection between the RMS spectrum levels of each stimuli and coupler-based audiograms. Low frequency thresholds were extrapolated to 50 Hz. High frequency thresholds were limited to 8 kHz.

Sensation Level[6]: Difference between threshold and dB SPL. Frequencies beyond audibility limits were set to 0 dB to avoid negative dB SL values. Grouped into 4 ranges: Ultra Lows (50-200 Hz), Lows (250-500 Hz), Mids (630-4000 Hz), Highs (5000-8000 Hz)

Envelope Difference Index[7]: Used to characterize effect of envelope time constants between a test signal and a reference signal. Lower values suggest the test signal more closely resembles the reference (= better SQ)

Short-Term Compression Ratio[8]: Mean ratio of the reference dynamic range (difference between 99th and 33rd percentile of long-term spectrum) to the test signal dynamic range for frequencies 50-8000 Hz.

RESULTS: Electroacoustics

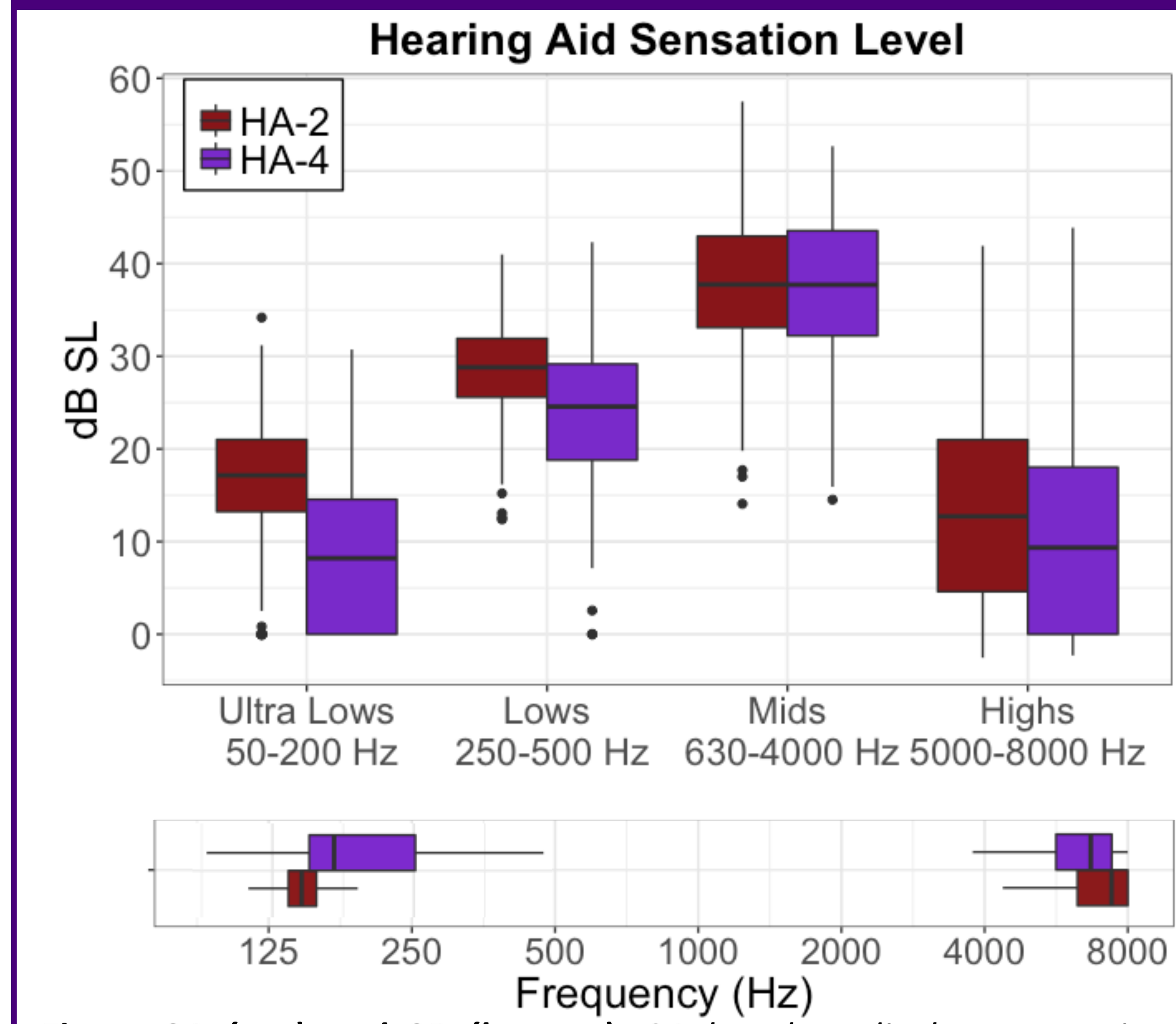

Figure 3A (top) and 3B (bottom): 3A boxplots display comparisons of sensation levels between HA-2 and -4 across all genres. 3B horizontal boxplots display comparisons of the lower and upper limits of audibility (left and right, respectively) between HA-2 and -4 across all genres.

A discriminant function analysis (DFA) was performed using all electroacoustic measurements as predictors of HA-2 or HA-4. The analysis was significant (Wilks' $\lambda = 0.621$, $x^2(8) = 199.6$, $p < 0.001$). The canonical correlation coefficient was 0.62, suggesting relatively good predictability of hearing aid.

Measure	Descriptives (mean, SD)		ANOVA (F value)	DFA (matrix coefficient)
	HA-2	HA-4		
Envelope Difference Index	0.26 (0.1)	0.29 (0.1)	11.426**	-0.210
Compression Ratio	1.03 (0.05)	1.04 (0.04)	0.493	-0.044
Ultra Low SL	**16.9 (7.0)**	**9.4 (8.4)**	**96.005***	**0.630**
Low SL	**28.4 (5.2)**	**23.9 (7.6)**	**51.126***	**0.446**
Mid SL	37.4 (7.4)	37.3 (8.2)	0.049	0.015
High SL	13.5 (10.7)	10.9 (10.8)	6.216***	0.156
Low Cut-Off (Hz)	**148.7 (36.9)**	**205.2 (111.2)**	**48.365***	**-0.426**
High Cut-Off (Hz)	6961.1 (1189.5)	6458.2 (1218.3)	16.282*	0.252

**p < 0.001, **p < 0.01, ***p < 0.05*

CONCLUSIONS

Sound quality differences are most apparent between hearing aids.

A music program improves ratings for two hearing aids, although less than the difference between a high- vs. low-rated hearing aid.

Electroacoustic measurements performed in this study can be used to classify a relative good- or poor-SQ market-level hearing aids.

The three most predictive measures for these hearing aids are sensation level in the **ultra lows (50-200Hz)**, **lows (250-500Hz)** and **lower limit of audibility.**

Future Directions

Investigate potential sound quality interactions due to genre.

Investigate sound quality differences with a wider variety of hearing loss types and audiogram configurations.

Perform hearing aid measurements using an auditory model rather than electroacoustic analysis.

ACKNOWLEDGEMENTS

The authors thank Bilal Sheikh, Adrian Lizzi, and Scott Aker for assistance with hearing aid recordings and stimulus preparation, as well as our research participants for their time and effort.

REFERENCES

[1]Chasin, M. (2006). Hearing aids for musicians. *The Hearing Review*, *13*(3), 1–11.
[2]Madsen, S. M. K., & Moore, B. C. J. (2014). Music and hearing aids. *Trends in Amplification*, *0*(0), 1–29.
[3]Vaisberg, J. M., Folkeard, P., Parsa, V., Froehlich, M., Littmann, V., Macpherson, E. A., & Scollie, S. (2017). Comparison of music sound quality between hearing aids and music programs. *AudiologyOnline, Article 20872*. Retrieved from www.audiologyonline.com
[4]ITU-R. (2015). *Recommendation ITU-R BS.1534-3: Method for subjective assessment of intermediate quality level of audio systems*. Geneva: International Telecommunication Union.
[5]Moore, B. C. J., & Tan, C.-T. (2003). Perceived naturalness of spectrally distorted speech and music. *The Journal of the Acoustical Society of America*, *114*(1), 408–419.
[6]Gabrielsson, A., & Sjögren, H. (1979). Perceived sound quality of sound-reproducing systems. *The Journal of the Acoustical Society of America*, *65*(4), 1019–1033.
[7]Jenstad, L. M. & Souza, P. (2005). Quantifying the effect of compression hearing aid release time on speech acoustics and intelligibility. *Journal of Speech Language and Hearing Research*, *481*, 651-667.
[8]Kirchberger, M., & Russo, F. A. (2016). Dynamic range across music genres and the perception of dynamic compression in hearing-impaired listeners. *Trends in Hearing*, *20*, 1–16.