

# ADVANCED MEASURES OF BONE ANCHORED HEARING AIDS: DO THEY CORRELATE WITH PERCEPTUAL JUDGMENTS?

W. E. Hodgetts<sup>1</sup>, G. Chen<sup>2</sup>, and V. Parsa<sup>2</sup>

<sup>1</sup>Dept. of Speech Pathology and Audiology, University of Alberta, Edmonton, Alberta, Canada, T6G 2G4

<sup>2</sup>National Centre for Audiology, University of Western Ontario, London, Ontario, Canada, N6G 1H1

Contact email address: bill.hodgetts@ualberta.ca

## 1. INTRODUCTION

It can be argued that, as the Bone-Anchored Hearing Aid (BAHA) continues to become the standard of care for patients with conductive hearing loss, comparisons between BAHA and traditional Bone-Conduction Hearing Aids (e.g. those held in place by headband) have ceded their importance to comparisons between different types of BAHAs.

Currently, there are two ear-level BAHAs (the Compact and Classic 300) and a body-worn processor for more severe hearing losses (the Cordelle). The two ear level devices are linear but limit maximum output differently. Specifically, the Classic 300 saturates like a peak clipper, while the Compact limits output by compression. The Cordelle II uses a K-amp circuit but also saturates at high levels.

Neither subjective nor instrumental comparisons of sound quality have been formally evaluated with the current BAHA devices. Subjective ratings from patients are often confounded by a number of biases. For example, patients are not blind to the BAHA under test and may have several thousand dollars invested in the device. Rather than using patients for the subjective ratings, normal hearing listeners can be used to evaluate the sound quality of recordings made from each device. We were also interested in whether the subjective sound quality ratings correlated with instrumental measures of sound quality such as the Perceptual Evaluation of Speech Quality (PESQ; ITU, 2001) and the Perceptual Evaluation of Audio Quality (PEAQ; ITU, 2001).

The following research questions were of interest: 1) Are there perceptual differences between the different BAHA recordings, and 2) Do these perceptual judgments correlate with objective measures of sound quality?

## 2. METHOD

Fourteen adults with normal hearing participated in this study. Their task was to listen to the BAHA recordings and provide a mark on a visual analogue scale (VAS) between 1 and 10 that best represented their overall impression of the sound quality of each recording.

Three frequency responses (F1=Manufacturer's default setting at full volume, F2= Manufacturer's default setting at volume 2, F3=Potentiometers adjusted to opposite of Manufacturer's default setting at full volume) and two input levels (65 & 75 dB SPL) were chosen for the three BAHAs for a total of 18 listening conditions. The "carrot passage" from the Connected Speech Test (CST; Cox et al., 1987) spoken by a male talker was used as the input stimulus to each BAHA on a skull simulator (coupler). Recordings were digitized through an Aardvark Q10 audio interface and stored as .wav files. These .wav files were then RMS equalized.

The two objective measures of sound quality (PESQ and PEAQ) were obtained from the input and output BAHA recordings using MATLAB.

## 3. RESULTS & DISCUSSION

Mean and standard deviation VAS scores for each recording condition are presented in Table 1.

Table 1. Mean and standard deviation values ordered from highest to lowest mean score for all 18 recording conditions.

Condition	Mean VAS	SD
F1_Compact_65	7.21	1.52
F2_Compact_65	6.93	1.91
F3_Compact_65	6.44	1.69
F2_Cordelle_65	6.42	1.80
F2_Classic_65	6.39	1.42
F3_Classic_65	6.33	1.35
F1_Classic_65	6.14	1.36
F2_Compact_75	5.54	2.12
F2_Cordelle_75	5.39	2.18
F1_Cordelle_65	4.81	2.12
F3_Cordelle_65	4.77	2.49
F1_Compact_75	4.69	1.48
F2_Classic_75	4.18	2.04
F3_Compact_75	4.03	1.41
F1_Cordelle_75	3.18	1.61
F3_Classic_75	2.75	1.41
F1_Classic_75	2.30	1.52
F3_Cordelle_75	2.26	1.09

A 3 (Device) x 3 (Frequency Response) x 2 (Input) repeated measures ANOVA was computed. Results are plotted in Figures 1 and 2.

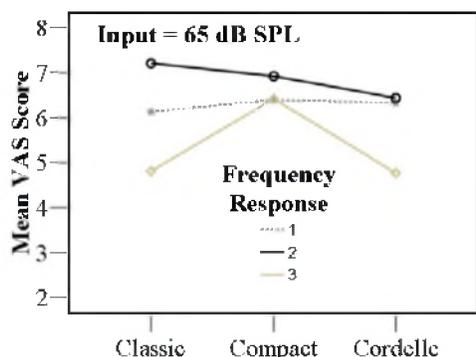


Fig. 1. Mean Frequency Response x Device VAS scores for a 65 dB SPL input to the BAHA.

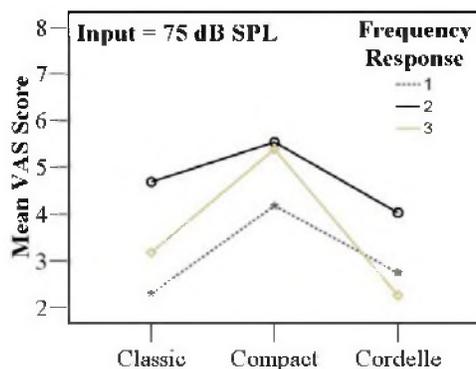
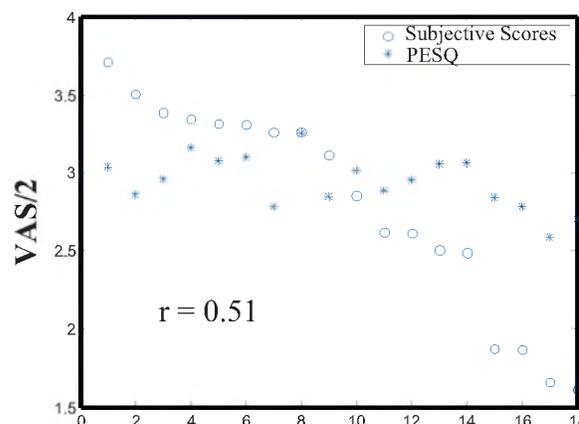


Fig. 2. Mean Frequency Response x Device VAS scores for a 75 dB SPL input to the BAHA.

A significant main effect was found for “device” with the Compact receiving the highest sound quality ratings. There was also a clear preference for F2 regardless of type of device or input SPL. This was a logical result as the F2 frequency response was obtained for all devices set to volume 2 (out of 3). Significant interactions were also investigated. It was expected that the Classic and Cordelle would saturate at full volume (F1 and F3) and that ratings would be lower as the input level increased. Indeed, this was the case. Conversely, since the Compact employs output compression, ratings were expected to remain high for all conditions regardless of input level. This was true with the exception of F1 at an input of 75 dB SPL. Unfortunately, F1 represents the “default” frequency response for the Compact. From a sound quality perspective, it would appear that F3 would be a better option for patients wearing the Compact at volume 3 in the presence of loud speech.

Next, the subjective scores were correlated with the PESQ and PEAQ instrumental measures. Results for the PESQ are plotted in Figure 3. Similar results for the PEAQ are not shown due to space limitations. The scores for the

subjective ratings show greater dispersion compared to the instrumental measure. This is reflected in the relatively low correlation ( $r = 0.51$ ) between the two measures.



Recording Condition Best to Worst (see Table 1.)

Fig 3. Mean VAS and PESQ scores by recording condition. VAS scores were divided by 2 so that data could be plotted on the same 5 point scale as the PESQ data.

#### 4. CONCLUSION

This paper investigated whether normal hearing listeners were able to differentiate the sound quality of different BAHAs in different processing conditions. A predictable advantage was found for the Compact with output compression as the input speech level increased. However, for the Compact, a consequence of output compression is reduced MPO. It is not clear that BAHA users would still prefer the sound quality of the Compact if the compression compromised the audibility of speech. More research is needed to answer this question.

A second goal of this study was to determine if the perceptual data correlated with instrumental measures of sound quality used in the telecommunications industry. Correlations were modest for both the PESQ and PEAQ, suggesting further modifications are required for the instrumental measures to match with the perceptual data.

#### REFERENCES

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