ACOUSTIC FACTORS RELATED TO EMOTIONAL RESPONSES TO SOUND

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1 Introduction

People with hearing loss are at increased risk of reduced subjective well-being, increased depressive symptoms and reduced quality-of-life [1]. One of the contributing factors to the relationship between hearing loss and negative psychosocial consequences may be disrupted emotional processing. Positive emotional experiences can improve well-being [2]. Negative emotional experiences can improve cognition and prepare a body for action [3]. Mild-moderate hearing loss has recently been shown to disrupt emotional processing [4] and the range of emotional responses to sound [5]. However, little is known about the effects of hearing loss or amplification on a listener's emotional response to sounds. The purpose of this study was to evaluate the effects of hearing loss and hearing aid use on emotional responses to non-speech sounds and to explore the potential related acoustic factors.

2 Method

2.1 Participants

Participants included 13 adults with bilateral, mild to severe sensorineural hearing loss (M = 65.6 years, range = 49 to 74), in addition to 13 adults with normal hearing (M = 57.3 years, range = 50 to 80). No participant reported middle ear, neurogenic, or psychological pathology. All participants passed a screening survey, indicating low risk of clinical anxiety or depression.

Participants with hearing loss, who were all experienced hearing aid users, were fitted with bilateral, behind-the-ear hearing instruments for research purposes. Hearing aids were verified using probe-microphone measures to match validated prescriptive targets. All digital features were disabled in both programs, except feedback reduction.

2.2 Procedures

2.2.1 Stimuli

Sounds were 75 non-speech sounds from the corpus of the International Affective Digitized Sounds (IADS-2) [6]. Example sounds included human emotion (laughter, crying), machine sounds (dentist drill, helicopter), animal sounds (mooing, barking), and music (classical, guitar). The 15 sounds in each of 5 pre-determined categories were chosen; categories included 1) pleasant, low arousal, 2) pleasant, high arousal, 3) neutral, 4) unpleasant, high arousal, and 5) unpleasant, low arousal. Fifteen sounds were selected to represent each category. Sounds were 1.5 seconds long and were matched to have the same peak level.

Participants used the Self Assessment Manikin (SAM) [7] to make subjective ratings of valence and arousal. For each dimension, the SAM provides 5 pictorial representations of emotional responses (ranging from low to high). Numbers 1 through 9 are indicated under the pictures and indicate low to high feelings on each dimension. During testing, participants listened to a sound and then rated their emotional response using a computer keypad. While responding, the SAM was displayed on a computer monitor. Stimuli were presented from a loudspeaker located at 0˚.

2.2.2 Conditions

Participants with normal and impaired hearing made ratings of valence and arousal for stimuli presented at 60 and 80 dB SPL. Participants with hearing loss also made ratings of valence and arousal for stimuli when using hearing aids (60 dB presentation level). Sounds were blocked such that all items were presented in one condition before progressing to another condition. Within a condition, the sounds were presented in a random order. Condition order was counterbalanced across participants.

3 Results

3.1 Subjective Ratings

Subjective ratings of valence and arousal were analyzed separately. Considering the unaided responses from both groups of participants, analysis results of the arousal ratings revealed significant main effects of Stimulus Category ($F(4, 89.9) = 6.3$, $p < 0.001$), Level ($F(1, 244.7) = 5.9$, $p < 0.05$), and Hearing ($F(1, 244.7) = 9.9$, $p < 0.01$). These results suggest that ratings of arousal were higher with the higher presentation level and were higher for listeners with normal hearing. The interactions were not significant. Analysis results of the valence ratings, displayed in Figure 1, revealed significant main effects of Stimulus Category ($F(4, 103.5) = 155.$, $p < 0.001$), Level ($F(1, 225.5) = 12.7$, $p < 0.001$), and Hearing ($F(1, 225.5) = 15.4$, $p < 0.001$). In addition, there was a significant Hearing x Category interaction ($F(4, 103.5) = 8.2$, $p < 0.001$). These results suggest that ratings of valence were significantly lower with the 80 dB presentation level and for listeners with hearing loss. Furthermore, hearing loss negatively impacted the ratings of sounds in the pleasant categories, but not the unpleasant categories.

Considering only listeners with hearing loss, analysis of arousal ratings revealed only a significant effect of Category ($F(4, 60.0) = 5.2$, $p < 0.01$). Analysis of the valence ratings revealed significant main effects of Condition ($F(2, 94.6) = 6.4$, $p < 0.01$) and of Category ($F(4, 79.9) = 90.9$, $p <$

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0.001). These results suggest that the ratings of valence were negatively affected by increasing the overall level, but there was a trend for hearing aid use to mitigate the negative effects of an overall increase in level (see Figure 1).

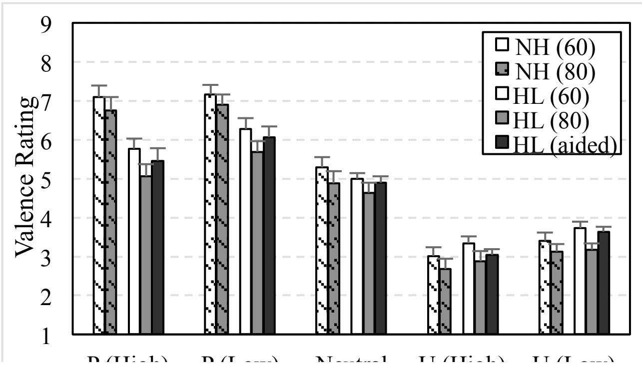

Figure 1. Mean subjective ratings of valence for listeners with normal hearing (hashed bars) and listeners with hearing loss (solid bars). Error bars represent +1 standard error from the mean.

3.2 Acoustic Factors

3.2.1 Hearing Loss

Correlation analysis, focused on ratings of pleasant stimuli, revealed a significant positive correlation between ratings of valence and arousal ($r = 0.17$, $p < 0.05$) and a significant negative relationship between ratings of valence and pure-tone average (better ear, 0.5, 1.0, 2.0, 4.0 kHz; $r = -0.34$, $p < 0.001$). These results suggest that higher ratings of valence were associated with higher ratings of arousal and also better hearing thresholds. Furthermore, sounds that were more sensitive to the effects of hearing loss were more likely to have less low frequency energy (through 600 Hz).

3.2.2. Hearing Aids

There was a significant relationship between a sound's high frequency content (2-6 kHz) and hearing aid effect; sounds with more high frequency energy were more likely to have lower valence ratings in the aided condition ($r = -0.34$, $p < 0.01$). In addition, sounds with the smallest dynamic range were most likely to be negatively affected by hearing aid use for valence ratings ($r = 0.29$, $p < 0.05$).

4 Discussion

The present results confirmed previous findings, suggesting that hearing loss negatively affects emotional responses to sounds [5]; listeners with hearing loss demonstrated a reduced range of ratings of valence and lower general arousal relative to their peers with normal hearing. The most notable effects of hearing loss on emotional responses of valence were related to ratings of pleasant stimuli. Participants with more hearing loss were more likely to be negatively affected. Hearing aid use did not increase ratings of valence for sounds in any category, although the effects were less detrimental than increasing the overall level.

Some of the effects of hearing loss and hearing aids were related to the acoustic properties of a signal. Specifically, signals with more low frequency energy were more resilient to the effects of hearing loss. Conversely,

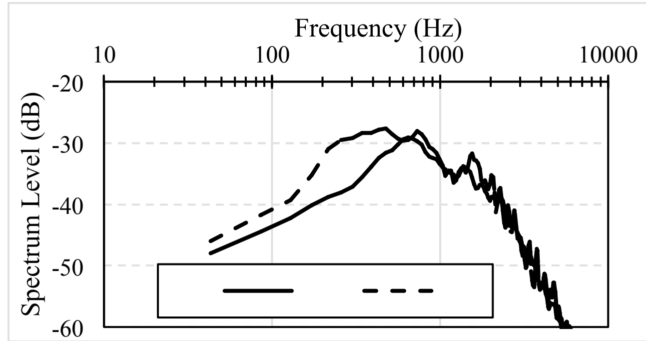

Figure 2. Average long term average spectrum of sounds that were sensitive to the effects of hearing loss (solid line) and of sounds that were not sensitive to the effects of hearing loss (dashed line).

more high frequency energy in a signal was related to negative effects of hearing aid use on ratings of valence. These results suggest that manipulations of hearing aid gain may influence ratings of valence. Future work is warranted to explore the effects of hearing aid gain and other feature parameters on emotional responses to sound.

5 Conclusion

Listeners with hearing loss exhibit a smaller range of emotional responses than their peers with normal hearing, primarily as a result of lower ratings of valence for pleasant stimuli. In addition, listeners with hearing loss reported lower levels of arousal. Although hearing aid use did not restore emotional responses, using personalized amplification had a less detrimental effect than increasing the overall level. These findings may have clinical implications for hearing aid fittings.

Acknowledgments

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