SKIN CONDUCTANCE RESPONSES TO EMOTIONAL SPEECH IN HEARING-IMPAIRED AND HEARING-AIDED LISTENERS

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1 Introduction

Age-related hearing loss is present in many individuals and can have negative effects on an individual's quality of life [1]. Hearing aids are a useful device to combat this problem, and operate by amplifying sounds in the environment so that they are more audible at the level of the eardrum. The focus of optimization in hearing aids tends to be speech intelligibility. Perception of speech emotion tends to be a secondary consideration, and at present we have little research available on what parameters support this important aspect of hearing. Signal processing in hearing aids may lead to erroneous attributions of emotion; for example, because both joy and anger tend to be loud, they both result in dynamic compression of the signal, reducing discriminability of these emotions, and potentially leading to social misunderstanding. Current work from our group with hearing impaired older adults has found that while word identification in spoken sentences improves with the use of hearing aids, emotion identification does not.

The skin conductance response (SCR) is a measure of the amount of sweat on the skin and is considered an index of sympathetic nervous system activity, or arousal. In normal hearing adults, characteristic skin conductance responses are triggered in response to emotional stimuli such as pictures [2] and music [3]. In these studies, greater SCR magnitudes are seen in response to more arousing stimuli. How this response might be affected by hearing impairment—or by the use of hearing aids—has not been investigated.

The current study sought to investigate the effects of hearing impairment on the SCR to emotional speech. Additionally, we were interested in the extent to which hearing aids would help to recover the SCR seen in normal hearing participants. It was predicted that hearing impairment would result in a dampened SCR, and that hearing aids would not be able to recover the normal response. Based on previous work, we also predicted that hearing impairment and the use of hearing aids would decrease both accuracy and reaction time of categorizing emotional speech.

2 Method

Normal hearing (NH) and hearing impaired/aided (HI/HA) participants listened to semantically neutral sentences spoken to convey different emotions (happy, sad, angry, calm). These emotions vary with respect to arousal and valence and are representative of the four quadrants of the circumplex model of affect [4]. Stimuli were taken from the Ryerson Audio-Visual Database of Speech and Song (RAVDESS), and were validated in a separate study prior to the main study [5]. The RAVDESS database contains audio and audio-visual stimuli spoken in 8 different emotions and 24 different actors. HI/HA participants performed two blocks of the task (stimulus sets with different actors), one without their hearing aids (the same stimulus set as NH) and one with their hearing aids. The order of stimuli and blocks was randomized and were presented over loudspeakers in a sound-attenuated booth. Since loudness is a cue to emotion in speech, loudness was not normalized across stimuli, resulting in a range of presentation sound levels.

For each stimulus, participants were asked to respond on a computer keyboard (with their left hand) which emotion they thought was conveyed (four-alternative forced choice). For the duration of the experiment, skin conductance levels were measured using sensors attached to the index and ring fingers of the right hand (Biopac, Inc.).

All data analyses were conducted in MATLAB using the PHZLAB Toolbox (github.com/gabenespoli/phzlab). For all analyses, trials with a response time greater than 7 seconds were discarded. Skin conductance data were filtered with a 4th-order high-pass Butterworth filter and baseline-corrected by subtracting the mean of 1-second prior to stimulus onset from the entire epoch. Trials with values exceeding 0.05 μS (microsiemans) were discarded as artifact and the resulting trials were smoothed using a 400 ms sliding average. Since the speech stimuli had an average length of 3.9 s (range 3.3-4.5) and SCR typically has a 1-second delay, a target window was defined from 1 to 4.9 seconds post stimulus onset. The mean of the target window was taken as the index of physiological response to a given stimulus.

3 Results

For behavioural responses (accuracy and reaction time), a 1-way ANOVA was carried out with Group as a between-subjects factor (3 levels: NH, HI, and HA). There was a significant effect of Group on accuracy ($F(2,33)=3.729$, $p=0.035$), with NH performing best overall. There was also a significant effect of Group on reaction time (RT) ($F(2,33)=5.002$, $p=0.013$), with NH being faster overall.

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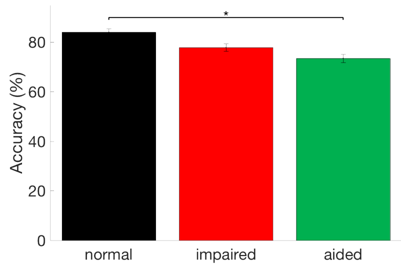

Figure 1: Mean accuracy scores across the three groups.

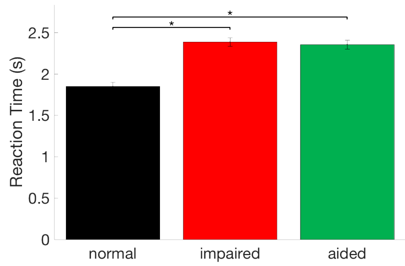

Figure 2: Mean reaction times across the three groups.

For physiological responses (mean SCR), a mixed ANOVA was carried out with Group as a between-subjects factor (3 levels: NH, HI, and HA), and with Arousal (2 levels: high and low) and Valence (2 levels: positive and negative) as within-subjects factors. This ANOVA revealed marginally significant main effects of Arousal ($F(1,33)=2.783$, $p=0.105$) and Group ($F(2,33)=2.238$, $p=0.123$), as well as a marginally significant Arousal-by-Group interaction ($F(2,33)=2.059$, $p=0.144$).

To summarize, high-arousal emotions evoke larger SCRs than low-arousal emotions. It also appears that HI have much smaller SCRs than the NH and HA, especially for the high-arousal emotions.

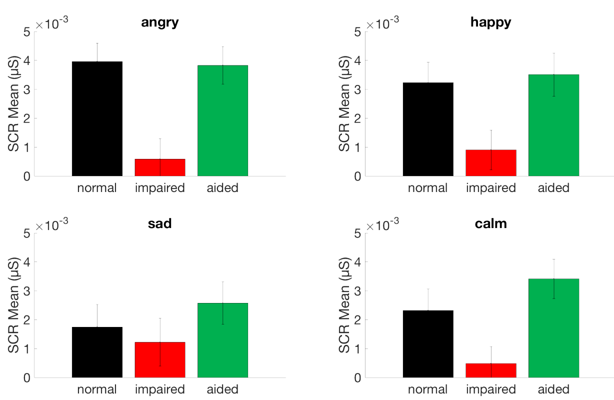

Figure 3: Mean skin conductance responses (SCR) from 1-5 s post stimulus onset. Normal hearing participants (NH) show a larger response for high-arousal emotions (angry, happy). Hearing impaired participants (HI) have a dampened response, while hearing aided participants (HA) seem to show increases for all emotions.

4 Discussion

As predicted, NH participants displayed superior accuracy and reaction time when discriminating emotional speech. Thus, hearing impairment impairs the ability to recognize emotion in speech, and hearing aids are unable to ameliorate this deficit. Also, there appears to be a trend where hearing impairments is associated with a deficit in the SCR to emotional speech. Hearing aids seem to be able to recover the SCR overall, but SCR levels are not discriminable across emotions.

It seems likely that loudness was driving many of the results seen in this study. For the normal hearing participants, they might have used loudness as a cue to the level of arousal of the emotion being expressed; for example, a louder stimulus would be more likely to be happy or angry. For the hearing impaired participants, all stimuli would have been perceived as very quiet. As such, they are slower to respond when discriminating emotion, and they do not show a characteristic arousal response in terms of SCR. For the hearing aided participants, their hearing aids would have applied gain and compression in order to maximize intelligibility. This would have minimized sound level differences between the quieter stimuli (i.e., sad and calm) and the the louder stimuli (i.e., happy and angry), which would have a) eliminated the use of loudness as a cue to emotion, causing them to respond slower and less accurately, and b) made all stimuli sound loud and potentially arousing, thus increasing SCRs for all emotions.

5 Conclusion

The current study found behavioural and physiological evidence for a deficit in the perception of emotion in speech for hearing impaired individuals. In addition, hearing aids were unable to ameliorate these deficits.

References

[1] Dalton, D. S., Cruickshanks, K. J., Klein, B. E. K., Klein, R., Wiley, T. L., & Nondahl, D. M. (2003). The impact of hearing loss on quality of life in older adults. The Gerontologist, *43*(5), 661–668.

[2] Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, a O. (1993). Looking at pictures: affective, facial, visceral, and behavioral reactions. *Psychophys.*, *30*(3), 261–273.

[3] Khalfa, S., Isabelle, P., Jean-Pierre, B., & Manon, R. (2002). Event-related skin conductance responses to musical emotions in humans. *Neurosci. Letters*, *328*(2), 145–149.

[4] Russell, J. A. (1980). A circumplex model of affect. *J. of Pers. and Soc. Psych*, *39*(6), 1161-1178.

[5] Livingstone, S. R., Peck, K., & Russo, F. A. (2013, June). Acoustic differences in the speaking and singing voice. In *Proc. of Meetings on Acoustics, Ac. Soc. of Am.*, *19*(1), 035080.