Chapter 6

Do Hearing Aids Improve Affect Perception?

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Abstract

Normal-hearing listeners use acoustic cues in speech in order to interpret the speaker’s emotional state. This study investigates how hearing loss affects the perception of the emotion dimensions arousal (aroused vs. calm) and valence (positive/negative attitude) in older adults using hearing aids. Affect ratings by 23 hearing aid users are compared for aided and unaided listening and are also compared to ratings by an age-matched group of 24 participants with age-normal hearing. More specifically, we investigate whether wearing a hearing aid improves the correlation between affect ratings and affect-related acoustic parameters.

The rating results for the evaluation of arousal show that the hearing aid users rated utterances as generally more aroused in the aided compared to the unaided condition. Both listening condition and hearing loss severity differences among hearing aid users changed the use of certain acoustic parameters. Compared to the reference group, hearing aid users showed minor differences in the use of intensity for arousal rating.

For valence, hearing loss severity did not influence ratings, and neither did listening condition (aided vs. unaided). For both emotion dimensions, ratings of hearing aid users in the aided condition did not generally differ from those of the participants with age-normal hearing.

Hearing impairment and the use of hearing aids thus matter particularly for the interpretation of arousal. Therefore, future studies on affect perception in hearing aid users should treat perception of arousal and valence separately.

Keywords: emotion perception, arousal, valence, acoustic parameters

1 Introduction

People use several sources of information to perceive and interpret emotions. Visual information, such as facial expressions, is most informative, but auditory cues in affective speech also provide cues for emotion perception. Auditory information can signal semantics (what is said) and prosody (how something is said). Prosodic cues are acoustic parameters in speech such as pitch, intensity, and tempo from which a normal-hearing listener may derive emotions from the speech signal (Banse & Scherer, 1996; Scherer, 2003; Coutinho & Dibben, 2013). Note that prosodic cues may alter the meaning of a spoken message, which becomes apparent when irony is expressed. For example, the meaning of an utterance like “I like roses” can either be
interpreted as positive (I do like roses) or negative (I do not like roses), depending on the applied prosody.

In an ideal communicative setting both visual and auditory information is available. Everyday communication settings, however, may frequently deprive the listener of visual information, e.g., when the listener is not able to face the speaker. Consequently, auditory cues to the emotional state of the speaker become especially important in these situations.

Moderate and severe hearing loss is treated with hearing aids in order to improve speech intelligibility, i.e., hearing aids are designed to improve the understanding of what is said. It is unclear, however, to what extent hearing aids sufficiently restore information needed for emotion perception in speech, i.e., whether hearing aids improve understanding of how something is said. Several studies with severely hearing-impaired children and adolescents indicate that aided hearing-impaired listeners perform poorly compared to normal-hearing listeners when rating emotion in speech (Most et al., 1993; Most & Aviner, 2009; Most & Michaelis, 2012). Importantly, affect perception differences between hearing-aid users and normal-hearing listeners were independent of hearing loss severity in the hearing-impaired participants. These findings on severe hearing loss obtained with children and adolescents, however, cannot be directly transferred to older adults using hearing aids, as it is well documented that there are age-related differences in the perception of affective prosody between younger and older participants (Paulmann et al., 2008; Dupuis & Pichora-Fuller, 2010).

To our knowledge, so far only the effect of mild hearing loss has been investigated in older adults (not wearing hearing aids). For this group, inconsistent findings have been reported concerning the link between individual hearing loss and the perception of affect. Orbelo and colleagues (Orbelo et al., 2005) report no effect of hearing sensitivity on affect perception, while Rigo and Lieberman (Rigo & Lieberman, 1989) found that low-frequency hearing loss (\( \text{PTA}_{\text{low}}(0.25, 0.5, 1 \text{ kHz}) > 25 \text{ dB HL} \)) impacted affect perception. Note that both studies used acted speech, where the lack of a global effect of hearing sensitivity on affect perception could be due to the more prototypical prosodic expression of affect in acted compared to natural speech (Scherer, 1986; Wilting et al., 2006). More extreme expressions of affect may be relatively easy to perceive, even for people with hearing loss (Grant, 1987) thus obscuring a possible influence of hearing sensitivity on affect perception.

The purpose of the current study is to investigate to what extent hearing aids improve affect perception, and how hearing loss in older adults influences affect perception. Participants will be tested on natural conversational speech stimuli in order to mimic realistic listening condition. To that end, older (bilateral) hearing aid wearers are tested with (aided condition) and without their hearing aid (unaided condition). Second, their aided performance is compared to a group of age-matched normal-hearing listeners. In particular, this study focuses on whether the degree of hearing loss and the use of hearing aids change listeners' sensitivity to the acoustic parameters cueing affect. We will therefore evaluate whether the use of hearing aids improves the correlation between these acoustic parameters and affect ratings of speech.

2 Methods

2.1 Participants

Two groups of older adults aged between 65 and 82 were tested. All participants were Swiss German native speakers and were compensated for their participation. A group of 23 older hearing aid users with bilaterally symmetric sensorineural hearing loss (\( \text{M}_{\text{Age}} = 73.5 \text{ years, SD}_{\text{Age}} = 4.5; 17 \text{ men, 6 women} \)) was recruited via the Phonak AG participant database. Participants have worn hearing aids bilaterally for at least two years. Furthermore, a group of 24 normal-hearing adults (\( \text{M}_{\text{Age}} = 70.3 \text{ years, SD}_{\text{Age}} = 5.2; 10 \text{ men, 14 women} \)) was recruited via the Phonak human resource department and a local senior club in Staefa, Switzerland.
Participant’s hearing ability was tested by means of pure-tone audiometry (air conduction thresholds). The mean unaided pure-tone average (PTA) across 0.5, 1, 2, and 4 kHz for the hearing-impaired group was 49.8 dB HL (SD = 8.7, range: 32.5 – 68.8). The normal-hearing participants were expected to have age-normal thresholds, i.e., given their age, a downward sloping hearing loss in the frequencies above 1 kHz was expected, applying the statistical distribution of hearing thresholds as a function of age (ISO 7029:2000). Thresholds below the ISO’s maximal pure-tone average threshold (across 0.5, 1, 2, and 4 kHz) at the age of 70 for men (PTA = 33.5 dB HL) and women (PTA = 26.0 dB HL) was considered as normal hearing. Additionally, participants underwent a brief cognitive screening test in order to exclude participants with mild cognitive impairment. We used the German version of the Montreal Cognitive Assessment Test (MOCA, Nasreddine et al., 2005), using a cutoff criterion of 67% (cf. Waldron-Perrine & Axelrod, 2012). The test was adjusted for hearing-impaired participants (Dupuis et al, 2015) by leaving out the tasks in which auditorily presented items had to be memorized (still applying the 67% cutoff criterion). None of the participants had to be excluded on the basis of this (modified) cognitive screening instrument.

2.2 Task and Procedure

Affect perception was tested in this study with the dimensional approach, in which participants do not label perceived emotions (as sounding “angry”, or “sad”), but rather indicate the level of a specific emotion dimension on a rating scale. Participants rated the emotion dimensions arousal (calm vs. aroused) and valence (positive vs. negative attitude) separately. Stimuli were short utterances (audio-only) from an authentic and affectively-colored German conversational speech corpus (Grimm et al., 2008). Note that emotion inferences from speech correlate across languages; they particularly correlate for similar languages (cf. Scherer et al., 2001). Given the close relationship between German and Swiss German, the way affect is encoded in Swiss German is not expected to differ considerably from that in German as spoken in Germany. The corpus comes with mean reference values for the degree of arousal and valence for each utterance. These reference values had been collected with a simple 5-step pictorial rating tool (Bradley & Lang, 1994), ranging from -1 (calm/negative) to +1 (aroused/positive). The same rating tool was used to collect affective ratings in the current study. Utterances were selected to be neutral with respect to the content of what was said. Twenty-four utterances were selected for the arousal task (reference value range: -0.66 – 0.94) and 18 utterances were selected for the valence task (reference value range: -0.80 – 0.77). From these stimuli sets two randomized lists were created differing in the order in which the stimuli were presented for each emotion dimension.

Affect ratings were related to four acoustic parameters which are traditionally related to affective prosody: mean F0 (e.g., Hammerschmidt & Jürgens, 2007), mean intensity (e.g., Aubergé & Cathiard, 2003), global temporal aspects (Mozziconacci & Hermes, 2000), and spectral measures (e.g., Tamarit et al., 2008), the latter being related to vocal effort. For the current study, mean F0 and mean intensity were calculated for each utterance by averaging over the utterance using Praat (Boersma & Weenink, 2013). As a measure of tempo, articulation rate was calculated by dividing the number of syllables in the canonical transcription of the utterance by the file length, excluding pauses longer than 100 ms. Spectral slope is reflected in the spectral information described by the Hammarberg Index (Hammarberg et al., 1980). The Hammarberg Index is defined as the intensity difference between the maximum intensity in a lower frequency band [0 – 2000 Hz] versus that in a higher frequency band [2000 – 5000 Hz]. In this study, the Hammarberg Index was used as an energy distribution measure of relative intensity, averaged across the entire utterance.

Participants were comfortably seated in a sound-treated room and were tested in the free field. The pictorial rating tool was displayed on a computer screen and stimuli were presented via a single loudspeaker which was placed at head level in front of the participant (0° azimuth) with a distance of 1m from the participant’s ears. Participants received written and oral instructions
and performed four practice trials before proceeding to the test stimuli of either rating task. Both rating tasks were completed at the participant’s own pace. Utterances were rated one at a time and there was the possibility to replay the sentence.

All participants performed the rating tasks in two conditions. For the hearing aid users, these two conditions were with (aided) and without their hearing aids (unaided). The normal-hearing participants completed the tasks in a normal listening condition and in a condition with simulated hearing loss (data of the latter condition are not reported here). Order of rating tasks and listening conditions were counterbalanced over participants. The two different lists were used to present listeners with a different order of the stimuli in the two listening conditions. There was a short break between the two listening conditions and between the two rating tasks.

3 Results

The data were analyzed using R statistical software (R Development Core Team, 2008). Two comparisons were carried out separately for each emotion dimension (i.e., aided vs. unaided listening, and hearing-aid wearers vs. the normal-hearing group). The aim of the first analysis was two-fold. It investigated 1) whether the severity of the hearing loss modulates affect ratings and 2) whether wearing a hearing aid changes listeners’ affect ratings, and, in particular, whether wearing a hearing aid makes listeners more sensitive to subtle differences in acoustic parameters. To that end, the affect ratings (the dependent variable) were compared for the hearing-impaired listeners in the aided and unaided conditions using linear mixed-effects regression analyses with random intercepts for stimulus and participant. The initial model allowed for a three-way interaction between listening condition (aided, unaided), individual hearing loss, and each of the acoustic parameters (mean F0, mean intensity, articulation rate, Hammarberg Index). Interactions and predictors that did not improve model fit (according to the Akaike Information Criterion) were removed using a stepwise exclusion procedure. Interactions were removed before simple effects, and those with the highest non-significant p-values were excluded first.

The second analysis investigated whether the use of a hearing aid restores affect perception to the level of normal-hearing older adults. Method and model-stripping procedure were identical to the first analysis. The initial model allowed for two-way interactions between group (HA users aided, normal hearing) and each of the four acoustic parameters.

3.1 Aided versus unaided listening

For arousal, mean intensity was found to be a strong cue for arousal rating ($\beta = 0.35, SE = 0.08, p < 0.001$): higher mean intensity is associated with higher ratings of arousal in both the aided and unaided conditions. Moreover, compared to the unaided condition (mapped on the intercept), ratings were generally higher in the aided condition ($\beta = 0.07, SE = 0.02, p < 0.001$). Moreover, significant interactions between listening condition and articulation rate ($\beta = 0.04, SE = 0.02, p < 0.05$) and the measure of vocal effort ($\beta = 0.08, SE = 0.02, p < 0.001$) were observed: even though vocal effort and articulation rate did not influence ratings in the unaided condition, they did in the aided condition. In the unaided condition, those with poorer hearing had lower ratings ($\beta = -0.08, SE = 0.03, p < 0.05$) than those with better hearing, but this was less the case in the aided condition ($\beta = 0.06, SE = 0.02, p < 0.01$). Furthermore, those with poorer hearing associated increases in F0 ($\beta = 0.03, SE = 0.01, p < 0.01$) and in articulation rate ($\beta = 0.02, SE = 0.01, p < 0.05$) more with higher arousal than those with better hearing across listening conditions.

For valence, a significant simple effect of mean F0 ($\beta = -0.31, SE = 0.06, p < 0.001$) was found, i.e., higher pitch is associated with lower ratings, i.e., higher pitch was associated with more negative ratings. None of the other acoustic parameters was predictive of the valence ratings. Importantly, no effects for listening condition and hearing loss were observed: valence ratings
are independent of whether the participants wore their hearing aids or not and independent of individual hearing loss.

3.2 Hearing-aid users (aided condition) versus normal-hearing controls

As in the previous arousal analysis, a significant simple effect for mean intensity (β = 0.39, SE = 0.07, p = 0.001) was found: higher mean intensity was associated with higher arousal ratings. Although ratings of the hearing-aid users did not generally differ from the normal-hearing participants (i.e., from the group mapped on the intercept, β = -0.02, SE = 0.05, p = 0.75), use of mean intensity differed between the two listener groups: hearing-aid users respond more to differences in intensity than participants with age-normal hearing (β = 0.04, SE = 0.02, p < 0.05).

For valence, as in the previous analysis, pitch was associated with lower valence ratings as shown by a simple effect of mean F0 (β = -0.30, SE = 0.08, p < 0.01). No other acoustic parameters were predictive of ratings of valence. There was no effect of group, nor any interactions between group and the acoustic parameters.

4 Discussion

This study aimed to investigate whether the use of a hearing aid restores affect perception to the level of older adults with age-normal hearing. Furthermore, our study investigated to what extent hearing aids modify sensitivity to the acoustic parameters cueing affect in older hearing aid users. Moreover, we investigated the role of hearing loss severity, particularly in unaided listening.

Hearing aid users wearing their hearing aid generally showed the same pattern of affect ratings as participants with age-normal hearing, particularly for the valence dimension. However, for arousal ratings, those wearing a hearing aid actually used intensity information more than participants in the reference group. This may be because hearing in the reference group was normal for their age, but still implied higher thresholds for the high frequencies. Consequently, by using a hearing aid, hearing aid users have become more sensitive, at least to some acoustic differences, than the reference group.

For the hearing-impaired, the use of the hearing aid changed the pattern of acoustic parameters serving as cues for arousal. Two acoustic parameters that did not generally cue arousal in the unaided condition did cue arousal in the aided condition, namely articulation rate and the Hammarberg Index (measuring vocal effort). Note also that, across the aided and unaided conditions, whether or not listeners used alternative cues to interpret arousal (i.e., other cues than intensity) was modulated by hearing loss severity: hearing-impaired listeners with more severe degrees of hearing loss made more use of articulation rate and F0. This suggests that changes in sensory input quality will make listeners rely on different cues for their interpretation of arousal. In other words, gradually acquired hearing loss will make listeners rely on different cues, but restoring their hearing by means of a hearing aid will also change which cues they rely on for their interpretation of arousal. Possibly, the reason for using articulation rate is different for the poorest hearing (across listening conditions) than for those who start to use it in the aided condition. In a related study by Schmidt, Scharenborg, and Janse (Schmidt et al., in preparation) in which older adults with mild hearing loss were tested who were not wearing hearing aids, only mean intensity emerged as a significant predictor of arousal. While older listeners with mild hearing loss rely on just one acoustic parameter when rating arousal, older listeners with severe hearing loss may rely on several acoustic parameters in order to compensate for the lost information. Note again that this does not hold for valence, where F0 is the only prosodic cue listeners are using.

In sum, the current study underlines the importance of hearing aids in the rehabilitation of affect perception in older hearing-impaired listeners. Wearing hearing aids particularly matters for the interpretation of rating prosodic information related to arousal. Due to this difference between
emotion dimensions, future studies on affect perception in hearing aid users should treat perception of arousal and valence separately.

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References


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