Annoyance perception for hearing impaired listeners: A revisit

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For hearing impaired (HI) listeners, it is well known that certain sounds are much more annoying than others even though they may have similar spectral shape and level. For example, HI listeners often report paper rustling noise as highly annoying. A common approach to deal with this complaint is to reduce high frequency gain. While this approach may mitigate the complaint, it can create audibility issues for speech. A more effective approach is to determine the underlying cause of annoyance and then design an algorithm to selectively reduce it. While existing literature on annoyance perception for HI listeners is scant, a previous attempt was made to investigate this perception using real-world recordings (Vishnubhotla, et al, 2012). The study showed a large variability of annoyance ratings across listeners that may have been due to subjective associations with the sound sources. In this study, we use abstract psychoacoustic stimuli designed carefully to avoid possible confounding subjective associations. A magnitude estimation method was used to measure the annoyance of each stimulus in hearing impaired listeners. All stimuli were presented over headphones in a sound treated room. Results will be presented along with implications for hearing aid applications.

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INTRODUCTION

Listeners with hearing loss often report certain sounds as being annoying. This becomes increasingly more common in hearing aid users. It is the case that annoyance of these sounds can lead a hearing aid user to being unsuccessful with their hearing aids. To this point little work has been done to investigate the annoyance of these sounds in the hearing-impaired population. This study is designed to identify and evaluate characteristics of sound that add to or dominate the perception of annoyance in listeners with hearing loss.

There are established methods for the subjective measurements of annoyance (e.g. Sailer & Hassenzahl, 2000) that have been used in other fields, such as urban design (Alayrac, Marquis-Favre, Viollon, Morel and Le Nost, 2012), transportation (Versfeld and Vos, 1997) and environmental studies with normal-hearing listeners. Additionally, the study of annoyance has begun to incorporate psychoacoustic modeling to predicate the annoyance of various signals (Ellermeier, Mader and Daniel, 2004).

Vishnubhotla and colleagues, over the past few years, have started investigating the similarities and differences in annoyance perception between listeners with hearing loss and with normal hearing. Vishnubhotla, Xiao, Xu, McKinney and Zhang (2012a) compared the perceived annoyance of realistic environmental sounds, with low frequency emphasis, between normal-hearing and hearing-impaired listeners. The results of that study showed a strong relationship between overall loudness and annoyance ratings for both normal-hearing and hearing-impaired listeners. Additionally, a linear regression model was developed for normal-hearing listeners based on specific loudness and other features of interest. However this model was not able to account for the hearing-impaired data. To follow-up on this work Vishnubhotla Xiao, Xu, McKinney and Zhang (2012b) used a group of listeners with unilateral hearing losses and a group of listeners with normal hearing to determine if hearing loss affects annoyance perception. Figure 1 shows the annoyance ratings for each of the different real-world stimuli for normal-hearing listeners and for unilateral listeners, broken down by their impaired ear and their better ear. In general, the hearing-impaired listeners showed a greater range and less consistency in their annoyance ratings compared to the normal-hearing listeners. For certain stimuli, differences did exist between the normal-hearing and hearing-impaired listeners, such as the washer and the elevator. Loudness was a better predictor of annoyance than sound pressure level, but overall, the correlation between loudness and annoyance perception was still fairly weak.

Figure 1. Annoyance ratings for normal-hearing (black bars) and hearing-impaired listeners for 16 different stimuli. The hearing-impaired data is plotted for the impaired ear (red bars) and the better ear (blue bars). The mean is represented by the dot within the bar.
A possible source of variability in the annoyance ratings of that study may be the semantic meaning of the real-world recordings used as stimuli. To eliminate this possible bias of the semantic meaning of real-world sounds, the current experiment will use synthesized stimuli, in which a variety of acoustic parameters of the stimulus will be systematically varied.

**Goal**

The goal of this project is to determine which acoustic properties of a stimulus drive the annoyance perception for listeners with hearing loss. Additionally, we set out to determine if those properties are different between listeners with and without hearing loss. From gaining a better understanding of the properties that drive annoyance it might be possible to develop a more accurate model of annoyance. With an accurate model of annoyance perception for listeners with hearing loss, it may be possible to develop signal processing algorithms to address annoyance.

**METHOD AND MATERIALS**

**Participants**

Three groups of listeners will participate in this study, listeners with normal hearing, listeners with bilateral mild to moderate sensorineural hearing loss and listeners with unilateral sensorineural hearing loss. Participants will be both male and female, ranging in age from 25 to 85 years. Participants are being recruited from within the Eden Prairie, MN community and are paid for their participation.

**Stimuli**

Stimuli will be designed to vary in their perceived annoyance by systematically adjusting parameters known to affect sensory annoyance. Previous research has shown that perceived annoyance of sound is linked to the overall loudness, spectral shape (e.g., sharpness), and temporal modulations (e.g., roughness) (Zwicker & Fastl, 1999). In addition, it has been documented that particular environmental sounds (e.g., water running, paper shuffling, dishes) are often particularly disturbing for hearing aid wearers (Jenstad, Van Tasell, & Ewert, 2003). Characteristics of these sounds will be analyzed and then systematically varied in our stimulus set with the aim of deriving a psychometric function between stimulus characteristic and perceived annoyance. Reference stimuli will be used throughout the experiment, designed to elicit annoyance ratings near the mid-range of all tested stimuli.

**Procedure**

The testing method is different for the listeners with unilateral hearing loss and the listeners with normal-hearing or bilateral hearing losses. All listeners will complete one training block that will include all the test stimuli as well as each reference stimulus.

*Normal-hearing listeners and bilateral hearing losses*

The stimuli will be presented unilaterally via headphones in a sound treated room. On each trial the participant will be presented a reference stimulus and a test stimulus. The participants will be asked to rate the annoyance of the test stimuli relative to the reference stimuli. The rating scale will range from -5 to 5, with a rating of 5 indicating that the test stimulus is five times as annoying as the reference stimulus, whereas a rating of -5 indicates that the test stimulus is one-fifth as annoying as the reference stimulus. Participants will mark their rating via a touchscreen monitor displaying a slider ranging from -5 to 5. Participants will have the option to repeat the reference stimulus and the test stimulus as many times as necessary to make their rating.

*Unilateral Hearing Losses*

For listeners with unilateral hearing losses, the reference stimulus will be presented via headphones to the ear that has normal-hearing and the test stimulus will be presented to the ear with hearing loss. Using the same rating scale
as the other participants, these listeners will rate the annoyance of the test stimulus in regards to their own perception of the reference stimulus.

**Analysis**

The data collected during this experiment will be analyzed in terms of the relative contributions of the different acoustic properties of the stimulus to annoyance perception for normal-hearing and hearing-impaired listeners. From this analysis a model will be developed to help understand annoyance perception in hearing-impaired listeners.

**REFERENCES**


