
Mapping auditory percepts into visual interfaces for hearing impaired users

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Abstract

Auditory-visual interfaces for hearing aid users have received limited attention in HCI research. We explore how to personalize audiological parameters by transforming auditory percepts into visual interfaces. In a pilot study ($N = 10$) we investigate the interaction patterns of smartphone connected hearing aids. We sketch out a visual interface based on two audiological parameters, brightness and directionality. We discuss how text labels and contrasting colors help users navigate in an auditory interface. And, how users by exploring an auditory interface may enhance the user experience of hearing aids. This study indicates that contextual preferences seemingly reflect cognitive differences in auditory processing. Based on the findings we propose four items, to be considered when designing auditory interfaces: 1) using a map to visualize audiological parameters, 2) applying visual metaphors, turning auditory preferences into actionable interface parameters, 3) supporting the user navigation by using visual markers, 4) capturing user intents when learning contextual preferences.

Author Keywords

Hearing impairment; health; aging; augmented audio.

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]:
Miscellaneous

Introduction

Designing interfaces for the changing demographics of an increasingly aging population should not be limited to haptics or visual impairment, but include auditory paradigms, as a third of 65+ years old have a disabling hearing loss.

It is estimated that 20% of the American population have a hearing loss [10], and one in 3 adults aged 65 or older is suffering from a disabling hearing loss (40 dB or more) [14]. The World Health Organization (WHO) further estimates that 1.1 billion young people are at risk due to loud music exposure [15]. Yet, only limited research within the HCI community has been addressing how to improve the current haptic interfaces of hearing aids. The focus has typically been on visual interfaces, as exemplified by the WCAG 2.0 guidelines making web sites accessible for the visually impaired [4]. How to map auditory percepts have previously been related to visual shapes and size as in Köhlers Gestalt principles, reflecting how sounds like "bouba/kiki" are associated with round or edged forms [8, 11]. Conversely, how to map visual icons into auditory sounds [2, 6, 13]. However, the challenge of visually representing and interacting within auditory scenes has rarely been addressed. Nor the potential in designing interfaces enabling hearing impaired users to manipulate how sounds are perceived based on audiological parameters.

Recent advances in user experience (UX) have been driven by speech interfaces, including speech recognition and speech synthesis, combined with the uptake of smart-speakers and digital assistants such as Alexa, Siri and Google Assistant. Gartner predicts a third of all search will by 2020 be non-screen based on voice [5]. However, for a large part of the aging population voice interaction involves enhancement of speech intelligibility or ambient noise reduction.

Pilot study

Using smartphone connected hearing aids, we explore how to map such auditory preferences into actionable parameters in a visual interface. Based on a pilot study ($N = 10$), we asses how high dimensional auditory percepts may be conceptualized as simple color contrasts and spatial metaphors.

$N = 10$ participants volunteered for the study (one female, nine males), from a screened population provided by Eriksholm Research Centre. Age ranged from 39 to 76 (median age of 65 years). All participants had more than a year of experience using hearing aids. The participants suffered from a symmetrical hearing loss, ranging from mild-moderate to moderate-severe. The study has two goals: 1) to investigate the ability to modify audiological parameters using a visual interface, and 2) to investigate the individual behavioral patterns, inferred from continuous contextual data collected by hearing aid and smartphone sensors, coupled with the users interactions as illustrated by Johansen et al. [7] and Korzepa et al. [9]. In this paper we focus on the first goal. In particular, we wish to address the following issues: 1) How do we design 'intuitive' interfaces, using map and navigation as metaphors? 2) how do we map characteristics of brightness or noise reduction to colors, shapes or other markers? 3) Could such interfaces enable users to successfully navigate and adapt the settings of their hearing aids?

Extending the haptic interface of hearing aids

Hearing aids have been engineered as small behind-the-ears devices with built-in microphones. Thin cables connects to the speaker units positioned inside the ear canal. The most prevalent interface for hearing aids are physical buttons, used to increase or decrease volume gain. Users may press buttons on either device. The same buttons may

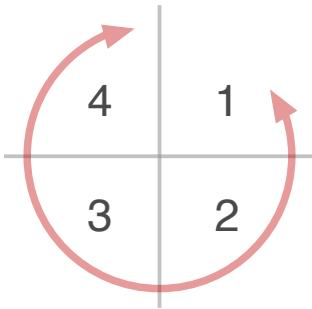


Figure 1: Haptic button press interfaces enable users to sequentially move within a cycle of programs. Perceptually the user moves clockwise or anti-clockwise, but can only move in steps to the nearest neighbor, but not jump from e.g., 1 to 3.

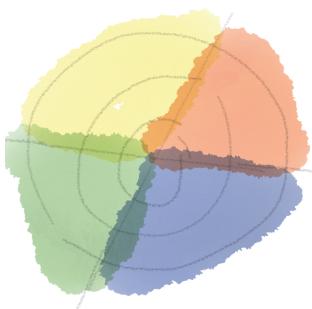


Figure 2: Four distinct programs illustrated as four different colors.

enable the user to change between alternative programs, by sustained button presses. The devices provide auditory feedback through series of 'beeps', depending on the interaction. Volume changes happen within a second, while program changes may take several seconds before being fully engaged. The haptic interface is essentially a sequence of steps, which enables the user to move through alternative programs in a cycle as illustrated in Figure 1. Volume adjustments moves up or down. The haptic interfaces allow for rapid interaction. However, the user may struggle to keep track of what constitutes the current program or volume setting.

Bluetooth connected hearing aids can enrich the interaction by visualizing settings on a smartphone app. One approach enables users to select between program settings associated with symbolic icons related to locations such as "restaurant", or activities like going for a walk in "nature" [12], thus mapping one context to one setting. This helps to inform the user of the current state of the hearing aid. Both haptic button presses and symbolic icons are limited to sequential steps, and do not support parallel interaction patterns.

Mapping from auditory to visual metaphors

Bregman [3] describes auditory scene analysis metaphorically, as similar to making out the numbers and size of boats at sea, as well as the characteristics of the wind, based only on two handkerchiefs being excited by the waves. We similarly face the challenge of transposing the sense of moving within a high dimensional auditory space into a two dimensional visual interface.

Initially we investigated whether symbolic icon buttons would reflect the actual usage scenarios. Hearing care professionals (HCP) often simplify the usage of alternative set-

tings by labeling programs to a specific location, activity, or with a generic "program"-name. However, our findings indicate that such contextual labeling may introduce a limiting bias, obscuring the highly individual preferences related to different usage scenarios. This means that one program translates into many scenarios, unlike the current approach where a program maps to one scenario.

Labels, colors and space as markers

Our metaphor can abstractly be interpreted as a spherical 'space', where the user can move around. In this space we use both positioning of the ball, contrasting colors and labels, to help the user navigate.

We used two audiological parameters, brightness and attenuation, to create a map, rather than symbolic icons. Essentially empowering users to modify their listening experience, and to explore the auditory map. Increasing the perceived brightness enhances spatial cues, enabling the user to selectively allocate attention to separate voices. Or, conversely attenuate ambient sounds to increase the signal-to-noise ratio (SNR), making it easier to separate competing voices. The enhanced brightness perception is visualized as two color segments in the top half of the circle, combined with associative labels naming them "lively" and "crisp". The two remaining parts were assigned noise attenuating programs, accordingly labeled "natural" and "focused". Discrete program selection is illustrated in Figure 2, with four distinct programs.

A colored ball is used as a visual pointer, reminding the user of their current location. The ball can be moved accordingly, and augment the sound while updating the settings. To help the user navigating we use text labels, rather than icons. Four labels characterizing the sound are, "lively", "crisp", "focused" and "natural". As an example, "crisp"

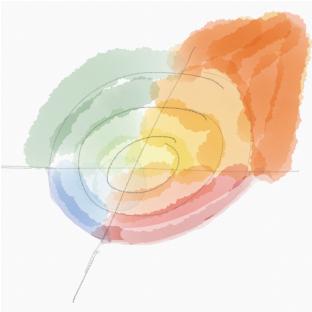


Figure 3: An abstract visualization of the interface based on color contrasts and saturation, without associative textual labels .

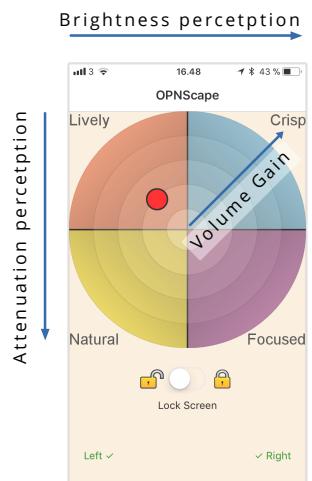


Figure 4: Proposed app interface. By moving the red ball, users may increase the brightness perception (x-axis , attenuate ambient sounds (y-axis) and adjust the perceived loudness (from center to edge).

might be associated with the sensation of auditory cue localization, while "focused" might reinforce aspects of directionality. Assessing the spatial metaphor, all users in the pilot study, spanning the age of 39 to 76 years old, find it easy to adjust both the brightness, and the attenuation. Additionally, most users prefer a visual interface to the current haptic interfaces of hearing aids. The subjects find the moving ball responsive and visually intuitive in navigating the auditory space, irrespective of age.

However, attaching labels, may bias the end user. An alternative view of navigating the auditory scene is presented in Figure 3. The labels have been removed, and colors, saturation, depth, contrasts, and shapes alone define the auditory space visualized as a sphere. This may support the user in exploring the room, rather than moving through a discrete space.

Learning to navigate the map

To build up auditory awareness one would assume that training is needed to navigate spatially, just as it is when learning to ride a bike. When first learning to ride a bike one may start pedaling, and can thus get from A to B. This is the stages where one starts to use a hearing aid. Later, one experiences the gears of the bike. This is similar to changing between four discrete programs. Later, brakes are discovered to regulate speed. This corresponds to adjusting the volume. Wearing the devices combined with a contextual selection of programs and volume, allows one to steer the bike. However, navigating a bike, or an auditory space requires practice. The perceptual difference when adding brightness, or adding attenuation, impacts the loudness. The brighter sounding programs may perceptually exceed or fill the sphere, compared with the lower bottom attenuated programs.

Our interface depicted in Figure 4. allows for parallel modification of both sound perception and volume intensity. The ball can move horizontally, to alter brightness perception and soft gain, i.e., the frequency response in mid- and high frequencies. Navigating vertically allows the user to attenuate ambient sounds, i.e., removing noise while still preserving sounds with voice-like characteristics. Moving the ball from the center towards the periphery increases or decreases the volume intensity. Several users found it difficult to simultaneously modify both the gain and program. This may be due to the mapping from higher granularity of the haptic interface, to the more coarsely controlled volume gain in the visual interface. Only 6 out of 10 found the visual volume adjustment easy or very easy.

Translating auditory scenes into intents

An added outcome when observing user preferences in real life listening situations, is to learn the preferences in a given context. Established hearing aid paradigms, e.g., as proposed by Stuart Gatehouse [1], would assume that noise reduction should be increased as the signal-to-noise ratio deteriorates, to enhance speech intelligibility. However, given the ability to explore an auditory space, our pilot study indicates that most of the subjects rather prefer the omnidirectional "lively" program without attenuation of ambient sounds, to improve speech intelligibility. All of the 10 subjects indicated they prefer the "lively" (7) or "crisp" (3), illustrated in Figure 5. These programs offer little or no noise reduction in order to enhance speech intelligibility. Whereas they select programs like "focused" or "natural" to attenuate ambient sounds in noisy environments. Our visual interface, thus seem to spatially reflect the user intents for either increasing brightness along the horizontal plane, or vertically to reduce background noise.

The subjects also showcase the importance of considering

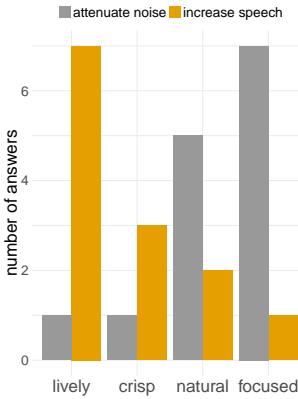


Figure 5: User preferences for attenuation (grey) and speech intelligibility (orange). Sum of program as "most preferred" and "preferred" for each condition.

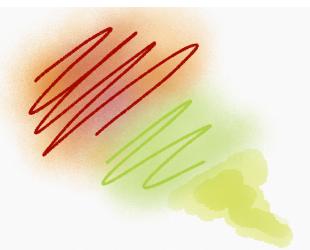


Figure 6: An acoustical environment (red). The hearing aid signal processing compensates for the hearing loss based on the program and volume interaction (green). The modified auditory percept should contextually reflect the desired outcome supporting the user intents (neon).

intents in relation to preferences. One says: 'When I'm in meetings with 4-5 people I prefer to use the "lively" program to better understand speech. When I'm attending a presentation in a larger hall with more people, I prefer to attenuate noise, especially behind me. I also use the "focused" program in the cinema to minimize annoying background noise'. Several subjects reported: 'The program I select to enhance speech intelligibility depends on the people I'm focusing on. Female voices or small kids have higher pitched voices, and the "bright" program becomes too shrill'. The translation from auditory scene to user intents is illustrated in Figure 6. The user is subjected to the demands of an acoustic scene marked in red. Through interaction with the hearing aid, marked in green, the user changes the settings to modify the perception of the auditory scene. The modified auditory percept should contextually reflect the desired outcome of the user intents, marked in pointy neon green.

Future work

Designing next generation interfaces, reflecting the changing demographics of an aging population, may provide novel opportunities for the HCI community to redefine voice interaction in a broader sense as augmented hearing. However, the interaction models would need to be redefined, in order to facilitate personalized hearing care by empowering users to adapt settings along audiological parameters.

We found the usage of visual metaphors and spatial exploration empowers hearing aid users. The users intuitively understood the two-dimensional mapping of audiology parameters. Providing markers such as color, labels, and a ball to indicate current position, helps the user navigate in an auditory space. However, compensating for the perceived loudness of contrasting settings requires further work. We furthermore see a potential in empowering users to become an active part in compensating their hearing loss at any

age, in order to explore the potential of augmenting hearing. In our pilot study the users were equally capable of modifying hearing aid settings regardless of their biological age. Their preferences might rather reflect how they cognitively process auditory percepts differently. It is therefore crucial to provide added means of personalization, rather than providing "one size fits all" settings based on age. It might not be feasible for all elderly users to engage with their hearing aids to the extent outlined above. Although even if only some users would engage actively, it might still facilitate a crowdsourcing of user generated data, making it possible to learn behavioral patterns as a foundation for designing next generation augmented hearing interfaces that adapt to "users like me in soundscapes like this" as outlined by Korzepa et al. [9].

We propose the following points to consider when designing such auditory interfaces: 1) using a map as a metaphor to visualize audiological parameters such as brightness perception and attenuation, 2) applying visual metaphors together with associative text labels may help turn auditory preferences into actionable interface parameters, 3) support the user navigation by using markers, based on contrasting colors, spatial layout and position, 4) incorporating the perceived intents of the user whenever aiming to learn contextual preferences.

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