Transparent Hearing

Florian Mueller
MIT Media Lab
20 Ames St
Cambridge, MA 02139, USA
floyd@floydmueller.com

Matthew Karau
Media Lab Europe
Sugar House Lane, Bellevue
Dublin 8, Ireland
mattk@mle.ie

ABSTRACT
This paper describes what we call *Transparent Hearing*: the use of microphone equipped headphones for augmented audio. It provides a framework for experiments like real-time audio alteration, multi-modal sensory integration and collaborative listening experiences. We attach high-quality microphones to headphones and send the signal through a computer to these headphones. We have built headphones that stop the music if somebody wants to talk to you, a pseudophone, and collaborative *I Hear What You Hear* headphones that are triggered by eye-contact.

Keywords
Binaural, microphones, augmented audio, headphones, pseudophone, range finding, infrared

INTRODUCTION
Senses are our interfaces to the world; by enhancing them, we can create different kinds of interactions with our surroundings. Modifying your vision "on-the-fly" goes back over a hundred years ago, when Stratton used optical lenses in his glasses to turn his vision upside-down. [1] Mann used cameras on head-mounted displays to create a digital version of this. [2]

Audio augmentations are typically created by playing audio cues to the user from time to time (based on location, for example [3]). If one wants constant alteration of a person's perceived audio, one must look to hearing aids. Hearing aids augment audio by providing a flexible amplification of the existing environmental sound. We wanted to build a system that is different from this, that is independent from the surrounding audio.

RELATED WORK
Basu built smart headphones for use with a personal stereo that detect outside speech in order to mute the music [4]. One drawback of this system is that some speech must first occur before it can be detected, and users either fail to hear the beginning of the conversation, or the system has to deal with a delay.

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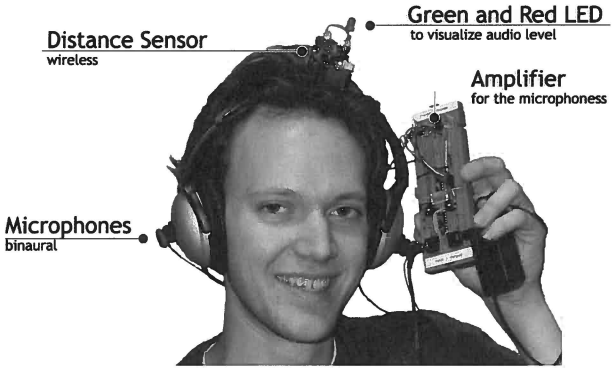

Transparent Headphones

IMPLEMENTATION
Transparent Headphones is a system in which sound is picked up just before it enters the ears, altered, and then played back in real-time, creating transparent augmented hearing.

Headphones play back the sound that is received by binaural microphones [5], which are attached to the ear cups, facing away from the head like the pinnae (ear flaps) of the human ear. This way the sound is picked up in a manner similar to the way our ears receive sound. Binaural microphones are generally used for musical recording and are placed in correctly shaped plastic ears of a dummy head and then placed where the audience would sit in a concert hall to record the music. It allows for superior recording quality and is designed for playback on headphones. This is ideal for our purposes!

The microphones pick up ambient sound, which is then amplified and sent to a computer, where it can be altered. The modified audio is then played back through the headphones. This allows switching between two modes: one sounds as if you have headphones on (opaque mode), dulling the external, environmental noise, while the other pipes through the audio from the microphones, sounding as if you are not wearing headphones at all (transparent mode).

Positions between these two extremes form a gradient from opacity to transparency and are called semi-transparent modes: each passes a different level of external audio to the ear.

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SCENARIOS

Having the ability to augment (or not augment at all) the audio presented to a user allows a variety of applications. If you take it even further and vary the augmented audio on the input of additional modalities, you can create a vast range of scenarios.

Our first application helps you concentrate on music and still be accessible to the people around you for interaction.

Headphones With a Sense

Headphones are great for listening to music without disturbing others, but they also create a hindrance to a conversation: if somebody started talking to you before you took the headphones off, she/he might have to repeat what has been said.

The *Headphones with a Sense* address this problem: They play the music, and if somebody comes close to you to talk to you, they pause your MP3 player on your computer and patch the person's speech through. If she/he leaves, the music resumes. The system detects if another person approaches you using reflective infrared distance sensors. You also can select the option for the music to fade out to a comfortable level for conversation and then fade back in when the conversation is over.

To give the people you interact with an indication of the current sound level of the music in your headphones, we attached two LEDs to them. Red means you are in opaque mode and cannot hear external sounds, green means external sound is put through to your ear. In this way, others can visualize your current state of hearing, transforming a status of hearing into the visual domain.

Pseudophone

We also have built a *Pseudophone* [6], which allows you to hear in your right ear what you would normally hear in your left ear and vice versa. Such a device has been used in psychology to study the cognitive processes underlying speech processing, but from personal experience, wearing such a pseudophone can also be fun and entertaining. It makes you aware of how much you rely on audio for location perception, like when you turn left if the phone rings to your right, for example. In contrast to previous systems we found, our device is light, mobile, uses high quality audio equipment and can be easily modified to fit the application.

I Hear What You Hear

We built a second set of our system and wired them up in such a way that person A's microphones were connected to person's B headphones and vice versa. This allowed you to put yourself "into somebody else's head". If the effect of the pseudophone was already impressive, this was astonishing. Again, locating audio sources is very difficult, and it takes some time to get used to the changed environment. As soon as the other person moves her/his head, the audio landscape rotates, and habituation begins again. This is an extreme interface for interpersonal communication: you can be constantly connected to somebody else's audio environment. It could either be an intimate relationship or a surveillance scenario where one could do other tasks without interrupting the monitoring.

Cocktail Party Effect 2000

The cocktail party effect describes the ability in perception to select one desired sound from a background of ambient noise. At a party, many voices are speaking simultaneously, but we can 'focus' our ears on one voice and ignore others that are equally strong. [7]

We applied the *I Hear What You Hear* system to a cocktail party scenario. If an attendee spots another person at the other end of the room, all they would need to do is to establish eye-contact to initiate a conversation. We equipped the headphones with wireless infrared transceivers, and as soon as they point at each other, they establish a connection and put each other's audio through.

DESIGN

To simulate a realistic audio environment that makes you believe you are not wearing headphones, the system must employ high-quality audio equipment. We therefore used professional binaural microphones [8]. We also chose noise-cancelling headphones, because they block outside noise reasonably well.

FUTURE WORK

Currently, we are working on making the device smaller and lighter. We use noise-cancelling ear-bud headphones next which allow us to place the microphones very close to our pinnae. Having this framework available now allows us to do thorough experiments based on the scenarios we could only describe briefly here. The mobile system allows us to do long-term studies outside laboratory settings and investigate habituation effects in real-life audio environments.

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