IceBreakware: Designing Wearable Technologies For Spatial Awareness and Social Interactions

by

Amos Golan

M.Sc., Tel Aviv University

Submitted to the Program in Media Arts and Sciences
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 2018

Signature redacted

Author . . . .
Program in Media Arts and Sciences
August 10, 2018

Signature redacted

Certified by . . . .
Hiroshi Ishii
Professor of Media Arts and Sciences
Thesis Supervisor

Signature redacted

Accepted by . . . .
Tod Machover
Academic Head, Program in Media Arts and Sciences

"Mobile technology is here to stay, along with the wonders it brings. Yet it is time for us to consider how it may get in the way of other things we hold dear"

– Sherry Turkle, Reclaiming Conversation

IceBreakware: Designing Wearable Technologies For Spatial Awareness and Social Interactions

by

Amos Golan

Submitted to the Program in Media Arts and Sciences
on August 10, 2018, in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE

Abstract

We live in an era of constant connectedness; we carry a smartphone in our pocket, headsets on our ears and enjoy limitless and regular access to almost any content we wish. However, the use of the personal computing devices that allow this connection with the virtual world damages our ability to connect with the physical world surrounding us; our eyes are focused on screens, our ears are covered by headphones and our attention jumps between apps. As a result, many of us are actually finding it harder to have face to face interactions with others than ever before. We are getting worse at communicating with the people around us, in the present, and tend to prefer virtual alternatives, as they are easier to operate, less stressful and fully under our control.

This thesis proposes a perspective at wearable and personal computing devices and the role that their design may play in creating and fighting the epidemic of growing isolation. We hypothesize that the negative social trends that we witness as a result of using smartphones, headphones and other personal devices are not the purpose of these technologies, but rather an unwanted byproduct of their use. We propose to redesign ubiquitous personal technologies to reduce their isolating effect and use them to foster more physical interpersonal interactions and spatial awareness, by equipping them with additional modes of operation that force interpersonal interaction. We call this family of new interfaces **IceBreakware**.

As a proof of concept, we present LeakyPhones, an instance of IceBreakware and a social version of the ubiquitous headphones. LeakyPhones is an interface that allows colocated and real time audio sharing between two or more people by coupling music sharing with a gaze. LeakyPhones encourages users to explore their surroundings with their eyes, and interact with the people around them. They also change the meaning of a previously private medium such as the headphones and turn it into public at will. By doing this, Leakyphones tries to overcome some of the limitations of normal headphones.

This work explores corrective measures to standard personal devices that can possibly be implemented to existing technologies in order to encourage desired social behaviors. It demonstrates how gaze and music sharing may act as a social vehicle and help and encourage positive real-world interactions between people while not substituting them with virtual alternatives.

Thesis Supervisor: Hiroshi Ishii
Title: Professor of Media Arts and Sciences

IceBreakware: Designing Wearable Technologies For Spatial Awareness and Social Interactions

by

Amos Golan

Submitted to the Program in Media Arts and Sciences
on August 10, 2018, in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE
at the
Massachusetts Institute of Technology

The following people served as readers for the thesis:

Reader .... Signature redacted ......

Rosalind W. Picard, ScD

Professor of Media Arts and Sciences, MIT

Signature redacted

Reader ....

Sherry Turkle, PhD

Professor of the Social Studies of Science and Technology, MIT

This work is dedicated to my late grandmother safta Liza.

My beloved grandmother and a true music lover.

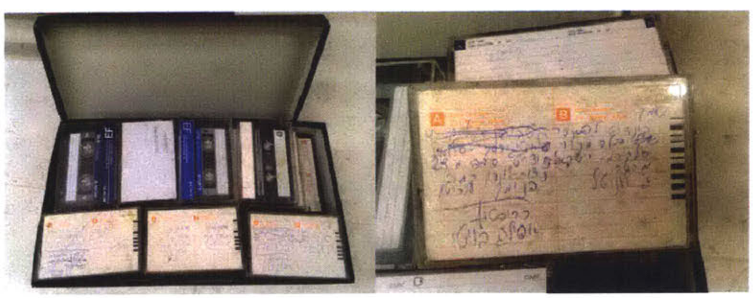

Figure 0-1: Liza's music collection

A small portion of my grandma's home-recorded compact cassette collection. Each cassette was self recorded from the radio, usually from the Israeli classical music station, "kol hamuzika". The details of the artist and the recording were meticulously scribed on the cassette's case, usually more then once. Recordings were constantly changed, reused and improved.

Acknowledgments

I would like to thank my advisor, Hiroshi Ishii, for his support, guidance and mentorship in the past two years and for coming up with the name for the group of devices described in this thesis - IceBreakware. Thanks for believing in me, supporting and letting me pave my own way.

Rosalind Picard and Sherry Turkle my thesis readers, for gracefully providing the advice and comments I needed and when I needed them the most.

The BOSE corporation and Dan Gauger for their generous support of this project and long helpful discussions.

The Tangible Media Group members and our admin Deema Qashat, for your friendship, help, and critique.

Tal Achituv, for your great technical contribution to this work and for teaching me a lot, on technology and people alike.

My friends at the lab and outside of it, in Israel and Boston, for helping, inspiring, believing in me and pushing me forward.

To my family: My brothers Michael and David, who are a constant source of inspiration to me. Mom and Dad, for your love, efforts, worries, and criticism, which are probably the main reason I made it to MIT.

Most of all I want to thank my wife Timna, for your love and support and for being a source of pride and happiness in my life every day. You made this adventure come true and now it is your turn!

Contents

List of Figures

Chapter 1

Introduction

1.1 Motivation

Our eyes are occupied by screens, our ears are covered with headphones and our attention is split between the people around us, emails, notifications and messaging apps. We use our personal computers, digital devices, and social media all day, often not noticing how being connected at all times changes us and how we interact with our environment. So often, we do not notice how it distracts us from the present, from our surroundings, and from our loved ones.

The merits of mobile and digital technologies are so grand that it is almost certain that they will only become more widespread and more central in our lives in the future. Yet they seem to be changing our behavior as individuals and as a society in some less positive ways as well. Personal technologies were built to serve specific practical goals so well, that sometimes it seems like their social side effects were not really predicted or taken into account in their design. The spread of phones and headphones together with Internet and social media have greatly affected how people interact at home, in public and in relationships. This has created a new kind of loneliness - the feeling of being ever connected, surrounded by people yet feeling alone [43]. A quick tour of the local train station, museum or office reinforces this statement: people, coworkers, friends, families, although in physical proximity, seem to ignore each other. If they share something, it is most likely something from their phones or Facebook account.

Many devices and services were invented to connect people back together. Most of them are quite naturally based on the same new technologies that might have caused the change in social behaviors to start with. But "real" conversations and interactions are collocated and happen in real time. It is not possible to edit a real conversation or to take back a wrong turn or a nasty comment. This is where both the strength and the weakness of an interaction in the real world comes from and what makes it human. These aspects of shared and distributed interactions, both in space and time, were heavily researched in the field of Computer Supported Cooperative Work.

	Real time	Asynchronous
Colocated	Face to face interactions Conversations Ice Breakware?	Continues tasks e.g Public displays
Remote	Remote interactions e.g Video conferencing	Communication & Coordination e.g email

Figure 1-1: The computer supported cooperative work (CSCW) matrix. [24] Most interactions supported by personal computing devices that connect people lay outside of the blue cell. Can IceBreakware push digital interactions to the realm of real-time and collocated interactions?

This thesis tries to explore how redesigning personal digital devices and their capabilities, and more specifically, reimagining headphones, may promote and induce socially desirable interactions that lead to face to face conversations or other forms of meaningful and genuine interactions between physically collocated people.

Music sharing was chosen as a medium for this work; it is implicit and abstract enough to encourage conversation, yet explicit and expressive enough to be a strong statement of one's own identity. Music listening is an activity done both privately and in company and can provide an insight into people, strangers and friends alike. It can induce a strong emotional response or serve as a shield from showing emotions. It exists at the intersection of private and public being.

Figure 1-2: Rembrandt's famous "The night's watch" and school kids on their phones with their back to the masterpiece.
Photo credit: Dekel Golan.

1.2 Purpose

Skills such as engagement in a conversation are slowly redefined and reshaped, some even disappear as a result of the constant use of technology. This changes our perception of relationships, intimacy, and conversation [42]. This thesis presents a wearable device which possesses the form factor of an ordinary headset. The common form factor was chosen to increase the chance that the device will be accepted by potential users and will be properly tested for its potential social benefits. This headset was designed to serve as a mediator between people to help and reintroduce or encourage certain social skills, which the writer of this thesis believes are disappearing as a result of the ubiquity and constant use of personal computing devices. In addition, we were interested in examining how personal devices such as headphones, which usually signal specific messages of alienation to the environment ("I'm not interested in interacting right now"), may change when introduced with new capabilities like gaze-based sharing are added to them The work describes a headset that allows a range of social interactions that are designed to encourage conversations between strangers, colleagues or friends using a widely used and highly accepted wearable device. It illustrates two approaches to implement such a device; a distributed version that uses proprietary hardware and software, and a centralized version that uses off the shelf products in combination with custom software. The design of these systems and a thorough user study and evaluation of the concept and the interactions that result from it are also included in this work. A group discussion regarding the concept and the feeling associated with participation in the study sheds more light on the validity of the idea of LeakyPhones, regardless of its exact technical implementation.

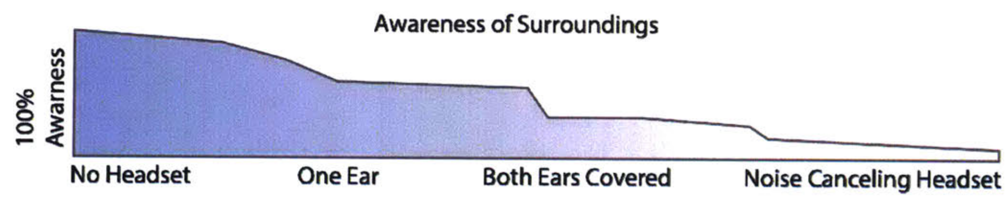

Figure 1-3: Illustrations of one's attention when using headphones in different ways Can Leakyphones make users more aware of their surroundings?

1.3 Contribution

This thesis presents a wearable device, LeakyPhones aimed at facilitating a range of interactions between people. The design principles and considerations and user testing results of this device are presented herein.

In addition, this work introduces a rather generalized toolkit for modeling, prototyping, and testing of auditory interfaces and experiences in space called A.SAP. This toolkit combines web-based architecture and a simple to use GUI, built on top a physical computing [36] platform in order to provide the ability to quickly prototype and experiment with Augmented Auditory Reality and space-audio experiences.

We have conducted a range of qualitative and quantitative evaluations of the LeakyPhones concept using the A.SAP system and have shown that at least to some extent, participants in the study reported more interactions when using LeakyPhones as opposed to using noise canceling headphones and that it increased their awareness of their surroundings.

The A.SAP toolkit described in this thesis, and the design principles and lesson learned from the design and testing the concept of LeakyPhones with it could potentially assist in building technologies that let us reshape our future with digital technologies while making sure we remain human and keep our social skills.

1.4 Overview of The Thesis

The Related work section positions this work in relation to closely related fields such as music sharing, digital and physical facilitators of human interaction, and auditory augmented reality systems. It also introduces prior art in other attempts to affect people's social behavior using music and interpersonal connectivity.

Section **3** describes the engineering work done to create the LeakyPhones prototype - a decentralized platform for social music sharing with controllable privacy.

Section **4** presents the A.SAP system and its use in creating a stable, testable centralized version of the LeakyPhones experience. This section describes the benefits and disadvantages of a centralized approach and other potential uses of the A.SAP platform in prototyping auditory experiences in physical space.

Section **5** discusses the details of the user study and group discussion conducted to evaluate the LeakyPhones concept and the complexity of testing user experiences of novel interaction types. It also illustrates the different technical considerations taken into account when planning the LeakyPhones user study.

Section **6** illustrates the results of the LeakyPhones user study, surveys, and group discussion.

Section **7** concludes the efforts of this thesis and illustrates future work that can be based on the infrastructure of LeakyPhones and A.SAP for perhaps designing better technologies for people.

Chapter 2

Related Work

This work is based on existing and emerging work in three fields:

1. Music and audio sharing
2. Physical enablers of interactions
3. Auditory Augmented Reality

2.1 Music and Audio Sharing

Music had been a shared experience for centuries, enjoyed in a small group mostly due to physical limitations. Examples include listening to a concert or meeting with friends and family to listen to a radio show or record. With the appearance of the headphones in the 20th century and the early means to record and play music at one's will, like the transistor radio [1] and tape recorders, this trend started changing, resulting in a change of social music listening behavior. Music and music sharing turned into a new medium for expression [7], and listening to music alone became a common practice.

2.1.1 Physical and Digital Audio Sharing Devices

The appearance of headphones, turned music listening into a mostly solitary activity, as these new devices provided a means to listen to music in absolute privacy. This resulted in an opportunity and a problem: personal listening is in many ways more appropriate than listening to the radio; for example,it provides a means to listen to music without interrupting others. On the other hand, personal music listening results in physical and perceptual isolation between people present in the same physical space.

Many early devices tried to address this limitation. These devices had dual modes of operation: the ability to play music privately-by using headsets, or publicly-through an on-device speaker. Other solutions to this problem were additional add-on physical devices like an audio jack splitter(e.g as used with the Walkman), that allowed two headphones to be connected to the same device. Sometimes, people even shared an earbud with a friend, allowing for some form of shared music listening with what is considered a personal device.

The appearance of recording and playing technologies, such as the tape recorders pushed music sharing farther and surprisingly created a new form of communication around music sharing. People were listening to music individually but were interacting with each other in the real world in order to discuss what they are listening to and to switch physical copies of music (e.g mixtapes) with each other. The "mixtape" [7] was a physical object that was given to friends or circulated to share new bits, show affection, or expose yourself to the world as an artist. It is believed by some to be the most practiced form of art because of its popularity. With the progress of technology, the mixtape turned into the playlist; a digital collection of songs, which was very rapidly introduced to the world and was shared not in the "real" physical world but in the digital domain.

The appearance of digital music sharing platforms such as Napster, Gnutella, Kazzaa, Soulseeker Myspace and others which provided peer-to-peer music sharing, made the tangible component of music sharing from previous technologies obsolete and didn't require that you live in the same country or know the person you are sharing the music files with. People could share music from the comfort of their homes, with others they have never met. They could do all that without interacting with them in the real world. Following that, they could listen to the music by themselves using their personal music players headsets.

This trend grew even stronger with the appearance of cheap personal music players (the "mp3" players) and with Internet connectivity and advanced music managing software such as iTunes. One could now buy music from an online store or download it from an anonymous source without having any other human in the loop. Gigabytes of content could be stored in the virtual world without having any physical manifestation[35]. YouTube and the other peer-to-peer sharing mediums connected people once again, but through a digital medium, which is, in essence, different from physical sharing: you don't need to know who is the person on the other side and they don't need to know who you are. In addition, the communication between the two sides does not happen in real time if it at all happens. These are some of the factors that changed what was in the past a reason for a conversation to merely a form of communication or transaction.

2.1.2 Novel Approaches and Devices for Sharing Audio

In addition to standard or improvised ways to share music, a large number of audio related projects tried to propose solutions for music sharing that challenge the notion of private vs public listening, or challenge the affordances of standard platforms. In the next section, we present a number of these attempts The different types of efforts related to real-time physically-based music sharing can be roughly divided into 4 categories:

1. Location-based music sharing
2. Passive systems for social and environmental awareness
3. Active systems for social and environmental awareness
4. Context-based music sharing (DDP, Silent Disco, etc.)

Location Based Music Sharing

A couple of examples showcasing proximity and location-based peer-to-peer synchronized music sharing exist in the literature and in popular culture. Some prominent examples include TunA [9], a wifi-based localized music sharing app, BluetunA [11], a Bluetooth-based sharing app and Genius-on-the-Go [47] an FM-based device for close range localized music sharing. In these systems, the user gets a view of the digital profile of participating peers in his vicinity and can obtain information about their musical taste by looking at their playlists through an app. The users can also share their actual music using a distributed network based on physical proximity. While these examples let users share content with their surroundings, this approach suffers from two main drawbacks:

1. A mobile app to explore their surroundings and to initiate interactions. This results in a user's gaze being focused on a screen rather than towards full awareness of the surrounding people. This limits engagement in conversation and human-to-human interaction as eye contact is not formed.

2. People fear for their privacy; therefore, they tend to limit the information they share in their public profile. It is very common for public profiles to be non-revealing to fit what the users consider "safe"[41]. These profiles often do not include a photo and use only a nickname. As a result, localization does not necessarily reveal the identity of other users in one's vicinity. Since these systems do not match with high certainty between a user and their music and where they are located in space, real-world interaction based on music sharing are somewhat limited.

As a result, location-based sharing of content seems to have only a few advantages over other forms of non-location-based content sharing platforms such as Youtube, Spotify etc.[41, 28, 25].

We hypothesize that the localization of an event is not enough to initiate an interaction with the people around us, but an intention and direct, unmediated behavioral invitation to interact in the form of gaze or head direction[46], is needed in order to initiate some kind of interaction between strangers

Passive Systems for Social and Environmental Awareness

The literature is packed with examples of passive gaze-awareness based interfaces. These examples usually rely upon a state change triggered by a gaze at the wearer and distinguish this change from a state change based on proximity. Some representatives of passive headset systems such as these are the Attentive Headphones [45] which let the user wear a noise-canceling headset while still remaining available to his peers, or Transparent Hearing[31], a headset that uses IR sensors to sense if someone approaches the user and stops his music. The Smart Headphones [10] do the same thing by picking up speech events directed to the wearer using microphones. While these examples let others affect ones musical content, they are passive on the user's side. They do not provide a means for an active interaction or activation from the user. In addition, the user is interrupted by others, whether he wishes to engage in an interaction or not.

Active Systems for Social and Environmental Awareness

There are a few examples of headsets that rely on an active user's gaze at something or someone else to make changes to their listening experience. Soundscope Headphones [20] for example, control an audio mixer through the natural movement of the user's head, thus enabling music mixing. Concert Viewing Headphones [6] detect the gaze direction of the user and enable them to focus on specific instruments during the performance that they wish to augment and hear them louder than others. The headset does this by tracking gaze direction and playing pre-recorded parts of the concert played individually by the chosen instrument. The Smart Headphones [15] detect speech events, and thus can technically be controlled by the user as well. Most of these examples give the user active control over his content, but do not provide bidirectionality, or content sharing capabilities.

Context-Based Music Sharing (DDP, Silent disco, etc.)

In popular culture, there are two notable examples of content sharing based on proximity which lead to bidirectional interactions with strangers. One example is Tom and Gary's concept of Decentralized Dance Parties (DDP) [19]. In a DDP, participants follow a DJ leading a party parade. They are equipped with boomboxes that let them tune into the leader's music, and thus can experience the party themselves. Since the radio transmitter has a limited range, participants are forced to walk together in close proximity to each other. This inevitably initiates an interaction between strangers. Another popular example is the concept of mobile clubbing, in which participants listen to the same concert or DJ through multiple headsets [18]. While these examples are designed to lead to an interaction between users, they don't necessarily create an interaction between the active transmitting side and the passive receiving side. In addition, they do not provide users with the ability to express themselves by sharing their own content and rely solely on receiving content from a centralized source. The party atmosphere facilitates the interaction between people.

2.2 Enablers of Interaction and Collaboration

2.2.1 Factors Affecting Interaction

Many factors have a profound effect on the way people's attention and interest in interaction is perceived by others. Some of the major factors include gaze and eye contact [29], head direction [27, 26], body direction [34], as well as other factors such as gender [32], age, and cultural conventions [44]. These factors, which are so evident and important in a normal conversation, lack in many digital interactions, mostly because excluding them simplifies the performance of the task of communication.

2.2.2 Physical Enablers of Interactions

Physical enablers for interactions and communication differ from their digital counterparts (such as messaging app, social media etc.) in that they usually require and encourage the interacting parties to share an experience in the same point in time and space.

A great deal of research in HCI has focused on supporting social processes and facilitating these kinds of real-time physical experiences and extending them in order to ease and make them more meaningful. On one side of the spectrum are devices that serve as mediators for an interaction and recreate intimacy and awareness that are found in a real physical experience. These devices are aimed at situations when the interacting parties are not colocated. On the other side of the spectrum are devices that are meant to help people engage in a real conversation and interactions when they are collocated. These devices add "spice" to the conversation [12] and serve as icebreakers that help in initiating the conversation. LeakyPhones is closer to this group of devices, but because it relies so heavily on gaze and creation of intimacy it inherits also from the first category.

A prominent example of the first category is ClearBoard [23]. ClearBoard is a computer-supported cooperative work (CSCW) platform that allows for remote collaboration while maintaining direct eye contact and the use of natural gestures. ClearBoard is unique in its ability to create gaze awareness usually found only in face to face interactions and collaboration on a shared goal. Gaze awareness allows one to follow another person's attention by noticing what they are looking at while two or more people collaborate. InTouch [13] is another prominent example of a tangible interface for collaboration and interaction that allow people to experience a synchronous tangible interaction with each other even when they are spatially separated. The InTouch nodes could be separated in space, but since the experience is shared in time, and employs the sense of touch which we usually associated with intimate, physical interaction, it is to serve as a very strong enabler for emotional interactions.

Enablers of physical interactions can also help individuals in gaining confidence to talk to another person and start a conversation or share something in common. Social badges are a good example of physical enablers of social interactions that target this issue. The Thinking Tag for example [12] is a clever way to help people get to know how much they share in common with their peers and can be programmed based on the user's preferences and needs. Knowing that you share a lot in common with someone is by itself soothing and helps people interact with more ease and provides a subject to talk about, but even knowing that you do not share a lot in common with someone helps in establishing a conversation based on the differences between the two of you. Some other badge based technologies like musicFX or Flytrap [16, 30] use the user's musical preference to dictate what genre to play as background music. The users of this system thus get a better starting point for an interaction as the system provides a musical common ground.

The LeakyPhones project has its roots in the research traditions of (CSCW), Facilitators of social interactions such as the thinking tag, peer-to-peer music sharing technologies such as TuneA and tries to take lessons learned from these works to create a wearable device that supports social processes.

2.3 Auditory Augmented Reality

Augmented Reality (AR) is a process of embedding or overlaying digital information on one's physical reality. AR is considered by many as a future modality that will allow people to exist in the digital and physical worlds simultaneously while keeping their attention with their surroundings. Most AR technologies rely primarily on the sense of sight to experience interactions. Since the sense of sight is so heavily employed in human-to-human and human-environment interactions, this route of augmentation may prove to be distracting and problematic. Current AR technologies also require the use of cumbersome head-mounted displays, which makes them less appealing.

An interesting field of AR that is rapidly growing and may circumvent some of the issues associated with classic AR is Auditory Augmented Reality (AAR). In AAR, additional layers of information are added to the reality via audio using headsets [38] or special audio-enabled fashionable eye wear [2]. The major benefits of using these systems lay in the combination of the intrinsic properties of the sense of sound: it is omni directional, allows source localization, is low bandwidth and does not crowd our visual attention. Because most of our daily interactions with other individuals and objects are based on eyesight, the auditory augmentation route does not greatly interfere with visual information processing [40, 21] This makes audio augmentation a good channel for human-to-human interaction in our already visually overwhelming reality. Several related works in the field of auditory augmented reality present an extensive engineering effort in audio, location tracking, gaze direction determination, Sonification and other related fields. Some prominent examples include projects that aim to create spatial auditory experiences such as Audio Aura [33] which is a location-based sound office environment that uses the user's location and identity to induce auditory content delivery to their headphones. Other explorations in augmented auditory reality are Hearthere by Russell at al. [37] which managed to create an indoors and outdoors system for auditory augmented reality in 3D and the LISTEN project [48], which focuses on delivering a context-aware auditory experience in a museum environment.

Chapter 3

First Implementation: LeakyPhones

3.1 Overview

The first version of an IceBreakware we prototyped is the Leakyphones. The LeakyPhones system was designed to facilitate auditory content sharing based on the head direction of the users. We were interested to test whether paring gaze and content can serve as a strong enough ice breaker to engage users in more face to face interactions and meet new people. When designing the first prototype of LeakyPhones, we had 3 design goals in mind:

1. A system capable of transmission of personal content and receiving of external content from other users.

2. A source-agnostic system-a headset that allows sharing of music from any music source, physical or digital.

3. A system that provides users with full control of their privacy.

As an infrastructure, the LeakyPhones headset was built on top of a Bose Soundlink 35 headset. At its heart are the headset's original electronics; Speakers, BLE circuitry and charging circuits as well as additional electronics fitted on a specially made 3D printed plastic earcap.

Our design uses a directional IR receiver and omnidirectional IR transmitter to detect the head direction and to communicate the identity of the user to which one is looking, or more precisely, the identity of his FM transmission channel. An FM transmitter and receiver were used to transmit audio to the surroundings of each user and receive audio from detected users in the wearer's line of sight. A digital potentiometer-based mixer stage was used to mix the external and personal audio sources and a microcontroller (Arduino Pro Mini) was used to control the whole system.

Our goal in the design of the prototype was to primarily illustrate the possible interactions associated with bidirectional music sharing based on gaze and head direction, and to further explore the different privacy modes that the system provides.

3.2 Hardware

3.2.1 IR Transmission and Receiving

Our system uses IR to infer gaze direction and to obtain the FM transmission frequency of other users. In order to do so, we used a highly directional receiver for signal detection and an omnidirectional transmitter for the transmission of the information. To obtain a directional receiver we have used a standard IR receiver (TSOP392 IR Receiver, Vishay) housed in a built-in conic housing that was embedded in a 3D printed plastic ear cap shell that was fitted on top of the existing BOSE SoundLink headset ear caps. A cone angle of 20° tilted at 15° inwards from the symmetric plane of a person's head ensured that at a range of a potential interaction, the sensor will receive information that is exactly in the line of sight of the user. The first implementation of the system was based on a simple Tragus Bluetooth headset as seen in figure 3-1. This prototype used a single IR transmitter (940nm IR LED) and an omnidirectional beam-splitting lens (Luxon Carclo, side-emitting lens). We were not happy with the performance of the IR transmitter as the light beam proved to be too narrow and made aiming at a transmitting target tricky. To circumvent that, we altered the design of the Bose earcap to accommodate nine IR transmitters. The transmitter emits a unique ID code to the user's surroundings. The distribution of the transmitters around the ear cap, each having an effective light cone of 50°, ensured full coverage of the space around each user, to make sure that her ID code will be "visible" to any person looking at her. The unique identity of each user is encoded in the IR transmission using the common NEC protocol [39] Each headset transmits a unique code represented by a number in the range of 0-100. This ID represents a unique frequency in the FM range of 87.9-107.9MHz according to the formula:

$$Frequency(MHz) = 87.90 + 0.20 * (ID) \tag{3.1}$$

This frequency (87.9-107.9 MHz) is used by that same headset in order to transmit the user's personal audio via the FM transmitter. This IR configuration has been successfully tested for range and angle accuracy over 1-5 meters with mostly satisfactory results.

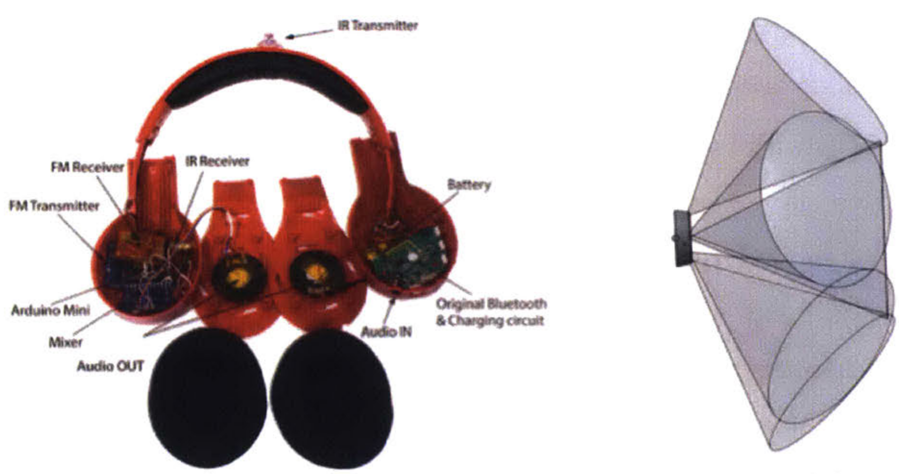

Figure 3-1: The very first prototype of LeakyPhones.
Implemented on a Tragus headset(left), and the new ear cap design for BOSE Soundlink 35 with illustrative light cones indicating the LED placement in the earcap to ensure full spatial coverage(right).

3.2.2 FM Radio Transmission and Receiving

For simplicity of the prototype implementation, we chose to use readily available FM technology and commercially sold breakout boards to send and receive the audio from other users. We used a radio receiver module based on the Si4703 tuner chip (Sparkfun) and a radio transmitter based on the si4713 transmitter chip (Adafruit). The transmitter was used to transmit the personal audio source (i.e. the audio from the user's phone or media player) at all times in a predetermined frequency (i.e the personal frequency) and the receiver was used to receive FM audio at a frequency determined by the IR ID input. A small modification of the receiver board was needed in order to bypass redundant pull-up resistors and to ensure that the board will work at the same logic level as the rest of the electronics. Additional information can be found in Appendix A. The antennas of the FM transmitter and receiver were wired inside the headset's headband to make sure its full length is used.

3.2.3 Audio Mixing

Mixing of the two audio inputs; external audio coming from the radio receiver and the personal audio hijack from the original SoundLink circuitry was achieved using a custom-made PCB with two dual channel 256 step, 10K linear digital potentiometers (mcp42010, Microchip). One dual potentiometer was used for the right ear audio inputs (personal and external) and one for the left, thus mixing personal and external sources for each ear separately. Each attenuated signal coming out of the four potentiometer channels passes through a unity gain amplifier stage (buffer) and is summed up with the appropriate signal in two inverting summing amplifiers biased to 2.5V with gain 2 using TLV2734 opamps.

The mixing scheme used in the first prototype was calculated to be closely logarithmic with 30 discrete steps. The values were saved in a lookup table, with control over the duration of the transition between audio sources. This design was used in order to try out different transition function such as a linear, sinusoidal and exponential transitions and experimentally test which one makes the most sense to the users.

Unfortunately, we did not get to test these different options within the scope of this work.

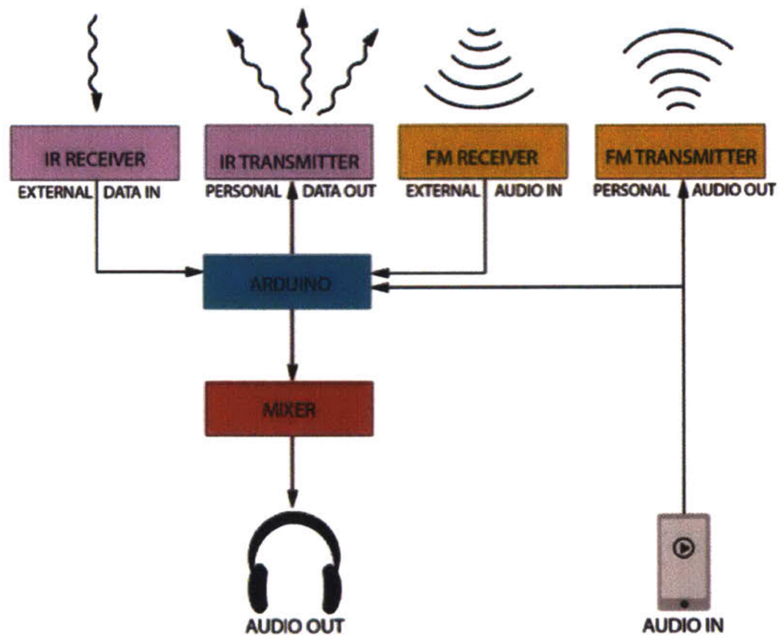

Figure 3-2: A schematic illustration of the LeakyPhones hardware.

The IR receiver code "searches" for a continuous signal to determine that the user is still looking at other users. In case the signal is lost for a period longer than a specified time, the audio will fade back to the original audio source according to the prescribed parameters in the lookup table. In the future, we plan on investigating other mixing rate functions such as which were previously discussed [6] to achieve the best possible response during an interaction.

3.3 Software

The software for the LeakyPhones self-contained prototype is rather simple. All code was written in the Arduino programming language. The algorithm looks for an outside signal, with an ID value different from its own. If such a signal is received, the FM receiver is tuned to the newly received FM frequency, decoded from the ID received via IR. For as long as the signal is received, the user's own music source is attenuated and becomes softer and the external source becomes stronger. In order to prevent sudden changes, the code is designed to be a little sluggish in its response to changes and is written such that it needs to miss a number of signals in order to change back to the user's audio source, thus ensuring that the experience will feel more natural. If enough time has passed since the last signal was received by the IR sensors, the system will slowly attenuate the external signal and the user will slowly hear his own as the volume increases.

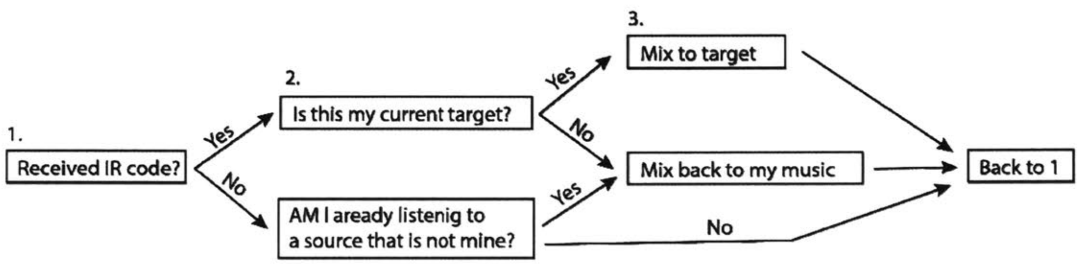

Figure 3-3: Pseudo code for audio mixing

3.4 Privacy

One immediate consequence of the design of LeakyPhones is that it provides with full control of their privacy. The ability to separately turn on and off both the transmitter (sharing) and receiver (receiving) provides users with four distinct privacy states. We like thinking of this as a means to control the degree of being together or alone [43], based on the user's desire. Privacy control is perceived as highly important for the social acceptance of wearable technologies [14], and the fine-tuning of it according to the situation and the desired interaction seems to be beneficial. Below are four possible interaction modes exhibiting varying degrees of privacy.

3.4.1 Traditional Headphones

For a standard headset mode, both the transmission and receiving of content are turned off. This practically turns the LekyPhones into a normal headset. This function promises that users will still be able to use the basic technology they are used to and have full control over their privacy.

3.4.2 Transmission Only Mode

In a transmission only mode, the user may be interested in sharing content with his immediate environment. They may want to express themselves, but are unwilling to be exposed to the content others are sharing. To achieve this, the FM transmitter of the system is turned on while the FM and IR receivers are kept off. While the user is sharing his content, they are unwilling to receive content from others, thus communicating, but not sharing a bidirectional exchange of content.

3.4.3 Receive Only Mode

And what if a user is interested in their surroundings but does not feel like sharing? If they just want to explore what others are listening to? Perhaps the user doesn't even have their own music source? Or ran out of batteries in their music player? In that case, the receive-only mode, the receiver is turned on, while the transmitter is turned off. This allows for unidirectional content sharing, where the user is only receiving from others. We imagine people looking around, scanning their surroundings for new sources of inspiration. Or perhaps, in an active mode of looking at others to initiate a conversation. One of the most intriguing aspects of this mode is that the user does not need an audio source and can rely on other users as sources of content.

3.4.4 Bidirectional Mode

The bidirectional mode illustrates a case in which both the transmitter and the receiver are on. Since the act of receiving is by default coupled with eyesight due to the system's design, and because the users are in a give and take mode, essentially, this mode is the closest to a real conversation, in which both parties contribute their own point of view, and listen to the other side. We hope that this kind of music sharing will result in enough interest to continue to a real conversation between users who would otherwise remain strangers.

Despite the fact that the literature indicates a strong correlation between head direction and gaze, it is not clear to us if this is entirely true for indoor interactions, where people often move their gaze without moving their head [22]. In addition, the design of LeakyPhones, even though self-contained within a standard headset, uses IR to detect head direction. This could be problematic in crowded areas where many reflecting object and physical barriers exist and require special hardware to be installed in the headset.

While looking at others during a conversation may be very common, looking at others before initiating a conversation may feel awkward and cause people to feel as if their privacy is compromised. Moreover, in the current design, there is no indication for the privacy setting chosen by each user which may result in disappointment or embarrassment when one of the users realizes that the other user is not interested in an interaction.

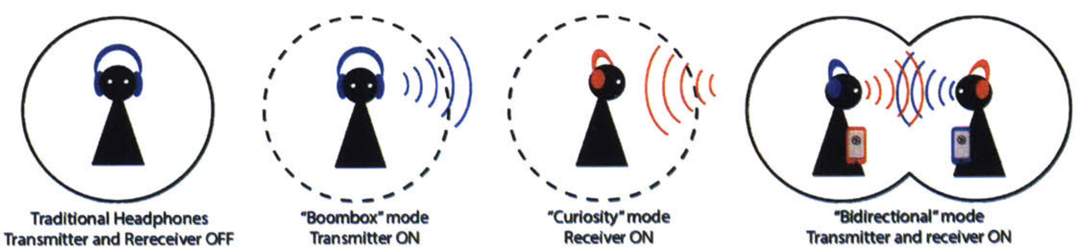

Figure 3-4: The four possible privacy modes of LeakyPhones.

3.4.5 Multi User Experience

The LeakyPhones experience is not limited to two users. Since each headset is both a radio station and a radio receiver, a multi-person experience can be achieved in which few people are looking at the same person, all listening to the same content (like mobile dancing or DDP) or, multiple people sharing content with each other each listening to someone else's music. This scenario was already proposed by Bassoli et al[8] but as previously discussed, listeners did not know necessarily who they were listening to and the person transmitting did not know who was listening to him in real time. LeakyPhones connects between music-sharing and head direction or gaze, thus involving the real people behind the music in the interaction.

Figure 3-5: The LeakyPhones in a multiuser scenario.

3.4.6 Discussions and Limitations

We conducted a preliminary evaluation of LeakyPhones in a semi-formal in-house user testing during the Media Lab's 2017 spring Member's event. We decided to use this chance as a very informal chance to evaluate the system and to learn what needs to be changed for future iterations. Ten participants of various backgrounds, ages and genders were asked to try the headset during the media lab's members event during the demo session. Six of the participants were men (3 graduate students from our institution and 3 technology-savvy professionals, ages 25-60) and four were women (1 graduate student and 3 of various backgrounds, ages 25-60). Participants in this informal testing were asked to try LeakyPhones with each other and with a static IR beacon. Participants were asked to describe their feelings and thoughts in a talk-aloud evaluation. In addition, general questions about the subject's music listening habits were asked to get a better understanding of potential target users. Participants who did not express any concerns regarding privacy issues were specifically asked for their opinion.

During this user testing, LeakyPhones has attracted interest and overall positive feedback as well as concerns and suggestions for improvement. Some users were excited about the idea of exploring what other users are listening to and had a very positive reaction to the technology. Others expressed sincere fear for their privacy. A common comment heard more than once was: "Will this allow people to listen to my phone calls as well?" Another issue raised frequently by the users was that the headphones do not have any visual indication of their affordances and of the mode each user has selected. The users claimed that this may lead to frustration among potential users.

The system that was described earlier in this text was functional but rather limited. The long time it takes to build a single headset and its rather poor audio quality resulted in a prototype that is very hard to test in use order to assess new kinds of user experience associated with the concept. It has proven especially challenging to manually build enough headsets to provide the infrastructure needed to conduct a large-scale user study to test user's behavior and how they may perceive this new experience.

As a result, we decided to build a more robust and general purpose system, A.SAP, based on of the shelf products which is much easier to scale up and test. The A.SAP system is described in the next section.

Chapter 4

The A.SAP System

4.1 Overview

The LeakyPhones system performed well, but because of its decentralized architecture approach, it proved to be difficult and cumbersome to scale and test with a larger number of users. In addition, it was less convenient to design and tweak the interaction between users or monitor them since its hardware was built for a very specific kind of interactions and lacked flexibility. To address these difficulties, we have built the A.SAP system. The A.SAP system was designed to facilitate content sharing based on the head direction of the users using a centralized approach. Our aim when designing and building A.SAP was to create a system that allows for 8-10 people to use Laekyphones for a few days while having full control, monitoring and data collection abilities of all aspects of the users' interpersonal interactions.

A.SAP transmits the location data of each headset to a central computer. The central computer then detects gaze events and controls an audio interface equipped with a number of transmitters that transmit the music directly to the participants' headphones. Music is acquired directly for the participants' phones, thus allowing for actual, real-time audio sharing. The design of A.SAP separates between audio acquisition and redistribution and location acquisition. This makes the system much more versatile than the original LeakyPhones system: it can be used to prototype other location and interaction based auditory experiences with a slight change of some of the system's parameters.

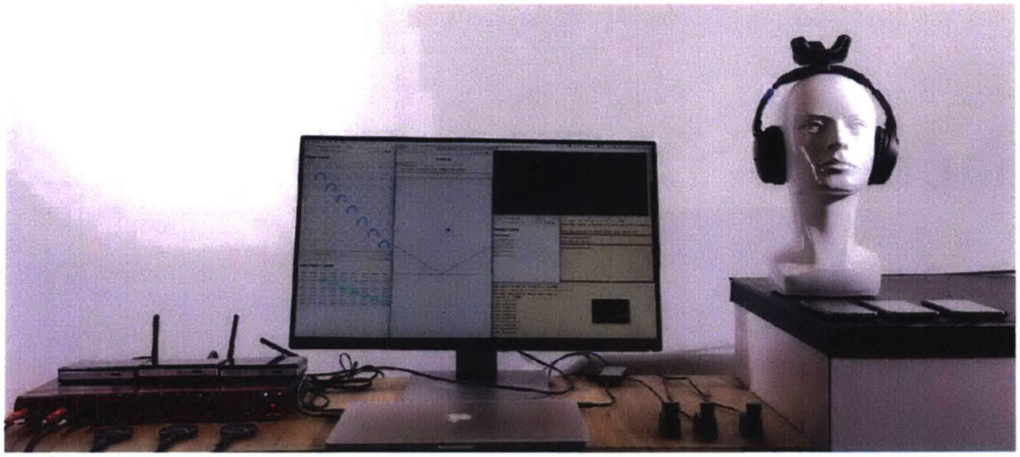

Figure 4-1: The A.SAP system.

4.2 Hardware

The A.SAP uses the off the shelf HTC Vive Tracker and Base Station technology [5] for its tracking and direction detection technology. These were chosen for their great performance and robustness and the ease of use together with the SteamVR software from Valve and the OpenVR python open source library from Triad. Trackers were mounted on BOSE QC35 noise canceling headsets using a 3D printed attachment. The headphones were used to deliver audio to the users, based on prescribed interaction: In cases where human-object interaction is desired e.g. sonification of objects, trackers could also be mounted or placed on other objects instead of the headset. All headsets were paired via Bluetooth to a long range Bluetooth transmitter (Nolan TRX HD) which was connected to an audio interface (Behringer FCA1616 audio interface) and a central computer running the control software. The A.SAP system is able to receive a number of audio sources as its input, these inputs include audio files from the central computer or audio streams transmitted from hand held devices to the central computer via WiFi, using Google Chromecasts connected to the audio interface inputs and cast-supporting apps or Bluetooth receivers paired directly to the user's phone.

The version of A.SAP that was used for the LeakyPhones user study has Bluetooth receivers connected to the audio interface inputs. These Bluetooth receivers are paired to a ZTE Android Phone. The phone functions as a personal device able to provide auditory content from the internet or from a library of files preloaded on it for the study.

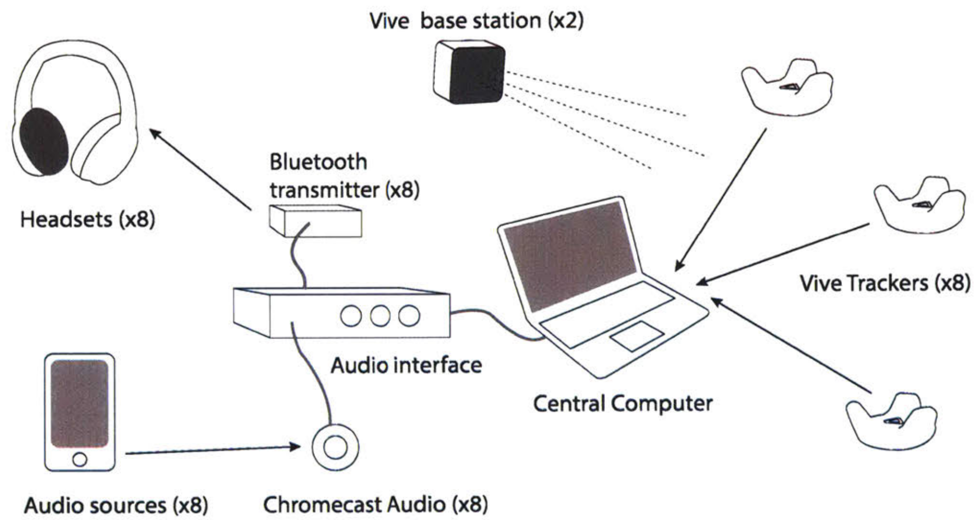

Figure 4-2: A schematic illustration of the A.SAP hardware components.

4.3 Software

A web-based architecture was chosen for the A.SAP system to make it more interactive and hackable. This was done to enable individuals with advanced programming skills to easily add additional functionalities while making sure people who are less proficient in programming will be able to use the GUI and directly control the system with a minimal set of parameters and operations. The web-based GUI also means that multiple users can use and manipulate the system together and use their personal devices to control it. The system's architecture has 4 main components:

1. The tracking VR Server - parses trackers' locations and transmits them to the

decision making software. This was written in python and based on the OpenVR [3] library and SteamVR software and emits the tracking data to via WebSockets to the Audio Server.

2. Audio Server and Audio Interface Control - written in Javascript and Python and responsible for audio distribution through a multichannel audio interface based on tracking information and triggered events. This audio server controls the auditory content that each user hears. It uses the python sound device library [4] to control the audio interface and deliver the correct audio source at the correct volume level to the appropriate outputs on the audio interface in real time, based on data from the tracking server.

3. Web GUI - these are a number of modules written as WebSocket and Socket IO clients in JavaScript. Their purpose is to give a real-time visual representation of users' location and head orientation, as well as visually show music transitions and sources of each user of the A.SAP system.

4. Data Logging - These python scripts are used to gather user behavioral data such as location and head direction during the study, events of music sharing and duration of interaction with the different users. The data accumulated from these was the primary source of "objective" user behavior and compared to user's responses to questionnaires and reported behavior in the group discussion.

Chapter 5

Experimental Design

5.1 Overview of the Experiment

We tried to assess the user experience and the potential effect of LeakyPhones through a number of complementary methods:

1. A pre-study survey aimed at screening the participants in the study and getting a preliminary understanding of their view of gaze, headphone use and interactions with other people.
2. A user testing and observation, in which 3 sessions of 4 people wore LeakyPhones for 15-30 minutes in a shared office or cafe environment. All other participants of the study (6 people) served as a negative control group.
3. A post-study questionnaire, asking participants about the possible interactions they had with others, as well as the performance of the headsets and open questions about how the experiment made them feel.
4. A group discussion, in which participants were asked questions about the Leaky-Phones concept, how it made them feel, what they think are the biggest issues with the concept and other related questions.

5.1.1 General Structure of the Study

In order to test whether LeakyPhones can induce any kind of social behavioral changes, we decided to compare users' behavior when using it compared with normal, noise-canceling headphones that we concluded are the most isolating of all headphone products. Testing the UX and performance of something as ubiquitous as headphones, proved challenging, as the system needed to have an almost flawless performance in order to ensure that any feedback that we get, focuses on the new UX and not on the technology's performance.

We decided to conduct the experiment using the A.SAP system described earlier in this text. The system allowed for good to acceptable audio quality and for control and data logging of user behavior. The A.SAP allows for an experiment consisting of up to 8 headphones, but since the experimental setup required a very large number of BLE devices (>60) which may cause interferences we decided to limit the experiment to 4 LeakyPhones users on the day of the experiment.

5.2 Pre-Study Survey

Within the limited scope of this study, we concluded that it would be problematic to recruit headphone objectors or people who are not interested in interactions with other people, as these are the bases of the technology and the aspects of it that we wanted to examine. On the other hand, it would be interesting to test a technology that is aimed at helping people engage in more real-time and real-life interactions, even if they report that they are struggling to be social and/or have mixed feelings regarding eye contact or report themselves as introvert or shy. We decided that the criteria for participation in the study will require participants to report that they are:

1. Daily users of headphones at some level.

2. Have expressed genuine interest in meeting new/other people.

In addition, although not a strict criterion for participation, we were interested in the subject's perception of eye contact and in getting some crude insight on their tendency for socialization, to understand if they may be a potential acceptor of such social technologies. We decided to ask 7 questions to try to get some insights on how extroverted and social a person sees himself. The questions are :

1. I prefer to be alone with my thoughts, rather than involved with other people.
2. I prefer to have many friends who may be less close to fewer friends who are very close.
3. I prefer to always keep to myself and rarely socialize.
4. I prefer to choose activities that I can do by myself rather than with other people.
5. My friends would consider me social, but I don't consider myself social.
6. I enjoy meeting new people.
7. People consider me the life of the party.

Participants rated their answer on a scale of -2 to 2 based on their agreement with the statement, -2 being "strongly disagree" and 2 being "strongly agree". Based on their answers, we calculated a sociability matrics, S.I(and possibly a very inaccurate one). A higher overall S.I result indicates what we would consider as a more social person.

The metrics for sociability were defined as:

$$S.I = -Q1 + Q2 - Q3 - Q4 + Q6 + Q7, 12 > S.I > -12 \tag{5.1}$$

Q5 is not included in this sociability index as it was found confusing for many, but it may give some insight into how a person sees his social behaviors in comparison to how he thinks he is viewed by others.

We also wanted to map how comfortable participants feel about engagement in eye contact with strangers. Since eye contact is a bidirectional interaction, we tried to break and distinguish between the case of looking at someone else, and the case of being looked at. The questions that we asked were:

1. How comfortable do you feel when other people/strangers are looking at you? (on a scale of 1-5).

2. How comfortable do you feel when looking at others/strangers you find interesting? (on a scale of 1-5)

Each participant in the study could now be placed as a point on a 3 dimensional space representing how comfortable they feel regarding eye contact, how social they perceive themselves, and how often they use headphones.These values could be used to gain insights and, together with their behavior in the study and reported experiences from the group discussion, provide possible explanations for their behavior.

5.3 User Study

The user study was held at the MIT Media Lab's 5th floor, in an area arranged more or less like a cafe or a work bar. Four tables (two tall bar tables and two standard tables) with 16 chairs around them were arranged in a small area of about 5X5 meters; the largest area that still allows for all components of the system (phones, trackers, lighthouses and receivers and transmitters) to function properly from any spot in it.

10 participants (7 men and 3 women) were recruited and divided into 3 groups. Upon arrival to the study location, participants met with the experiment coordinator and got a 15 minute brief on how the LeakyPhones work and how they can be used to listen to other people (by looking at them or just by facing them) In addition, participants were notified that the study will be around two hours, followed by a 1 hour group discussion and pizza. Participants were also told that they are allowed to sit anywhere within the designated experimental area, and that they may work or do any thing they wish to do, as long as they spend most of their time in the experimental area and use the headset as if it was their own. Participants were not asked to ware the headset at all times.At the end of the briefing, participants were asked to sign a consent form.

Members of each session received a pair of LeakyPhones for a time period of 15-30 minutes, in which they were asked to stay in a designated area, tracked by the HTC Vive tracking system. All other participants of each session (6 people overall) acted as a negative control group for that session; they were given noise canceling headphones paired to their personal devices and were asked to follow the same guidelines as the LeakyPhones users.

Figure 5-1: The experimental area and participants of the first session.

In addition to LeakyPhones, we decided to provide the users with phones that are part of the A.SAP system, these phones transmit the music that is played on them to a central computer that redistributes the music based on the participant's gaze. Since the phones that we used are not the user's phone, and we assume that the actual identity of the user's music may have an effect on potential interactions, prior to the experiment, each participant was asked to provide a list of five artists or music genres that they like. This music was downloaded to the correct phone prior to the study, to make the experimental phone as close as possible to the participant's personal devices.

It is worth noting that unexpected technical complications during experimental setup resulted in only the first session getting the phones preloaded with the music they asked for. Other sessions had to listen to music that could have been new to them or not to their liking. The phones had wifi connectivity which allowed users to listen to audiobooks, music or videos on the Internet or use almost any source of auditory content that they might use on their personal device. In practice though, it seems like participants only listened to music downloaded to their phones.

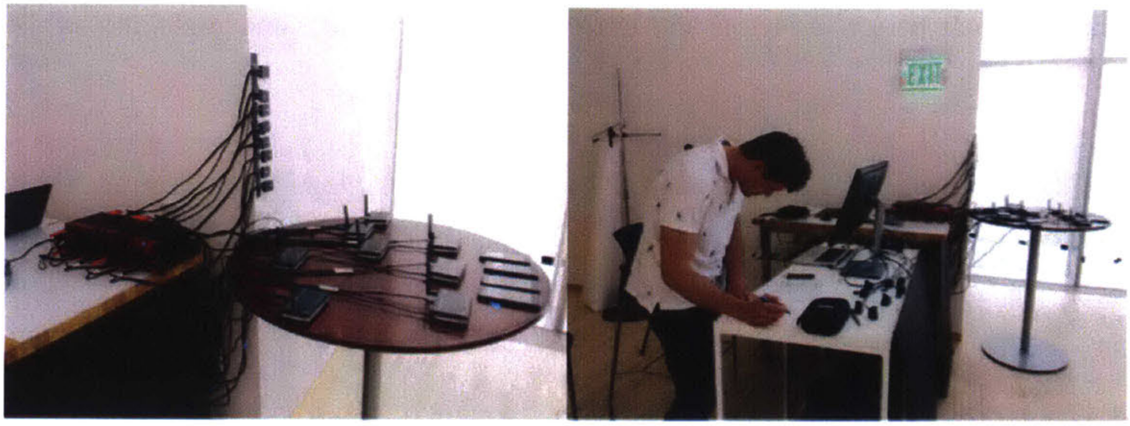

Figure 5-2: The A.SAP experimental setup.

5.4 Post-Study Questionnaire

The post-study questionnaire was formulated to try and give a quantitative subjective view of the number of interactions the participants had with other participants and to gain more insight into what kinds of interactions they had, how participants view the interactions they experienced and how it made them feel. We were mostly interested in answering the following questions:

1. How many interactions did the participants have?
2. How many interactions did participants have with other LeakyPhones users and how many of those interactions were with normal headset users?
3. What was the nature of the interactions participants had with other participants (talking, listening to music together, something else)?
4. Do they feel that LeakyPhones were responsible for their interactions during the study?

The post-study survey was used to measure user performance qualitatively. By asking questions concerning the frequency of interactions, their nature, length of interactions and their reason, we tried to acquire subjective data to compare to the experimental data accumulated by the system. This could give us some indication of how much of participants' experience was mostly internal (people felt more or less inclined to interact) or also had an external manifestation in the objective number of interactions.

5.5 Group Discussion

At the end of the study, we ran an hour-long group discussion with all 10 participants. The purpose of the group discussion was to provide a supportive infrastructure for participants to express what they liked and did not like in the LeakyPhones experience and to further explain how it made them feel and act. We also used it as an opportunity to ask and further understand how participants feel about gaze and eye contact, what they think could be done to improve the LeakyPhones experience and what would make it more appealing to them as potential users. Partial transcription of this group discussion can be found in Appendix B.

Chapter 6

Results

6.1 Pre-Study Survey Results

Demographics

10 participants (3 women and 7 men) of ages 20-31(median age 27, mean age 26) participated in the pre-study survey. Two of the participants, M1 and M2 knew each other before the experiment. It is important to note, that the group of participants were recruited from the MIT and MIT spouses community and were all university students (graduate and undergraduate students) or young professionals. For this reason, we should probably assume a given bias towards positive acceptance of new technologies, and a higher than average degree of collaboration with the researcher. Participants exhibited "Social index" scores as previously described in the range of 6 to -3, with women exhibiting some of the highest scores. It is interesting to note that in general, participants with some of the higher S.I scores indeed showed more interest in participating in the group discussion at the end of the study, but there were some exceptions like M7, who was very active in the group discussion, yet had a lower social score. Alas, there was no clear difference between the number of interactions that participants with high scores had as opposed to participants with lower scores and the number of participants is too small to assume any real correlation. We conclude that the sociability index can be helpful in analyzing the results, but does not, in the

scope of the current study, provide any statistically significant insights.

Identifier	Session	Headphone	Gender	Age	Social index
M1	1	2	M	24	-1
M2	1	4	M	27	4
M3	1	5	M	28	1
F1	1	6	F	28	2
M4	2/3	2	M	23	-3
M5	2	4	M	20	2
F2	2/3	5	F	31	6
F3	2	6	F	31	5
M6	3	4	M	23	2
M7	3	6	M	25	-3

Figure 6-1: participants' demographics
The unique identifier for each participant is composed of: Gender (M/F), Serial No. (1-10) and Headphone No. (2,4,5,6)

Headphones Use

Most subjects reported that they are moderate to frequent users of headphones with at least a couple of hours of headphones use on a regular day (>1 hour/day). It is interesting to note that the main reasons for using headphones listed by most participants were to "help with the noise" and "help them focus". Such a use of headphones could suggest that when a person wants to focus, they will be less inclined to participate in a social activity. On the other hand, almost all participants (9/10) said they also used headphones because they "like listening to music and podcasts", which seems like the opportunity to tap into a shared experience using LeakyPhones.

One exception to other participants of the study was M3. M3, a 28-year-old man, reported not to use headphones as much ("less than an hour a day") and also had a relatively low S.I score. Indeed, M3 exhibited unusual behaviors during the study: he was sitting away and with his back to the others participants. M3 exhibited very low engagement in interactions with other people throughout the study.

Socializing With Other People

In terms of the participants' desire to meet new people, most participants indicated that they are very interested in meeting new people (self-reported score of 4/5 or 5/5). Notwithstanding, almost everyone (7/10) noted that they "socialize sometimes and are interested in socializing more". Bridging this gap is the aim of LeakyPhones. Interestingly enough, M3 is the only person who mentioned that he does not socialize a lot (with good accordance with his behavior during the experiment), but would like to socialize more.

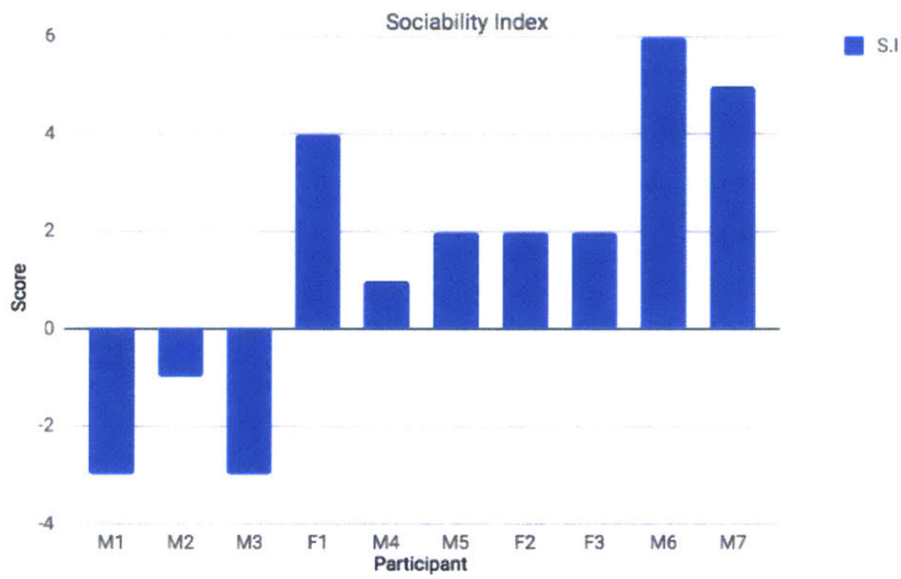

Figure 6-2: S.I for the different participants of the study

Reported differences between Men and Women in the Study

It is interesting to note that all women in the study (3/10 of participants) reported that they meet new people less frequently than men reported they do. For the women who participated in the study, a possible explanation could be that 2/3 of them are young professionals who work in larger organizations; they mentioned during the group discussion that they have fewer opportunities to socialize than the average university student. This could of course also be explained by the very small group that we worked with. Women who participated in the study were also older than most men. The average age for women participants was 30 compared to 24 for the men. This fact could introduce another source for bias in the behavior of women as opposed to man, as we might expect that more mature people will have better tools to deal with awkward social situations such as a user study at a university.

Gaze and Eye Contact

The pre-study survey tried to assess how participants feel about gaze and eye contact. 4/10 of participants didn't care too much about the fact that other people look at them. Two participants thought it was flattering and one person, who also reported later in the study that he felt uncomfortable looking at others (M2), reported that he feels uncomfortable when people look at him and gave it a score of 2/5 (5=Comfortable).

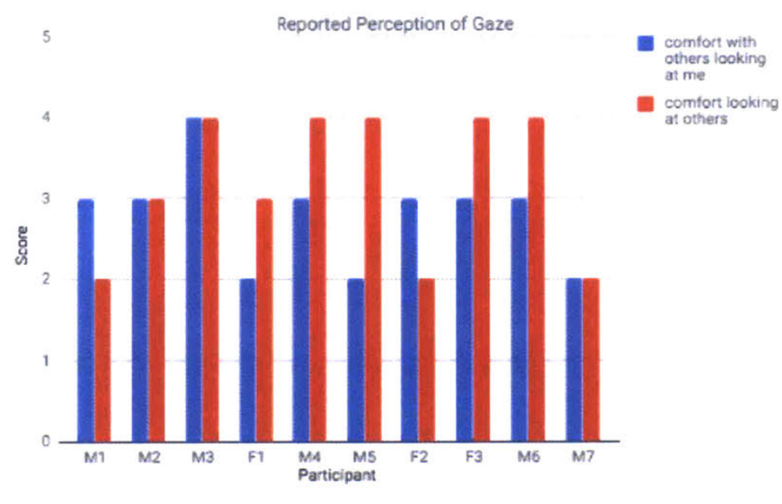

Figure 6-3: Self reported eye contact comfort by user

All women subjects reported that they do not feel comfortable with other people looking at them, with an average score of 2/5 as apposed to men with a score of 3/5 for men. It is interesting to note on the other hand the same women reported that they are rather comfortable with looking at other people with a similar score to men of 3/5.

It is also important to note that both women and men reported that the circumstances of a gaze or eye contact event have a strong impact on how comfortable they feel about it. Most people reported that when they find the person who looks at them interesting (or good looking?), they would be more tolerant to a gaze from them.

6.2 6.2 Study Results

General Considerations

The study had 3 sessions. session lengths were 30, 25 and 15 minutes respectively. All sessions were shorter than initially planned because of technical difficulties which postponed starting time by >40 minutes.

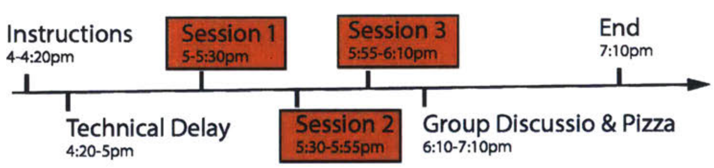

Figure 6-4: Study time line.

All sessions had a mix of genders. Since we had only 4 functioning Leaky headsets and only 3 female participants, session 2 was the only session that had more than one women participant in it. It is very possible that the results of the study were greatly affected by the session composition and the actual sitting positions in the room. Participants chose where they wanted to sit.

For all sessions and for all gaze metrics computed (Maximum gaze length, average gaze length, No. of gaze events at either sex), men in the study showed an indication of more intense use of the headsets than women: on average they looked at other people longer and had more independent gaze events at both men and women. This may indicate that the women in the study found the concept or its implementation in the current setting less comfortable and appealing than men, but could also be the result

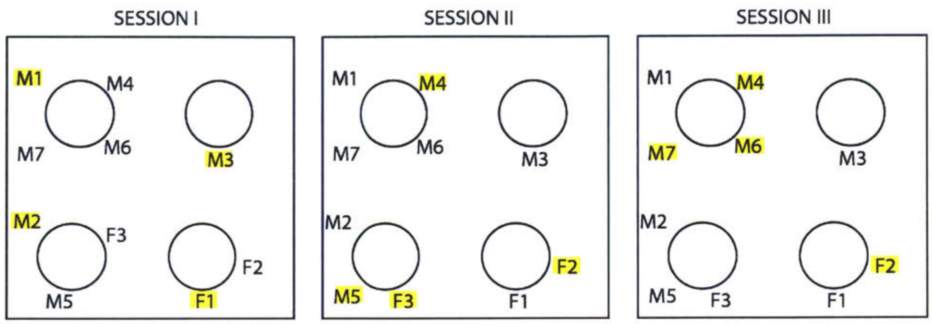

Figure 6-5: Top view of the experimental setup.
Code names of participants of each session and headphone numbers are marked. Leakyphones users are highlighted in yellow. Other subjects were wearing silver QC35 noise canceling headphones.

of inherent differences in gaze behaviors between genders, some differences such as the main focus point, length and number of gaze events were previously reported elsewhere in the literature [15] Men also consistently exhibited longer maximum gaze durations. This could perhaps indicate that most men in the study felt more comfortable being looked at and looking at other people, as our pre-study survey indicated.

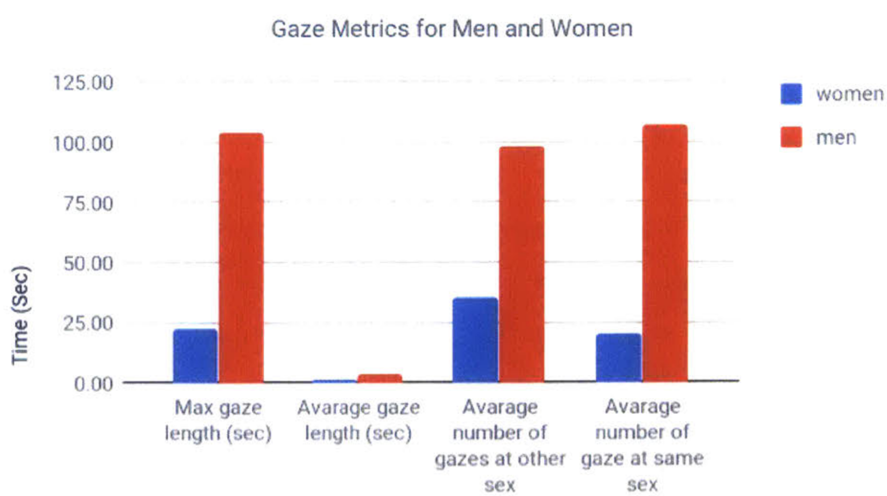

Figure 6-6: Metrics to compare women and men's behavior in the study.
Results are averaged for all sessions and normalized for the number of participants.

Women showed a slight tendency to look at the other sex while men showed some tendency to look at the same sex, but this could also be explained by the mere fact that only one session had more than a single women participant which greatly affected the results. Even though the results were normalized based on the number of same-sex participants, this could have a great effect as it greatly limits the kinds of interactions possible for each session.

Another artifact that could have superficially increased the number of gaze events recorded by the system is actually a result of the LeakyPhones experience itself: the LeakyPhones system was designed to play a smooth transition between a person's music and another person's music upon detection of a gaze event. Because of that, if a person looks at someone and does not aim exactly at them, it would take them 1-2 seconds to notice that they "lost" someone's channel before trying to aim back at them to continue listening to that person's music. This may result in artificially shorter listening times and a higher number of gaze events, even though the user perceives these as a single gaze event. Even with these effects in mind, it seems like there is a pretty good indication that men in the study experimented more with the system and potentially felt more comfortable with the concept-they looked at other people longer, on average and also in absolute values, with the longest gaze event among all women being almost 5 times shorter than the respective maximum gaze length for men.

Observations From the Data and Cross Session Comparison

It is important to note that the 3 sessions varied in the engagement of participants greatly, both reported and recorded by our experimental setup. This could be a result of many factors such as location in the experimental setup area, the session composition, gender balance and many more factors. Because of these reasons, we did not perform actual formal statistics on the data as they will likely be problematic and lack any significance when performed on such a small sample size. Regardless of that, the experimental setup allows us to get some rough feeling of the gaze dynamics during the study such as who looked at whom and for how long. We were able to record gaze event durations, number of gaze events and the identity of participants in each gaze or music sharing event, i.e; we know who listened to whom, for how long, and how often they looked at each other. Below are graphs depicting a summary of these metrics for the three sessions and broken out for each user. A deeper look at the data may suggest some of the insights presented in the next section.

Session 1	M1	M2	M3	F1
M1	78.62%	1.38%	0.54%	3.88%
M2	1.29%	78.72%	0.13%	0.08%
M3	11.79%	1.46%	99.23%	1.05%
F1	8.29%	18.44%	0.09%	94.99%
Session2	M4	M5	F2	F3
M4	23.08%	0.76%	0.79%	2.32%
M5	65.17%	38.75%	1.36%	0.34%
F2	2.35%	1.90%	93.86%	0.05%
F3	9.41%	58.59%	4.00%	97.28%
Session 3	M4	M6	F2	M7
M4	34.02%	6.00%	0.15%	31.48%
M6	31.36%	64.47%	0.30%	8.68%
F2	1.61%	4.93%	97.39%	2.80%
M7	33.00%	24.60%	2.15%	57.05%

Figure 6-7: A table showing the percentage of time of each participant dedicated to listening to other LeakyPhones users or to self (sessions 1-3).
The person across the top is the one doing the looking/listening. The ID's on the left are of the different sources.

Gaze and Eye Contact

A deeper look at the sitting map and source distribution of all users reveals an interesting yet somewhat expected outcome; subjects in the study tend to look more at people who were in a direct line of sight from them. The most likely explanation for that is because of the relative locations in the experimental area. Some of the most prominent examples that show location-induced interactions include the relatively

Session 1	M1	M2	M3	F1
M1	0	19	173	175
M2	16	0	50	255
M3	13	12	0	8
F1	76	6	41	0

Session2	M4	M5	F2	F3
M4	0	215	18	75
M5	14	0	28	293
F2	17	43	0	35
F3	20	3	4	0

Session 3	M4	M6	F2	M7
M4	0	278	26	165
M6	95	0	76	161
F2	38	31	0	44
M7	175	117	36	0

Figure 6-8: A table showing the number and target of gaze events per participant (sessions 1-3).
The person across the top is the one doing the looking. The ID's on the left are of the different people she was looking at.

high number of bidirectional interactions between M7 and M4 in the 3rd session, F1 and M1 and in the 1st session, as well as the large number of clear unidirectional interactions between participants and other subjects who sat in their direct line of sight.

But, it is interesting to note that even participants who sat within each other's "line of sight", sometimes had an overall lower tendency to interact depending on their orientation. When participants set in front of each other but did not have a clear and direct line of sight to each other they did not show a bidirectional gaze behavior, rather a unidirectional behavior (This tendency to interact can be roughly quantified by looking at overall time spent listening to that person). For example, M3, who sat with his back to other participants of the study, showed extremely low engagement in music sharing, spending >99% of his time listening to his own music.

A longer gaze event is believed to be a better indication of positive experience or interaction with another participant then the number of gaze events at another LeakyPhones user. This reveals a more complicated picture in which the A.SAP system may record a lot of short gaze events between one person and another which are in fact not a good indication for a strong interaction between the two.

Figure 6-9: M3, sitting by himself with his back to others.

M3 chose to sit by himself with his back to the rest of the participants of the experiment. Although M3, reported in the pre-study questionnaire that he would "like to socialize more" and that he "doesn't socialize a lot" he chose to sit at a table alone in a way that does not invite interaction. F1, a 28-year-old woman, spent very little time looking and listening to M3 music, even though he was sitting just in front of her. But, because of the setting of the room, F1 was forced to listen to M3 every time she faced forward. Even though she spent very little time looking at M3, a lot of short gaze events between F1 and M3 were recorded by the A.SAP system. We conclude that most of the events between F1 and M3 were possibly simply by mistake, because of the physical constraints of the experimental area and the relative locations of the subjects. This may also explain some of the overall dissatisfaction that F1 felt about the headset performance-she thought the headset was defected, but actually, M3 was sitting in front of her and she simply heard his music mixing with her music from time to time. We conclude that the fact that two users of LeakyPhones face each other, increases the chance for them to interact and that the length of their interactions may indicate how meaningful that interaction is, but the number of gaze events alone is not a good enough indication for the level of interaction between the two.

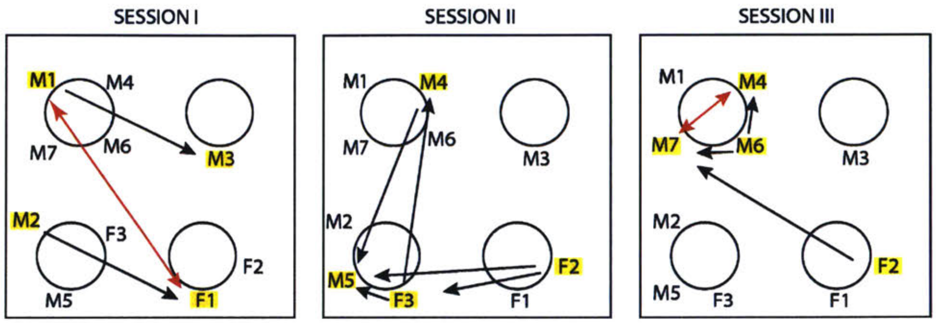

Figure 6-10: Bidirectional and directional interactions during the study. An illustration of dominant bidirectional interactions (red) and directional interactions (black) and the possible spatial reason for them.

In addition to the fact that the number of gaze instances is probably not a good metric for the strength of an interaction between users, after viewing the data from the experiment, we believe that the A.SAP's measurement of the No. of gaze events is also inherently somewhat inaccurate. The reason is that because of the "fade in" and "fade out" of the music upon initiation and termination of gaze events, it takes a user a few seconds to realize that they are not directly looking at another person since they can still hear that person's music. Only when their own music becomes dominant again, it is that they finally realize that they need to "fix" their head direction. As a result, Even though the subjects might have considered this as a single audio sharing/gaze event, our system records such an interaction as many, shorter interactions.

From our observations and from the participants' reports, we know that they were very focused on their work. This, according to them (from the group discussion and comments on the post-study questionnaire) resulted in fewer interactions than we expected. We did not notice any long conversations during the study. Some participants in the study mentioned that they would have liked to interact more, but "everyone looked so busy" (F2), others came to the experiment specifically to work (M3): "I was focused on my work" while others found that the whole concept and especially the gaze part was "very distracting" (F1) and chose to limit their participation or to completely stay away from interactions (M3).

Session to Session Differences and Musical Preference:

A big source of variance between the session was a result of the music on the experimental phones. Because of some technical complications on the day of the study, only the first session received a phone with music they reported to like. All others had to listen to music that they did not necessarily like or identify with, and this obviously had an effect on their choice to listen to someone else's music. During the group discussion, it was clear that the actual music subjects listened to had a major effect on their behavior and how others interacted with them. For example, F3 reported that she was interested in knowing what M5 was listening to and even asked him, but M5 did not know what to answer or what he was listening to since he did not choose the music on that phone. Another example is M1 who found M3 music to be interesting since it had a part which "sounded like the news" and was not just ordinary music. During the group discussion M1 asked M3 what that music was, and was surprised to learn that it was a Taiwanese pop band. These additional layers of complexity were, unfortunately, missing for sessions 2 and 3.

Most LeakyPhones wearers on sessions 2 and 3 did not recognize or identify with the music they were listening to and felt some uncertainty about whose music it was. As a result, often times they didn't know if they are listening to the music they were "originally" listening to or to someone else's music. When some of the participants actually talked to each other about the music, the other person could not say a lot about their music, since it was not "their" music.

Interestingly, even though some of the participants reported not to like the music on their experimental phone, they chose not to try and choose a different song or search online and play music they do like.

6.3 Post Study Survey Results

All ten participants of the study answered the post-study questions and reported their personal and interpersonal experiences during the study. Below are some of the most interesting observations from their responses.

Interactions

The most surprising result is that all participants subjectively reported considerably more interactions with people around them when wearing LeakyPhones than when they were in the control group. All LeakyPhones users reported having 2-4 (and an average of 2.6, std 0.7) interactions during the study. The same people, when serving as the control group, reported that they had only 0-1 interactions with other people (and 0.5 interactions on average, std 0.71). Interestingly, this fact is also true for sessions 1 and 2, who already interacted with other people around them using LeakyPhones during the first session. We were expecting to see people who already interacted with LeakyPhones feeling closer to each other also when they were wearing normal noise-canceling headphones during the second and third sessions, but most participants did not report such interactions. It remains an interesting question whether the effect of LeakyPhones is too weak to have a long-lasting impact or that the negative social effect of using noise canceling headphones is just so strong, that the short interactions using LeakyPhones were not strong enough to contradict.

Most participants reported that their interactions with LeakyPhones were generally positive. Their interactions mostly involved "talking to people who sat next to them" and "listening to music they liked". It is worth noting that one female participant (F2) reported that some of her interactions involved "listening to music she did not like". While almost all subjects reported that their interactions involved talking to other people, only 3/10 reported that they actually talked to people whose music they liked, suggesting that maybe the musical content itself is less relevant than the actual act of having eye contact with others or listening to their music.

Most participants in the study reported that they had "exchanges of smiles" or other kinds of exchange of facial expressions with the people they looked at. M1 reported that when you would look at someone and they would look back at you, many times you would both smile, as in "yes, it is actually working". F2 and F3 reported similar experiences. F1 shared in the post-study survey that when she used a standard headset as a control group, it was still paired to F2's tablet from the previous experiment. As a result, she started talking to F2 about her music, even though they had different kinds of headphones.

Most people (8/10) reported talking to the people who sat next to them, perhaps indicating that it was easier to talk to someone in a way that doesn't require additional commitment like approaching them in a different table etc. None of the participants talked to people who did not sit just next to them, even though they shared music with all of them (from experimental data, we know that all users interacted with all other 3 LeakyPhones headsets present at the experimental area)

All participants agreed to some extent that LeakyPhones was in a way responsible for their interactions during the study.

Eye Contact

Most participants in the study reported having eye contact with other participants, with a slight tendency for participants of the same sex, especially among women. It is interesting to note that meaningful gaze events and eye contact are harder to detect then it seems. For example, One of the female participants who participated in session 2, F3, reported in the group discussion that she "really liked" M5's music and asked him about his music a few times. This detail is not supported by our gaze event data, suggesting that interactions can be more subtle and complex then what we were able to measure in the experiment.

During the group discussion and in the post-survey, M2, a 27-year-old man commented that he did not feel comfortable looking at other participants regardless of their sex. His approach to music sharing was to point his headphones towards other people, without looking at them. M2 used this approach to be able to comfortably listen to strangers but surprisingly, also towards his friend M1. Interestingly though, like most other participants, even though M2's approach did not require eye contact, experimental data indicated that he "looked" mostly at the person who was just in front of him, F2, who was sitting in a table across from him.

A deeper look at the experimental data from the first experimental session shows that both M2 and M1 who are friends, looked more at F2, whom they did not know before the experiment, then at each other. We think that the most probable reason for that could likely be also because of their relative positions in the room.

Social Awareness

Most participants in the study mentioned that they feel that the other participants in the study did not really care when they looked at them. Some even explicitly said that they are not sure other people even noticed that they were looking in their direction.

F2, who was sitting a little further away from other participants during the second session, mentioned that she could look at people without them noticing her. Considering the fact that F2 felt that people did not notice her gazes at them, it is interesting to note that she did not display a more "exploratory" behavior then, other participants of the study. Her experimental gaze metrics show that the total time listened to other sources had actually been pretty modest compared to other people. One possible reason for this observed behavior could result from the fact that F2 set further away from other people in her session, and thus it was harder for her to effectively tune into people's music.

Negative Feelings As a Result of Using LeakyPhones

Three participants have explicitly mentioned that they felt uncomfortable with gaze. M6, reported that he felt "embarrassed" to look at others. M2 reported during the group discussion that he "did not feel comfortable with gaze, so moved his headset to pick up other people's music without looking at them".

M4, specifically reported in the post-study survey that he felt "uncomfortable with the LeakyPhones experience". A closer look at his gaze behavior reveals relatively few gaze events at F2 who was further away from him. It looks like M4 potentially just listened to the people at his table mostly by facing them with his whole body and not by actually creating eye contact with them or looking at them because he felt uncomfortable. Although M4 reported that he felt uncomfortable with LeakyPhones, we do know from the group discussion that when M4 eventually looked at other people when he took a break from his work, he chose to look at specific people because he felt that "they looked calm". M4 mentioned that when he listened to these people's music he was expecting to hear calming music and therefore was not surprised to learn that they were listening to "calm classical music". M4 reported this as a positive and calming experience.

Six of the participants in the experiment felt that the LeakyPhones experience made them feel "strange". F2 for example, said that it was strange because "others were so busy during the experiment" (working, reading etc.) or because they were not of the same sex. She reported during the group discussion that she felt more comfortable looking at F3, another woman and that they noticed each other's gaze from different tables. It is interesting to note, that by looking at the tables map and source distribution for each user of session 2, it can be seen that some of the time F2 was looking in F3's direction, she actually listened to M5 (man, 20) music, who sat very close by. Since none of the participants of this session knew what their original music was, F2 might have thought that she is listening to F3, but actually listened to M5 music at times. F1, who had a rather negative response to the LeakyPhones experience, said in the group discussion and in the post-study questionnaire that she felt uncomfortable and distracted by the concept of people looking at her while she works.

Positive Feelings As a Result of LeakyPhones

We did not explicitly ask participants about the LeakyPhones concept but rather focused more on their experience with gaze itself which was part of the experience. It seems like very positive feelings regarding the concept were limited; some participants enjoyed the experience and some did not. It also seems like some of the people who were less positive experienced technical difficulties like static noise, trouble operating the headset and more.

When it comes to gaze, most participants showed a different opinion regarding looking at others or having others looking at them, being the passive side in a gaze event. For most participants, the fact that people look at them was a neutral to a positive experience: 7 (men and women) of the participants said that they did not care that other people looked at them and about a third of the participants expressed clearly that they had a positive feeling as a result of other participants looking at them. On the other hand, most participants did not feel comfortable looking at other people.

From a thorough review of all subjects' post-study reports, many of them felt that the headphones did not function properly to some extent. This could definitely have a strong impact on the participants overall satisfaction with the experience. Some clues are found in the interesting comments to the question" how did the LeakyPhones function?" M3, for example, answered: "It only worked for a few minutes. If it functioned normally, I believe it will have positive effects"

Another participant, M5, said that: "When it worked, I enjoyed being able to look around and hear different songs playing. I would say it was a positive experience"

M2 provided a rather positive review of his experience, but also mentioned what he saw as a limitation: "They were fun to use and it could be interesting to connect to people. It can induce a conversation and even be an interesting way to interact with your friends and family. Though the problem could be that we have to keep looking into their eyes. "

F3 also reported liking the concept, more than the actual experience: "I was enjoying this possibility and it was like a game. I like to find new good music that other people could share. IâĂŹm not sure if IâĂŹm ready to share my music with everyone. But I really like the idea and I would probably use it with family, friends or during breaks at work."

To summarize, most participants felt that they had interacted more with other people due to LeakyPhones and also found the fact that more people were looking at the positive or didn't really mind it. On the other hand, many felt uncomfortable with looking at other people, even in the limited scope of the study.

6.4 Group Discussion Results

Following the study, participants set together in a meeting room and ate pizza and drinks. Following a short break we started a group discussion with some questions to direct the conversation.

At first, most participants in the study started talking about technical problems, in terms of performance of the headset. Since we were more interested in investigating the concept of LeakyPhones and their feelings in light of the experiment with the technology, we asked participants to focus more on their feeling, perception of the concept, eye contact etc., and less about the performance of the technology.

Many of the participants commented on gaze and eye contact. Some of them explicitly said that it made them feel "uncomfortable", or âĂIJdistracting" some even mentioned that they found ways to avoid it while still participating in the experiment and trying out the experience by changing the direction of the headset on their head without looking at other people. F2, for example, was even harsher at first saying that the problem is in the act of gazing at other people itself: "...I think staring in itself is a problem...it depends on the culture, I know that in Asia, people get killed for staring"

But, a few of the participants admitted that they actually like looking at people around them and are interested in exploring what people around them are doing. for example, M7 and F3 mentioned that the LeakyPhones experience is a nice form of Voyeurism. M7 mentioned about the use of Leakyphones: "It felt nice, it felt like a dramatic change, I could enter the experiential world of other people...I could scan".

F3 mentioned that she could imagine herself using LeakyPhones: "I like looking at other people, I don't feel bad about that, and I could say that I like your music...I am not looking to meet someone. If I was looking for someone, It would be a good chance to start a conversation"

It seems like many participants agreed that looking at other people is interesting and even something they already like doing regularly, but mentioned that there is something problematic about the gaze, in which the other side notices that you are looking at them and perhaps does not welcome you. Could this oversensitivity to gaze be soothed if Leakyphones becomes ubiquitous? Many of the study subjects thought this could change if you had a way to know who is participating in the "game", who is willing to have people look at them. As M2 said about having some indication of who is willing to share: "I think it would help... that would be like welcoming you" M7 mentioned that part of the strangeness of the interaction is because we have never experienced it before and it is not yet ubiquitous. He concluded that: "if this were to be a common thing it would be like a form of self-expression, you can present yourself in the same way"

Many of the participants agreed that music is an emotional medium and that their relationships with loved ones (family and friends) involve sending sharing and conveying emotions with music. Some even thought that music would be too personal to share with strangers without some curation. M6 mentioned: "Music is a huge window to someone's feelings, you can really know how they feel, it is a very personal thing. I imagined that I am not in a study and I found it awkward to stare at other people with that idea that music is so personal...I felt as if I was looking into that person".

Could be that music is too intimate or revealing to be used as a medium to connect with strangers?

6.5 General Conclusions From The Study

When looking at the study as a whole, we can try to draw a more holistic picture of how well the concept of LeakyPhones worked for our study subjects.

Social Awareness

Users of LeakyPhones seemed to be more aware of their surroundings. They interacted more with other people, (2-4 interactions, 2.6 on average vs 0-1, 0.5 on average without LeakyPhones). Subjects reported noticing other people in their environment more and that they could recognize other subject's emotional state more easily then when they were using noise canceling headphones.

While some participants found the action of being looked at distracting (e.g F1), most subjects did not mind being looked at too much and some did not even notice it. On the other hand, participants report heightened sensitivity to the active act looking at other people. They felt that they should get some permission to look at others and either found creative ways to circumvent that such as aiming the headset with their hands, looking at a participants that were of "lower risk" for embarrassment (for example the mutual gaze between F2 and F3, both women), or avoiding using the technology almost completely (by sitting with their back to other participants, e.g user M3). This, in combinations with what participants say about their genuine interest in looking at their surroundings brings us to conclude that people want to look, but feel they first should have permission!

Gender

Men and women in the study displayed a slightly different behavior and response to LeakyPhones. Men seemed to be more comfortable with the concept, consistently exhibiting what may be seen as a more exploratory behavior: longer gaze episodes, longer maximum gaze events and an overall higher number of gaze events at both sexes when compared to women. But, both women and men felt that looking at other people was sometimes problematic or uncomfortable and expressed that both verbally during the group discussion and during the post-study survey. Surprisingly, although most subjects reported in the pre-study survey that they are less tolerant to gaze from other people than actively looking at others, in reality, only one female participant reported being distracted by the gaze of other people. It is very possible that women have high sensitivity to gaze, since they experience these events with negative connotations more often. The small scale of our experiment does not allow any kind of generalization of this finding.

Gaze Hyper Sensitivity

Many subjects felt strange with the fact they had to look at someone in order to listen to their music, but it is hard to say if these were negative feelings or mostly a feeling of embarrassment and of breaking the norms.

On the other hand, many of the participants reported that the requirement to look at other people in order to hear their music made them feel uneasy. Almost half of the participants mentioned that looking at others made them feel uncomfortable in some way. From strange and awkward to simply "unpleasant". A small portion of the participants found the concept and actual experience with LeakyPhones distracting and strange, specifically because of gaze. Not withstanding, it was mentioned more then once that privacy control is needed (as discussed previously in this text but not implemented for the user study and solutions that do not involve gaze were proposed. Almost all subjects wanted some social filtering mechanism, or an ability to toggle between other people's channels before engaging in an interaction that will provide them with finer grained control of their privacy.

Interactions

The length and identity of interactions was greatly affected by the sitting locations in the study. When participants set one in front of the other, the chances of them interacting grew considerably. In cases that they shared a line of site but it was challenging to look at each other because of their head direction or distance, they found easier targets to look at. When interactions accrue in the study, they mostly involved listening to music together and switching music, but very rarely these interactions ripened to an actual conversation or face to face discussion.

Perception of the Concept

Many of the participants enjoyed the idea of being able to hear other people's music or learn more about those people in a less binding way than a conversation. They mentioned that music is a great enabler for interactions and described the interaction with the LeakyPhones as a "nice form of voyeurism" and specifically mentioned that it is very different and more interesting to them than a virtual interaction with a person's virtual profile:

"It would be MUCH more interesting than a virtual profile, a profile seems more like a curated list of things, and this... this is what they actually are, a real person" (M7)

The majority of subjects mentioned that listening to the music someone may share through his virtual social network profile is less interesting and genuine as social media are:

"...curated, people are so specific about what they put on because it shows a certain image or they want to portray a certain image" (F2)

Participants felt that they are exposing and expressing their real self when using LeakyPhones, unlike when using virtual profiles on social media. They mentioned that knowing that everyone can hear your music may lead to curation of one's content, or to a more genuine picture of people then what we now have access to through their social media. While some subjects found this to be a strength of the technology, others have showed heightened sensitivity for their privacy, fearing that they will expose more then they intended. Almost all participants during the group discussion that visual signaling of some sort is required - they want to know "who is playing the game" Some of the participants expressed interest in the concept of Leakyphones being turned into a real product. They said that they would be happy to use it in their everyday life, and expressed a couple of ideas for ways they believe would make it more usable. They mentioned that they would like for the system to have an ability to toggle between people's music without the need to look at each other (M5, M6), the ability to control privacy settings and choose when and what to share and with whom and a means to lock in to someone's music so that you would not have to continuously look at them. Almost all participants wanted to have some clear visual sign that indicated the afordance LeakyPhones to share music, and that will indicate the sharing mode of other people.

Most participants reported that they enjoy the concept, that it was fun, and think that they could see themselves using it in some situations in their everyday lives such as work, commuting, and for self-expression.

Chapter 7

Conclusions and Future Work

7.1 Conclusions

This thesis describes the concept of IceBreakware; ubiquitous personal technologies that are redesigned to reduce their isolating effects and foster more physical interpersonal interactions and spatial awareness. We presented LeakyPhones, an instance of an IceBreakware-a wearable device that allows real time, colocated audio sharing based on gaze.

This work included the development of and creation of two prototypes of the LeakyPhones technology that have the form factor of simple headphones and are designed to allow people to have a peek into each other's music by gaze.

LeakyPhones aims to encourage users to look at their surroundings, listen to other people's auditory content, and potentially engage in a conversation or other forms of more subtle positive interaction with the people around them.

The LeakyPhones interface and its performance were evaluated in a number of questionnaires, and in a user study and a group discussion with a group of 10 people, to assess its ability to engage people in interactions. The concept itself was also discussed to map its attractive and problematic aspects.

These evaluations suggested that users are indeed engaging in more interactions when compared to the control group and generally find the concept intriguing. Yet, subjects expressed a number of concerns regarding their privacy and gaze. They mentioned that since music is such a personal medium and reflects their emotions, sharing it with everybody exposes them in a very personal way. They want to ensure more control of what they are sharing and who they are sharing it with, In addition, subjects shows that gaze could be problematic. Surprisingly, it was found that the problematic aspect of gaze is not in being looked at, but in the uncertainty whether it is OK to look at someone else, and being noticed.

Further evaluations are needed to assess the real and longer lasting effects of LeakyPhones on people's behavior in a closer to real life scenario and for a longer period of time in order identify if the system or similar systems can indeed have a real effect and help people be more aware of their surroundings, feel less lonely and engage in more real-world interactions, while feeling comfortable.

Due to the fact that many of the participants felt uncomfortable with the gaze at some point, it is not clear if gaze was an enabler of the interaction, or actually had a negative contribution to them. It seems like the gaze is charged with cultural, personal and case-specific emotions that can be changed based on a change of norms or the settings. It would be interesting to test whether discomfort from being looked at or looking at other people would still exist if LeakyPhones ever becomes ubiquitous and how it will be used within groups of people who feel more comfortable with each other's gaze like colleagues or friends.

LeakyPhones was created with the belief that humans can benefit from more real time colocated interactions with each other. From the understanding that music is a strong social vehicle and a "resource for social occasioning"(DeNora)[5] While the user study and group discussion showed some potentially positive results that people may be more engaged with their surroundings, more work is needed in order to explore how strong and long-lasting these interactions really are, and the very interesting connection between gaze norms and heightened privacy sensitivity.

It is very likely that the Leakyphones will never be able to induce conversations between strangers at a larger scale, but we believe that its profound influence on people's behavior and feelings will highlight the importance of technology-based social enablers such as IceBreakware.

Leakyphones may not be strong enough to help people start a conversation, but perhaps it could relieve the feeling of being alone (together) [43], by reminding us of our surroundings and giving us the more comforting feeling of "accompanied solitude"[17].

"Maybe (we can) just listen to the music together, without saying anything" (GA, 31, Leakyphones group discussion)

7.2 Future Work

One of the major problems with the evaluation of LeakyPhones was its relatively poor performance compared to normal headsets in terms of audio quality and robustness; the design of the system and the inherent limitations of the Bluetooth technology (maximum No. of radios and their range) greatly limited the scope of the user study in terms of size, setting and control groups data collection. The studies were very short, which greatly limited the use and adoption of this new feature and the exploration of the new options for interactions it may provide.

Future work will involve deploying better performing headsets to a much larger number of users to get a better understanding of how people may use LeakyPhones when they are ubiquitous. We would then like to perform actual statistics to quantify their Leakyphones social effects.

Privacy control, which was included in the original prototype of LeakyPhones was omitted from the study. In future work we would add this feature to all experimental headsets. This will allow participants to use the headset in a way that allows them to switch between public and private states and take full control of how and when they may want to share and interact with others. This will also give us better insights into the use of Leakyphones for intentional audio sharing, and what kinds of auditory content (such as phone calls, podcasts etc.) people are willing to share.

The actual effect of LeakyPhones needs to be studied further, to pinpoint what part of this new experience may be responsible for the increase in interactions that we witnessed, and to determine if this finding has statistical significance. More control groups are needed in order to ensure that the effect that was shown in our studies, can be associated with the use of LeakyPhones and is not simply an artifact of the experimental design.

Gaze event detection is needed for all control groups as well, in order to compare the gaze events of LeakyPhones users to those of the control groups and see if they are indeed more exploratory in their behavior as a result of using LeakyPhones in their day-to-day.

The concept of Leakyphones and IceBreakware in general, was tested for a rather demanding goal - introduction between strangers. In the future, we would like to test Leakyphones and other forms of IceBreakware in environments that are more likely to foster its use, such as communities that meet on a professional basis (such as workplaces and theme-based conferences), or share a common interest (such as museums and exhibitions), or in groups of people who have some other factor that brings them together, such as families or friends.

Lessons learned from future explorations with LeakyPhones could possibly be transferred to other personal digital devices that are being used and developed today, turning them as well into instances of IceBreakware; smart glasses such as the Bose AR [2] could be used instead of headphones or could be designed and used to reduce the need to look at screens and help people learn and be aware of who is around them and reduce the chance of missing opportunities for encounters and experiencing the stress associated with new social situations. Smart headphones such as LeakyPhones and others, could be designed to change the perception of what is private and what is public and could be designed to free up people's ears and perhaps encourage them to engage in conversations (both metaphorically and in reality). We can even think of social robots that will be designed to promote and assist in conversations between people, instead of replacing them.

We hope that before these technologies are developed and deployed in the world, their social effects will seriously be taken into consideration.

Chapter 8

Appendix A

1. pcb design for connecting 9 IR LEDs to SoundLink 35 ear caps

2. pcb design for a 4 channel audio mixer

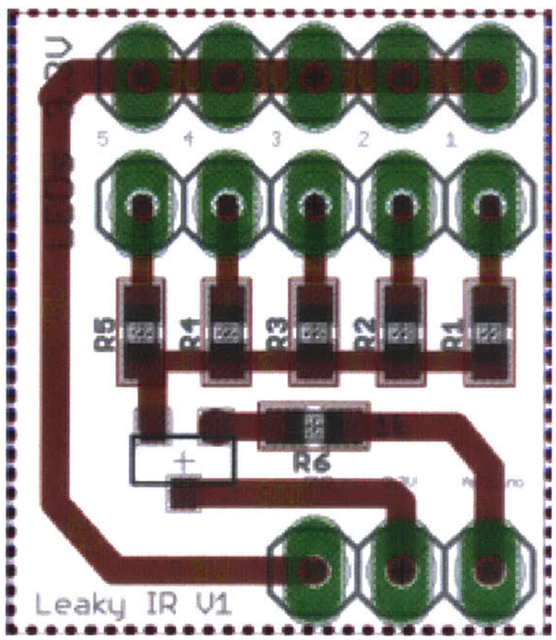

Figure 8-1: pcb design for connecting 9 IR LEDs to SoundLink 35 ear caps

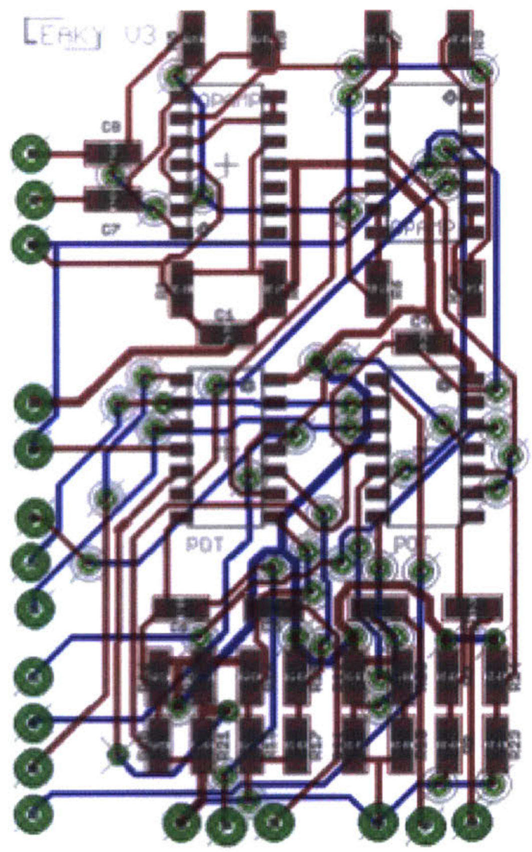

Figure 8-2: pcb design for a 4 channel audio mixer

Chapter 9

Appendix B

Group Discussion Q & A

Q: What did you feel when you were able to listen to other people with LeakyPhones?

M6: "Music is a huge window to someone's feelings, you can really know how they feel" "it is a very personal thing. I imagined that I am not in a study and I found it awkward to stare at other people with that idea that music is so personal". "I felt as if I was looking into that person". "A really good way to open a conversations, a great icebreaker" "can be awkward and a good icebreaker"

Q: Would you want to have a means to control with whom you are sharing your music?

M5: "It think it would be great if we could toggle and decide if you want to broadcast or receive music" "One of the best things is to listen to the same song with someone, that way you are sort of on the same page, same wavelength" "It would be pretty cool if when i listen to transmitting what someone else is listening to and I like I could broadcast it and it would be like a chain reaction" "Everyone gets the same playlist as the original broadcaster"

F2: "It felt a little awkward to be staring at people I don't know" "I moved around and I stared at the person, and I wasn't sure who's music it was". "It was weird, I was staring at people...it was interesting if I could know who's music I was listening to"

Q: Would you like a visual indication of other people's state? is staring the problem or staring at someone who you are not sure s willing to share?

F2: "Yes, I think so...I think staring in itself is a problem...it depends on the culture, I know that in Asia, people get killed for staring"

M7: 'It felt nice, it felt like a dramatic change, I could enter the experiential world of other people...I could scan" "On one hand it felt like a sense of agency to do that, but on the other hand, it didn't feel like a natural thing, it was an tacit thing like listening to regular music might be" "I wonder how can you make this to be more ambient, essentially like overhearing a conversation and joining a conversation...I wonder if there isn't a less active way to do that, so that it doesn't invade your personal space or something that feels forced"

F2: "Depending on where you were sitting you were limited by the number of people you could engage with while still working... so I was like engaging, and then get back to working"

Q: You mentioned that you were able to learn something about other people from there music, was it strong or not strong enough to actually talk to them?

F2: "I think it depends on the person you are looking at, when I was staring, I felt that everyone was so busy doing their own thing I didn't feel like I could interact with them, I spoke to people who sat next to me (to F1)"

F1: "I listened to her computer because the headphones were still connected to it, and I asked her about her music" (Comment: F1 listened to F2's music even when she was in the control group, since the Bose QC35 was still paired to F2 computer from the previous session.)

M7: “Maybe because you need to put on the headphones in order to listen to the music they are hearing, and then to engage in the conversation you need to take those headphones off”

(Interviewer interrupts...)

Q: People who had a screen in front of them seemed like they engaged with the screen more then with other people around them. was anyone using social media during the experiment? Did the experimental setting make you more aware of people around you and helped in creating a real time interactions?

M1: “I think it would help to have some notification that someone is looking at you, and if they like you, they can let you in to their music”

M3: “I was very focused on my work, I was listening to someone else only when I had to take a break, I cannot listen to music I never heard before because then I cannot concentrate...I listen to others only when I needed a break, it was pretty fun”. “I really liked the way the music was fading in and out”

M4: “I was working and focused because I was listening to kind of rock, but when I was looking at someone else who was listening to very peaceful (classical) music, they looked like they were very calm and relaxed, and in a way, it was a really nice break, in the moment I turned back to my screen, the music change back and I was like: you need to get back to work!” “It was a good potential for conversation”

Q: So M4, did you engage with that person because they looked calm?

M4: “Yes, I think the music had to do a lot with how they looked, they looked relaxed and the music was also relaxing, and listening to calm music... I knew that they were relaxed” “Yes, I was expecting to hear something like that because they looked very relaxed”

M2: "I was able to listen to others without looking at them directly...I was able to listen to others without looking at them" "I found it more comfortable not to have to look at others when I only wanted to listen to different kinds of music"

Q: (Question for the women) What did the women in the experiment feel about the need to look at other people and having other people look at you?

F3: "I like looking at other people, I don't feel bad about that, and I could say that I like your music...I am not looking to meet someone. If I was looking for someone, It would be a good chance to start a conversation"

"But...I'm a girl, and I imagine that if anyone had this mechanism, I could receive some annoying messages, I don't want to get any message that people are looking at me, that would be annoying"

M4: "I think a nice feature would be to be able to choose if you want to interact and switch between normal headphones and these, so you do not experience annoying messages"

F2: "If the experiment was on the first floor atrium and you couldn't so easily tell that people are looking at each other, and I would notice someone looking at me I would probably be like...is it me or are you looking for someone?" "I would be very confused, unless they came over and spoke to me, I'd be really confused and think they are up to something else"

Q: If there was a way not to share, so that when others look at you they don't hear anything and look away, would that help?

M4: "I think that would clear that up a little" (People in the room nodding and expressing agreement: that It would make sense for them if you could choose to participate in leaky or not, that way you could understand why someone is looking at you: you are sharing music)

Q: When, during the experiment today, someone was looking at you and you were not sure why, how did it make you feel?

F2: "I think it depends on the environment, whether you feel safe or not, if you are walking home in Manhattan streets in the middle of the night...you know... it depends on the situation, maybe I met that person before if they look at me(?)..."
Q: Do the guys have any opinion about eye contact?

M7: "I think that lets say, this becomes ubiquitous, I think that having them on will become a tacit invitation to contact with a stranger... would be normal it is accepted or not"

Q: Would you want to know who has this feature or would you not care? Would you want a visual invitation to interact?

M6: "I think it would help... that would be like welcoming you" It would be like a massage of your status

(M7, F2 and others agree)

Q: How about a visual signal, would you mind others seeing that you are in a sharing mode?

F2: "I think that is fine"

F1: "If I recognize that you are wearing those headphones but I'm not wearing mine, I could still start a conversation with you"

M4: "It is like tinder, if you see someone you know on tinder you know that they are looking for someone, something like that"

M2: "I think that if you are looking at other people you should be required to share"

F3: "It is kind of cool to be hidden, like voyeurism!"

M7: "It is a nice form of voyeurism, I think it is quite a nice feeling, I'm always curious what book someone is reading. I don't know why but this has the same kind of pleasure"

Q: Those of you who find it appealing in some way where would you use such a thing?

M7: "For me it would not really be something I use to invite social interaction... it would be something that I would use for listening to what someone next to me is listening to, not necessarily that I would want to go and talk to them yet" "I like the idea as a way to find new music and discover the lifestyle attached to it"

Q: Do you think that a virtual/digital profile of that person would serve in the same way?

M7: "It would be MUCH more interesting than a virtual profile, a profile seems more like a curated list of things, and this... this is what they actually are, a real person" "It is about the experience, not about their test and such"

Q: What kind of places can you see people using this?

F1: "I can see myself using this during lunch time, when I am not so much into work and I can eat at my desk and invite someone to talk to"

F2: "I think an office environment, we have a cafeteria, and sometimes you ran into the same people at lunch but you don't necessarily interact with each other... in a company there are a lot of people you don't know, but you see them every day, like in other departments, and if you have such a thing you could break the ice and connect"

M6: "I'm thinking about reasons that I would share....If I were depressed, would I want someone to know that from my music? I think it would be interesting to understand when people will be interested to share. If I were depressed would I want someone to come and talk to me, will my music be depressing?" "Would I share it because I am seeking for a relationship, or because I am bored? then all the gazing and contact becomes irrelevant, you have a deep feeling and a different goal for sharing"

Q: So in situations, what feeling would you want to share?

M7: "if this were to be a common thing it would be like a form of self expression, you can present yourself in a same way"

F3: "I'm thinking about depressive emotions, and sometimes you want to share your emotions with someone else that would be a nice subtle way"

M6: "On the train everyone has headphones and I look at everyone and kind of think about what the story of their day could be, I found it very interesting because if they were sharing that story with me and I could understand that story, I think that is a really powerful social tool"

Q: Do you think the experience of music sharing will be strong enough to make someone talk to you or for you to come and talk to them?

F3: "maybe just listen to the music together without saying anything"

M6: "I would really like to talk to someone and share. if I was really happy I would like to talk to them about it."

M5: "I just see myself broadcasting through the day, that would be fun, it is just that thing that connecting with other people through music is more powerful then just looking at their profile for example, even in the survey you sent (pre-study survey), asking what music to put on the phones felt personal so I didn't put my favorite music, just put some generic music people like listen to, so being able to really listen to what people actually listen to throughout the day would be like pretty cool"

Q: So you feel that you expose yourself if you share?

M5: "Yes in a way, depends on the context"

Q: Do you think about that stuff also when you use social media?

"Yeh, I don't really use my social media anymore, because I don't think it is personal enough".

Q: Are you using another form of music sharing?

F1:"A friend of mine sends me playlists on spotify...sometimes we email each other songs"

M6: "With my closest friends and family... we share the same taste in music so even of we are far away, the best way to contact with each other over distance is by sharing music".

F2:"You were asking about social media, and social media is now curated, people are so specific about what they put on because it shows a certain image or they want to portray a certain image. I was wondering if people's consumption of music will start to change...or you know, If people will try to create a specific image"

F1: "It is like a snapshot... perhaps they are listening to me when I'm listening to my angry music... I wouldn't be in sharing mood when I am in that kind of state, and they would know that from my music"

Q: So I guess two things can happen; we could change the way we behave, or we could just get back to being who we are, because it is pretty hard to play that game all day

F2: "It depends on the person"

Q: Can you see yourself changing what you hear based on the people around you? To make a different impression?

F2: "I think it would be tiring... but you know, if you are sitting next to your boss or something it is like someone will be able to read your mind"

M7: I could easily imagine brands paying wealthy, attractive, well-dressed people to listen to a particular kind of music and be ambassadors of brands"

Q: What about other auditory content? Audio books, podcasts, commercial content?

M1: "I think he (pointing at M3) was listening to the news (actually, M3 was listening to a Taiwanese pop song).... that grabbed my attention more, like what's the news? But it also depends on other things that person is listening to and then I am like what's going on..."

M5: "I think it was just different because everyone was listening to music... if other people were listening to the news it would not be like that..."

Q: Do you think this would be different within your communities?

F3: "I listen to a lot of music from my country and I would like to share that, it will also be a good opportunity for musicians outside of US to open up..."

M2: "I might be using it but because in a public place there are so many people that it would confuse me because how accurate it could be? It depends on what mood you are, if you want to connect and happy... for example in this experiment, we were trying to figure out what other people were listening to..."

(this was never asked of the participants)

... and when it worked, we shared a smile, showing yes... we are able to connect, I can hear you!..."

Q: And the smile you mentioned, was it because the technology actually worked, or because of the experience itself?

M2:"for me it was because I never experienced something like this, and I was like, its interesting, it is working!"

M4: "I think at this point it was like, this is something novel, but if this was real life, the novelty would fade, and if you were listening to someone's music that you liked, you would probably pay attention to that as well".

Q:How should we change the experiment next time?

M1: “Maybe, if someone is looking at you, a subtle change in the music...maybe a bass drop or something, to me that is important, to indicate that someone is looking at you..”

F2: “I was actually thinking that if the setting was different, people would have more interactions, instead of tables, bean bags, or instead of tables something else...even the atrium is more casual...”

F3: “I would like to know the name of what I was listening to...”

M5: “You need different activities, like the ping pong tables”

F2: “Everyone was working so hard, I didn’t feel comfortable approaching anyone”

Bibliography

[1] RegencyTR-1, 1954.

[2] BOSE AR, 2018.

[3] OpenVR, 2018.

[4] sounddevice, 2018.

[5] Vive VR, 2018.

[6] Kazuya Atsuta, Masatoshi Hamanaka, and Seunghee Lee. Concert viewing headphones. *International Journal of Computer Games Technology*, pages 22–24, 2011.

[7] Jared A Ball. I Mix What I Like ! In Defense and Appreciation of the Rap Music Mixtape as âĂIJ National âĂİ and âĂIJ Dissident âĂİ Communication. *International Journal of Communication*, 5:278–297, 2011.

[8] Arianna Bassoli, Cian Cullinan, Julian Moore, and Stefan Agamanolis. TunA : A Mobile Music Experience to Foster Local Interactions. *Social Research*, pages 1–2.

[9] Arianna Bassoli, Julian Moore, and Stefan Agamanolis. TunA: Local music sharing with handheld wi-fi devices. *Proc of 5th Wireless World ...*, pages 1–23, 2004.

[10] Sumit Basu and Alex Pentland. Smart Headphones. In *CHI, short talks*, 2001.

[11] Stephan Baumann, Bj Jung, ouml, rn, Arianna Bassoli, and Martin Wisniowski. BluetunA: let your neighbour know what music you like. *Proceedings of ACM CHI 2007 Conference on Human Factors in Computing Systems*, 2:1941–1946, 2007.

[12] R Borovoy, M McDonald, F Martin, and M Resnick. Things that blink: Computationally augmented name tags. *IBM Systems Journal*, 35(3.4):488–495, 1996.

[13] Scott Brave and Andrew Dahley. inTouch: a medium for haptic interpersonal communication. *CHI'97 extended abstracts on Human factors in ...*, (MARCH):363–364, 1997.

[14] Cherrylyn Buenaflor and Hee Cheol Kim. Six human factors to acceptability of wearable computers. *International Journal of Multimedia and Ubiquitous Engineering*, 8(3):103–114, 2013.

[15] Antoine Coutrot, Nicola Binetti, Charlotte Harrison, Isabelle Mareschal, and Alan Johnston. Face exploration dynamics differentiate men and women. *Journal of Vision*, 16(14):16, 2016.

[16] Andrew Crossen, Jay Budzik, and Kristian J. Hammond. Flytrap: intelligent group music recommendation. *Proceedings of the 7th international conference on Intelligent user interfaces - IUI '02*, page 184, 2002.

[17] Tia DeNora. *Music in everyday life.* Cambridge University Press, 2000.

[18] Mag Duguid. Dance with me...

[19] Tom and Gary. Distributed Dance Party.

[20] Masatoshi Hamanaka and SuengHee Lee. Sound scope headphones. *SIGGRAPH 2009: Talks on - SIGGRAPH '09*, pages 1–1, 2009.

[21] William Hirst and David Kalmar. Characterizing Attentional Resources. *Journal of Experimental Psychology: General*, 116(1):68–81, 1987.

[22] Yoshio Ishiguro, Adiyan Mujibiya, Takashi Miyaki, and Jun Rekimoto. Aided Eyes: Eye Activity Sensing for Daily Life. *Technology*, pages 1–7, 2010.

[23] Hiroshi Ishii and Minoru Kobayashi. ClearBoard: A Seamless Medium for Shared Drawing and Conversation with Eye Contact. *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '92*, pages 525–532, 1992.

[24] J.Grudin. Computer-supported cooperative work: history and focus. *Computer*, 27(5):19–26, 1994.

[25] Sari Komulainen, Minna Karukka, and Jonna Häkkilä. Social music services in teenage life. *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction - OZCHI '10*, (April):364, 2010.

[26] Sr Langton, Rj Watt, and I Bruce. Do the eyes have it? Cues to the direction of sTowards expressive gaze manner in embodied virtual agentsocial attention. *Trends in cognitive sciences*, 4(2):50–59, 2000.

[27] Stephen R.H. Langton. The mutual influence of gaze and head orientation in the analysis of social attention direction. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, 53(3):825–845, 2000.

[28] Lassi A. Liikkanen and Lassi A. Music interaction trends in Finland. *Proceedings of the 18th International Academic MindTrek Conference on Media Business, Management, Content & Services - AcademicMindTrek '14*, pages 127–131, 2014.

[29] C Neil Macrae, Bruce M Hood, Alan B Milne, Angela C Rowe, and Malia F Mason. Eye Gaze and Person Perception. *Direct*, pages 1–6, 2002.

[30] Joseph F Mccarthy and Theodore D Ha˜ost. MUSICFX: An Arbiter of Group Preferences for Computer Supported Collaborative Workouts.

[31] Florian Mueller, Matthew Karau, and Sugar House Lane. Transparent Hearing. *Perception*, pages 730–731, 2002.

[32] Anthony Mulac, Lisa B Studley, John M Wiemann, and James J Bradac. Male/Female Gaze in Same-Sex and Mixed-Sex Dyads Gender-Linked Differences and Mutual Influence. *Human Communication Research*, 13(3), 1987.

[33] Elizabeth D. Mynatt, Maribeth Back, Roy Want, Michael Baer, and Jason B. Ellis. Designing audio aura. *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '98*, pages 566–573, 1998.

[34] Arne Nagels, Tilo Kircher, Miriam Steines, and Benjamin Straube. Feeling addressed! The role of body orientation and co-speech gesture in social communication. *Human Brain Mapping*, 36(5):1925–1936, 2015.

[35] Kenton O'Hara and Barry Brown. *Consuming music together: social and collaborative aspects of music consumption technologies.* Springer Science \& Business Media, 2006.

[36] Dan O'Sullivan and Tom Igoe. *Physical computing: sensing and controlling the physical world with computers.* Thomson Boston, Boston MA,, Boston, 2004.

[37] Spencer Russell, Gershon Dublon, and Joseph A Paradiso. HearThere Networked Sensory Prosthetics Through Auditory Augmented Reality. *Augmented Human International Conference*, 2016.

[38] Spencer F. Russell. HearThere : infrastructure for ubiquitous augmented-reality audio. *Thesis: S.M., Massachusetts Institute of Technology, Program in Media Arts and Sciences.*, (2008), 2015.

[39] Vishay Semiconductors and Optocoupler Agency Table. Vishay Semiconductors Vishay Semiconductors. (7):95223, 1994.

[40] Jaka Sodnik and Sašo Toma{\v{z}}i{\v{c}}. *Spatial Auditory Human-Computer Interfaces.* Springer, 2015.

[41] K Strater and HR Lipford. Strategies and struggles with privacy in an online social networking community. *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction*, pages 111–119, 2008.

[42] Sherry Turkle. *Reclaiming conversation: The power of talk in a digital age.* Penguin, 2016.

[43] Sherry Turkle. *Alone together: Why we expect more from technology and less from each other*. Hachette UK, 2017.

[44] Shota Uono and Jari K. Hietanen. Eye contact perception in the west and east: A cross-cultural study. *PLoS ONE*, 10(2):1–15, 2015.

[45] Roel Vertegaal, Jeffrey S. Shell, Daniel Chen, and Aadil Mamuji. Designing for augmented attention: Towards a framework for attentive user interfaces. *Computers in Human Behavior*, 22(4):771–789, 2006.

[46] Roel Vertegaal, Robert Slagter, Gerrit van der Veer, and Anton Nijholt. Eye gaze patterns in conversations. *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '01*, pages 301–308, 2001.

[47] J Wang, F Cheng, J Wang, G Shen, and X Jiang. Genius-on-the-Go: FM radio based proximity sensing and audio information sharing. *10th ACM Conference on Embedded Networked Sensor Systems, SenSys 2012*, pages 363–364, 2012.

[48] Andreas Zimmermann and Andreas Lorenz. LISTEN: Contextualized Presentation for Audio-Augmented Environments. *11th GI-Workshop on Adaptivity and User Modeling in Interactive Systems (ABIS)*, pages 351–357, 2003.