"We can not not listen"

Wearasound

Beyond visual centric interaction

Designing sound for enhancing visual contents

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Beyond visual centric interaction

Designing sound for enhancing visual contents

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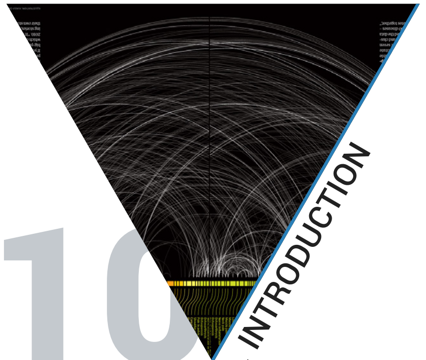
ABSTRACT

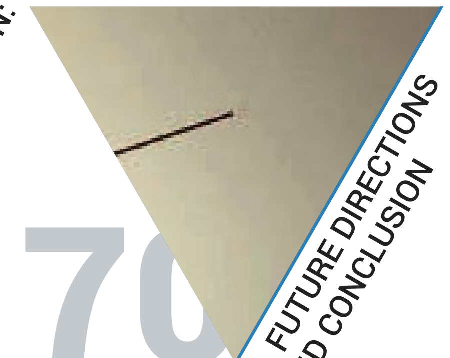
The appropriate use of sounds has the potential to add a great deal to convey information in interactive commodities. Sound is a largely unexplored medium as a design element in interaction design community, even though it plays an integral role in our everyday encounters with the world, on that complementary to vision. However, information and data are predominantly represented in visual form. I argue that sound should be used in designing interactive commodities as a way to improve and enhance visual experience of the artifact. Such strategy leads to build sound design guideline and framework to help designers who are not familiar with sound design. The first half of this project focuses on revealing potentials of sounds, where sound can be used and sound design methodological point of view.

These ideas are instantiated in the Wearasound, a wearable auditory device for conveying contextual information in real time without distraction. Wearasound is designed to be used while the user is moving. A range of auditory information provide peripheral awareness and indirect interaction. Delivering information is adaptive and context sensitive; appropriate information is presented as more or less obtrusive based on user's situated context. Preliminary user evaluation suggest that audio is an appropriate medium for conveying certain domains of information (particularly for content that is intrinsically voice/audio) in specific usage context (when the user's hands or eyes are busy).

CONTENTS





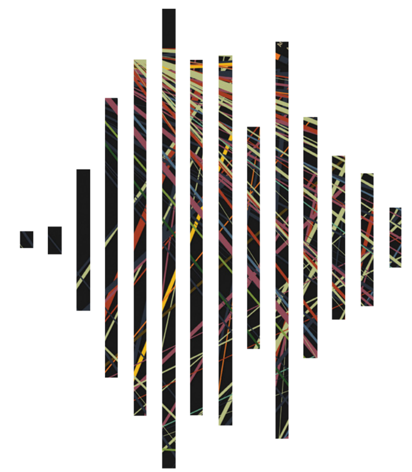
WHY DID I STUDY SOUND INTERACTION?

I consider myself a designer and a musician. Education for my music talent began when I was 13 years old, and I have been playing guitar since then. Playing music is such a joyful experience when seeing how people are influenced by sound. Then I realized how sound influences us in a very powerful way, and the field of sounds becomes where my passion is at. After a while, I accumulated many intriguing and unanswered questions, such as 'why sound affects us, what sounds are powerful, how do we perceive sounds'.

After college, my professional career became an interaction designer who design things for people's use, and how we interact and perceive sound is still intriguing question for me. Whenever I had a chance to work on a project dealing with sound, I experimented both my musical and design skill. In Tinker Lab course, I built the Visual Sound*(https://vimeo.com/66037982)* to explore sound visualization. The Visual Sound visualize surrounding everyday sound with RGB color. 500 LEDs in the light box react surrounding sound of the environment. And in 2012 fall semester, I built sound reactive moving boxes *(ht vtp://gilberthan.com/portfolio/the-sound-reactive-moving-boxes)* in Experiential Media Design course. The aim of this design is to experiment relationship between audio and physical movement. It react surrounding sound and 8 boxes are rotating according to sound frequency range. And different color is projected on the surfaces of boxes that represent intensity of each frequencies.

As my previous project addressed, I always tried to look for a good combination of interaction design and sound. In this thesis, I thought it was really valuable opportunity to answer fundamental questions I had, through the lens of design.

1.INTRODUCTION



1.INTRODUCTION

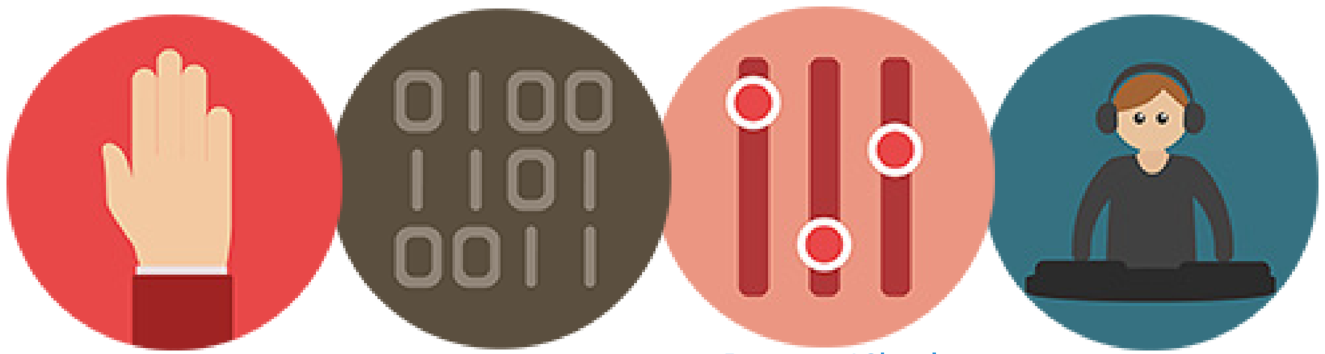
In our everyday life, we get information by listening to everyday sounds. If we imagine what life would be like without sound, we might miss many events — some pleasurable, like birds chirping in nearby trees; some useful, like hearing a person entering the room behind you. Sound plays an integral role in our everyday encounters with the world, but we are still focused on visual medium when conveying information in the field of interaction design. I argue that vision and sound are complementary modes of information in our natural world, so sound should be used to enhance user's mental model and, therefore, lead to intuitive comprehension.

The appropriate use of sounds has the potential to add a great deal to the effectiveness of digital interfaces. In response of this advantage, sounds are used in a wide variety of fields. The applications of sound range from bio-medicine, interfaces for visually disabled people, desktop computer interaction and mobile devices.

An increasing range of products include sounds, from mobile phones to washing machines, and thus an ever-increasing number of practicing interaction designers should be able to begin considering of the sounds of their products. In this thesis,

I will present arguments for how we perceive sounds. Next, I will briefly discuss the relevant existing projects and the framework for designing informational sound. Based on key insights from the existing project and the framework, I will explain six informational sound design implications, along with a initial guidance flowchart for sound design for designers. After this foundation is laid, I will describe the Wearasound in detail with real world scenarios, and illustrate the ways sounds are used in this interface with real world scenario, and how it can bring value to the current interaction. Finally, I will discuss why the sounds used in this interface can deliver information more effectively than visuals, and speculate about the future of auditory interfaces.

Figure 1.
Sound and understanding process



Interaction
(e.g. click, touch, notification)

Information source
(e.g. data drives sounds)

Represent/ Signal rendering/ Audio synthesis
(e.g. mapping technique)

Sensations and perceived patterns
(e.g. the human listener)

The matter of where the interaction happens, whether from physical interaction or from something changing. At this stage, the sound contain raw information regardless of understandability.

Information can be broadly classified as quantitative (numerical) or qualitative (verbal). According to the characteristic of the information, it can be represented as either visual form or sound form. The design of auditory display to accommodate quantitative data may be quite different from the design of a display the presents qualitative information. (2011, Bruce N. Walker and Michael A. Nees)

This involves a technique of mapping the data sources onto representational acoustic variables. This leads to a basic understanding of the nature of the sound that may be understandable to listeners of an auditory display. The matter of the form of sound include volume, attributes and parameters4. Sensations and perceived patterns — If the basic representation of information is appropriate, the sound becomes clearer about what information that the sound contains.

If the basic representation of information is appropriate, the sound becomes clearer about what information that the sound contains.

1.1. SOUND AND UNDERSTANDING

I started with literature review about how we perceive and understand meanings from sounds. I synthesized the process of understanding information as the following. It begins with an interaction and the meaning of information. The steps along this path described as figure 1:

By analyzing this process, the questions of "How the sound can enhance visual contents" become clearer. Here are the research questions involved in each phase.

1.1.1. Interaction

When should sound be generated? What kinds of interactions are more appropriate to use sound than visual element? (Interaction Design)

1.1.2. Information source

What kinds of information are appropriate to be represented as sound form? (Game and movie sound design)

1.1.3. Represent/ Signal rendering/ Audio synthesis

What attributes of sound are recognizable to people? How people perceive different parameters of sound? To make the sound perceivable, what is the potential method for informational sound design? (Computer science)

1.1.4. Sensations and perceived patterns

What type of information could be meaningful to user? (Psychology)

This thesis started with those meaningful questions that are involved in each phase of the process. Even though each of the questions is being researched actively, one problem with the individual approaches is that the separation of the fields leads to each person solving an isolated part of the problem. Interaction designers are driven to find out when the sound is effective using design methods, and computer scientists are brought in at the next stage will most often respond to specific problems, rather than focusing on the initial question itself. And psychologists research about how we perceive sound, but the result is not a clear answer to the initial question: how sound can enhance information.

It is clear that in such an interdisciplinary field, too narrow a focus on any of isolated disciplines could quickly lead to seeing the trees instead of understanding the whole forest. Furthermore, for practitioners of each of the fields that commonly deal with sonification and auditory display, it's often unclear the necessary methods to make it through the integrated steps necessary to arrive at a solution to the problem. An increasing range of products include variety of sound, from mobile phones to electric cars, and thus it is time to interaction designers make decisions about sounds in products. Designers should begin considering the sounds of their products at the concept generation stage.

The focus of the first general exploration phase of this thesis is on the design practitioner, and the way of encouraging designers to use sounds as one of design elements by providing better guidance. Video production was exclusively the domain of professional teams of people with expensive equipment, it's now possible to edit movies on a desktop through better tools that enable individual users. With this thesis, I foresee the future that designers can access sound design skill easily through appropriate methods and tools.

1.2 THE POTENTIAL OF AUDITORY DISPLAY

1.2 THE POTENTIAL OF AUDITORY DISPLAY

Until recently, designing useful sound in the interface has been an unexploited medium of communication and attention is increasing in the product sound design. (2009, Robare, Paul, and Jodi Forlizzi) Users often find sound notifications and alerts distracting. If this is the case, why should sound play a larger role in the interface?

1.2.1. People are good at listening

We all are equipped with powerful listening systems. We listen to the sound of a door closing to find out if it has closed properly, and to a car approaching sound to recognize what kinds of car are approaching. Mechanics listen to machine's engine sound, and doctors to heartbeats, both are getting information that are not visually accessible. Perhaps the reason we get information from listening so effortlessly is that we are not aware of incredible performance of our auditory system.

In proposing sound as one of our communication channel in the digital world, we can start design useful sounds that are explicitly designed to be useful.

1.2.2. Multi-dimensional channel

We are able to decode multiple layers of information from sounds. For example, from footstep sound we not only extract the materials of surface, how hard she is walking, but also the emotional state of whom who is walking on the surface. We can also recognize and identify where the sound comes from within a certain auditory scene. For example, in a concert hall, we can hear orchestrated music of the symphony orchestra. We can also focus on one instrument selectively.

So, we can decode multiple layers of information from sound. Understanding how we perceive multiple layers of information from the sound can help put multiple information to sound, as well as the situation when this multidimensional auditory interaction is more effective than visual interaction.

Robare, Paul, and Jodi Forlizzi, (2009). "Sound in Computing: A Short History."

Gaver, W. W., (1991). The SonicFinder, a prototype interface that uses auditory icons. Human Computer Interaction, 4, 67 - 94.

1.2.3. Sound complements visual contents

Most people both listen to and look at the world to understand information. This not only increases the bandwidth of available information, but also sound complement vision. While sound exists in time and over space, vision exists in space over time.(Gaver, W. W.,1991)

Sound and vision are not only complementary to each other, but also convey different types of information. We can hear events happening in the next room, or listen to complex mechanical sounds, even if we are not able to see them. In the interface, it often is more appropriate to use sound in providing information about what is happening in the background or events that keep changing than visual metaphors.

In general, auditory display has the potential to convey information that is difficult to display visually. Sound can provide information about events without visual attention, and about events that are obscured or difficult to visualize. In addition, visual complexity can be reduced by using sound that represent alternative means for information. These two modes should be exploited to find out which mode is more effective for which type of information.

My thesis focuses on the use of sound to convey information, which has been quite neglected in the brief history of interaction design. (2009, Robare, Paul, and Jodi Forlizzi) By understanding potential benefits of sound, this helped me understand why sound should be incorporated with visual contents. In the next section, I will describe the real world applications of sound.

2. HOW WE HEAR SOUND

2.1 WHERE ARE SOUNDS?

It is necessary to research the range of sound usage in different fields, to understand sound interaction deeply. I tried to find out what are functions that auditory displays might perform. To understand this, I read three books and 35 research studies regarding these subjects including auditory graphs, sonification, auditory icons and artistic approach. Given the number of rigorous research studies, I focused on categorizing general functions of sound. As an outcome of this phase, functions of auditory displays can be categorized in the following four broad categories:

Image credit: Google image search

Buxton, W.(1989). Introduction to this special issue on nonspeech audio. Human-Computer Interaction,4, 1–9.]

2.1.1. Alerting functions

Alerts and notification sound represent that something has occurred, or about to occur in the environment. (Buxton, W.(1989). This type of sounds tends to contain low-resolution information. This means that the sound indicates a single piece of information rather than the details of the event. For example, a simple beep sound is often used to indicate that the cooking time on a microwave oven has finished, not necessarily the type of cooking or how it's cooked. These sounds are intended to convey particular urgency. And warning signals is better to be represented as a sound form to capture an attention than visual warning signals. This is why fire alarm is mainly sound oriented information rather than visually represented.

2.1.2. Status and progress indication

The ongoing status of a certain system or process often requires the user's attention. In this case, sound uses the advantage of human's listening ability to detect subtle changes in auditory events. So a user can perform tasks without using her eyes. Auditory display for monitoring purpose has been developed for factory process states monitoring, patient data in hospital workstation and telephone hold time.

2.1.3. Data exploration

Definition of Sonification is *"the use of non-speech audio to convey information or data. Auditory perception has advantages in temporal, amplitude, and frequency resolution that open possibilities as an alternative or complement to visualization techniques."* (Hermann,T., 2008) Sonification for data exploration is different than first two categories in terms of how much the sound can elaborate the information. They use sound to offer more holistic representation of the data in the system. Auditory graphs (Brown & Brewster, 2003) and model-based sonification(Hermann & Hunt, 2005) are representative examples in this category.

Hermann,T.(2008)."Taxonomy and definitions for sonification and auditory display",Proceedings of the International Conference on Auditory Display, ICAD

Brown, L. M., & Brewster, S. A. (2003). Drawing by ear: Interpreting sonified line graphs. Proceedings of theory of sonification

Hermann T. & Hunt A, (2005) An introduction to interactive sonification, IEEE-Multimedia, vol. 12 no.2, 20-24

2.1.4. Entertainment, sports, and leisure

Auditory interaction has been actively researched and developed in the field of cinema and game industry as well as leisure and fitness activities. Also, audio-only games have begun to appear such as "Vanished"(Pixel Heart Studio, 2010,). With the help of a built-in compass and accelerometer, it recreate game player's movement in the virtual world. All exploration is done with the help of audio cues; as players move, the world "rotates" and provides different sounds. In the sports field, sonification has recently shown benefits as real time feedback for competitive sports such as rowing. (Schaffert, Mattes, Barrass, & Effenberg, 2009). Research in this field has shown that high quality audio can be perceived as high quality display, as high as visual displays in virtual environments.

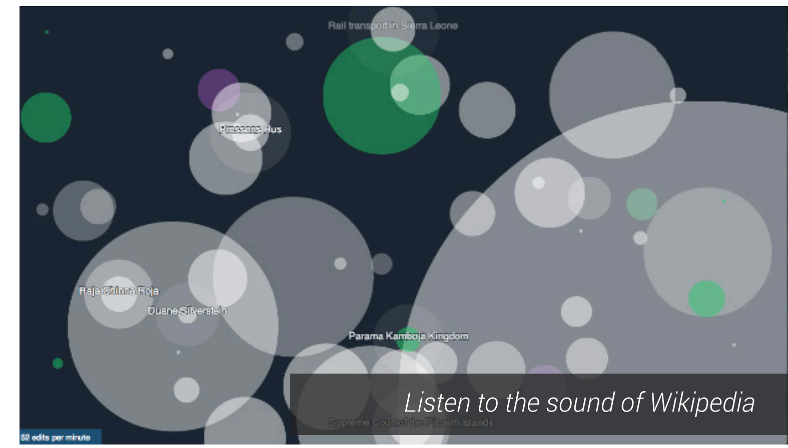
Stephan Barrass, Nina Schaffert, and Tim Barrass. (2010) Probing preferences between six designs of interactive sonifications for recreational sports, health and fitness. 3rd interactive sonification workshop, pages 23-29, Stockholm, Sweden

Pixel Heart Studios, Vanished - iOS audio only game, http://pixelheartstudios.com/vanished 2010.

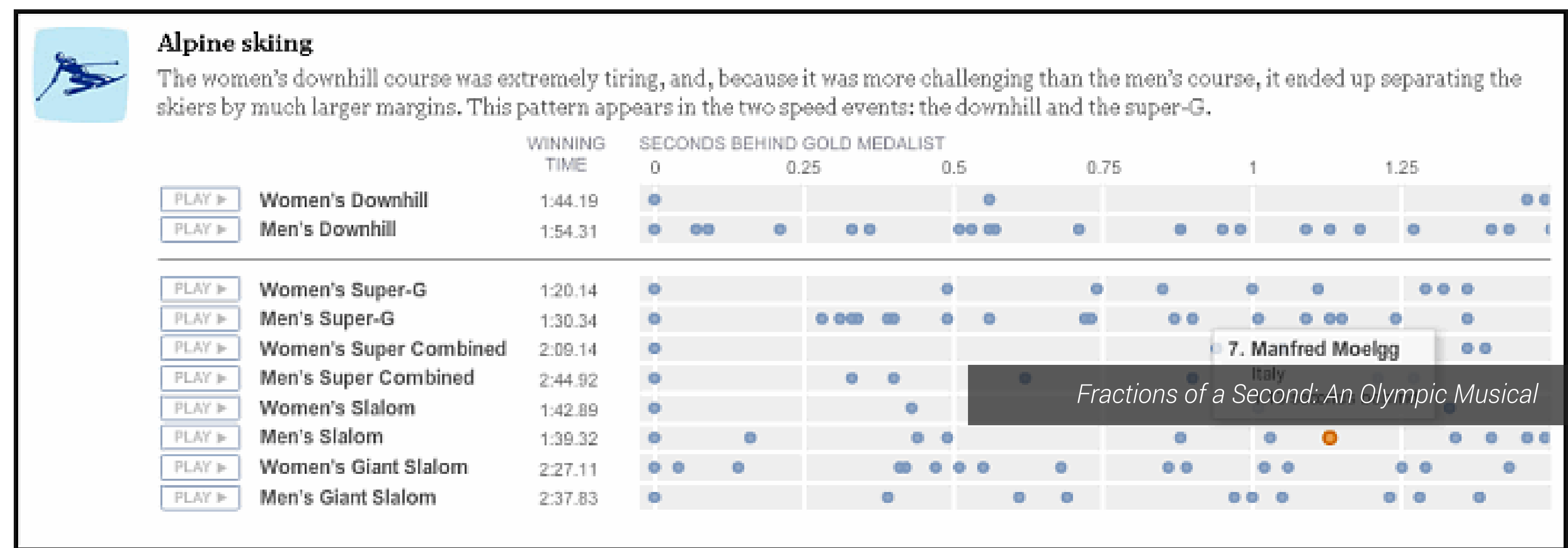
2.2. EXISTING PROJECTS RESEARCH

During the last 15 years, there have been many explorations to represent information through sound. Those projects span diverse topics including visual aid for visually impaired persons, auditory representation of sound and artistic sonic interaction design. I explored those diverse topics to acquire general knowledge regarding how sound is being used and investigated what are common patterns of sound for informative purpose. By investigating those existing projects, I could understand which sounds are useful and which are not. In the following, three impressive projects are described along with what I learned from it.

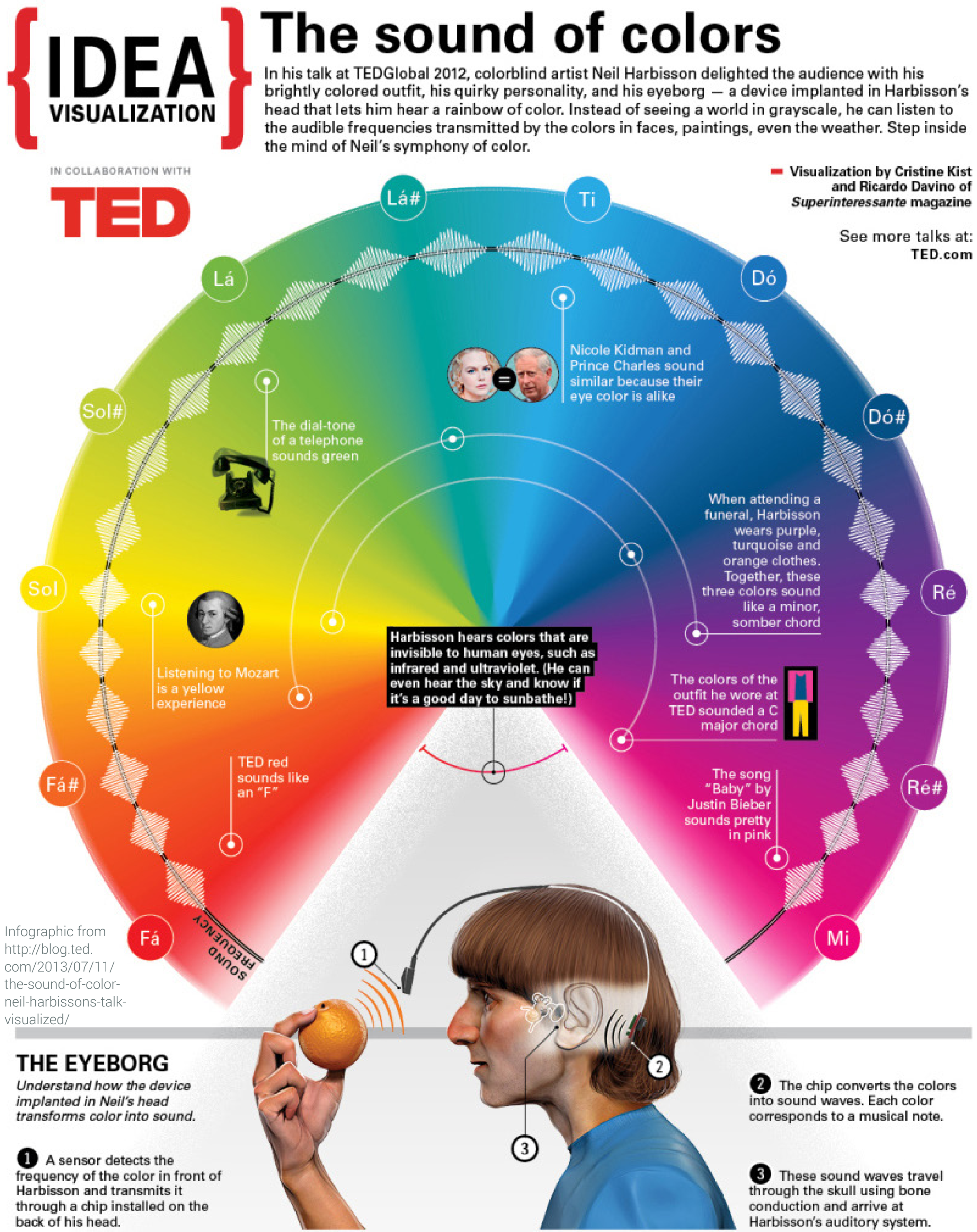
Neil Harbisson — eyeborg



Listen to the sound of Wikipedia



Fractions of a Second: An Olympic Musical



Infographic from http://blog.ted.com/2013/07/11/the-sound-of-color-neil-harbissons-talk-visualized/

2.2.1. Neil Harbisson — eyeborg (Habituation by repetitive listening)

Colorblind artist Neil Harbisson wears a device called "eyeborg". This device converts color into audible frequencies, meaning that Harbisson gets to hear color sound of an everyday world, instead of seeing the world only in gray scale. Here is a quote from Harbisson in his TED talk, 2012.

http://www.ted.com/talks/neil_harbisson_i_listen_to_color

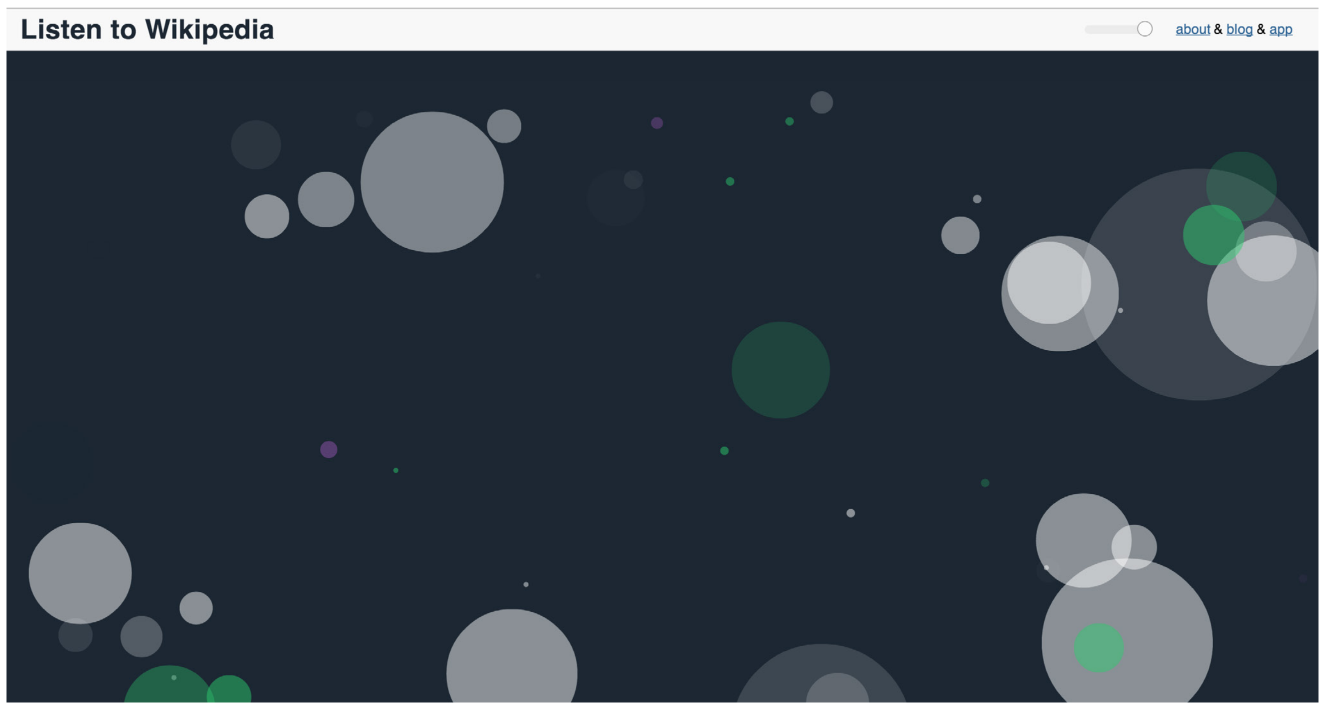
" I've been hearing color all the time for eight years, since 2004, so I find it completely normal now to hear color all the time. At the start, though, I had to memorize the names you give for each color, so I had to memorize the notes, but after some time, all this information became a perception. I did not have to think about the notes. And after some time, this perception became a feeling. I started to have favorite colors, and I started to dream in colors."

In this quote, Harbisson stated that color sound becomes perception and feeling. This shows that habituation of sound is quite powerful. Once our ear familiarizes certain sound with meaning, we can recognize subtle information. It took quite a cognitive load to distinguish each sound frequency that is mapped to different colors at the very beginning of his device usage. After he listens to the sound repetitively, however, the sound transforms itself to information in a very natural way. As he stated, it becomes a perception after repetitive listening experience. And perception becomes a feeling. This project shows a powerful process how sound becomes an intuitive medium of information delivery. One of the key processes of intuitive delivery of information through sound is 'habituation by repetitive listening'.

http://listen.hatnote.com/

2.2.2. Listen to the sound of Wikipedia (Representation of changing data)

Listen to the sound of Wikipedia is a website that generates musical sounds to represent Wikipedia's real-time editing data. According to the type of editing event, it generates different tones and notes. For example, pitch changes according to the size of the edit and bell sounds are addition and string sounds are subtraction editing event. This project shows potential of composing music piece from data. Each editing event create simultaneous, different instruments' play and those different sounds create aesthetics of harmony. In addition to that, sound is well-suited for conveying information about changing events because it is time-based medium that have a beginning and an end. This project is well suited to use sound as a communication medium because it deals with real time editing data which is constantly changing.



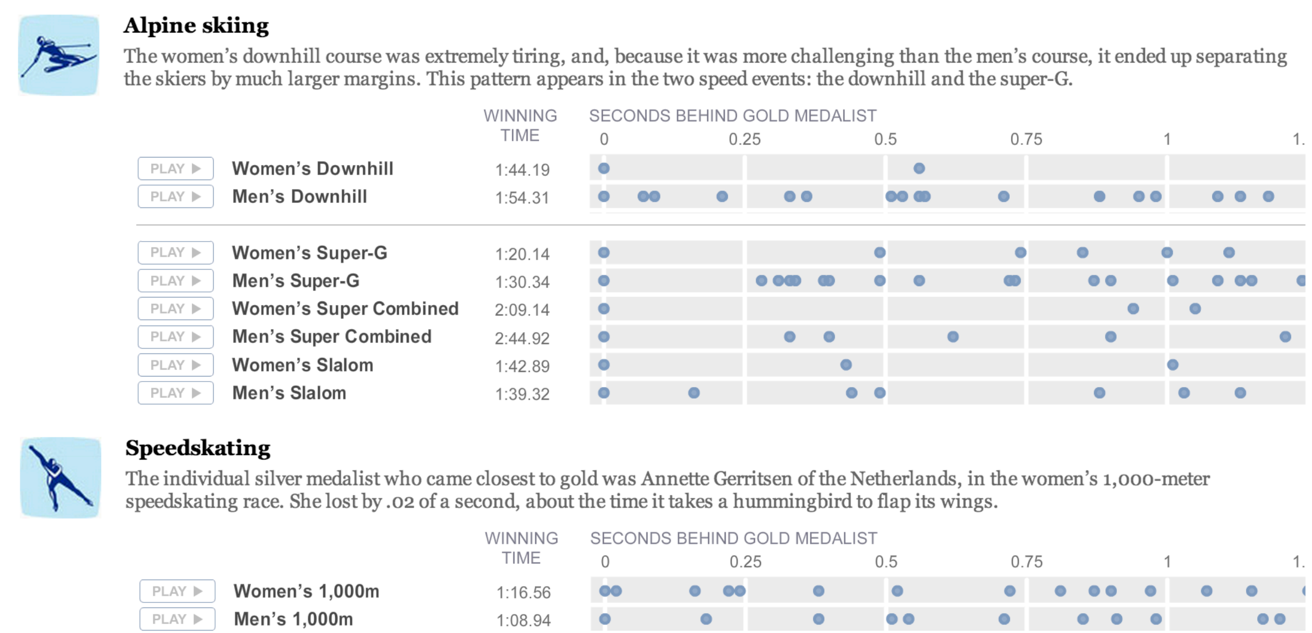
2.2. EXISTING PROJECTS RESEARCH

http://www.nytimes.com/interactive/2010/02/26/sports/olympics/20100226-olysymphony.html?_r=0

2.2.3. Fractions of a Second: An Olympic Musical (Use of rhythmical sound to represent subtle difference)

This project sonified time gap from gold medalist to 10th-place finisher at the Winter Olympics, particularly speed related matches. With our visual sense, it is hard to recognize how much the first finisher is faster than the next finisher. Interaction with visual object tends to produce static or persist information, which sound is well-suited for conveying information about subtle variation in repeating system and it works more effectively when it is paired with visuals.

When we look at the diagram below, it is harder to perceive the closeness of the race. When we listen to the information, it comes to us differently — we can acknowledge the difference in an easier way.



2.3. FINDINGS FROM THE RESEARCH

It helped me understand how the sound can contain information intuitively, by researching relevant existing projects. I synthesized my findings into three categories.

2.3.1. Habituation

People can understand subtle information once the sound has been familiarized after repetitive listening. So it enables listener decode subtle meaning from the sound. For example, some of us can identify who is walking by listening only footstep sound, if you know the one very well. However, the limitation can be pointed out that habituation should require a certain number of repetitive listening experience. If the context is not repetitive usage, such as data visualization or sonic art, the sound should be simple enough to contain information. If the designer should use complex sound, another method is using everyday sounds, for instance, when user delete files in the computer, a crunching sound is played to indicate the destruction of the file, that are already familiar to everyone.

2.3.2. Type of data

Vision depends on the reflection of light from surfaces, while sound is caused by vibrating materials. In other words, sound and visual can be used to represent different form of information in it's nature. Based on this inherently different characteristic, sound can provide information that visual can not, for instance about changing event. The type of data that is intrinsically changing data could be a good design opportunity. Rhythmical data with the subtle change in repetitive system is one of the possible opportunities for sonification.

2.3.3. Attribute of sound

How to map the sound to data intuitively is one of the key issues in this field. In the Listening Wikipedia project, one attribute of sound is consistently used to represent data in the same category — bell sounds are addition and string sounds are subtraction of editing event. Within the same timbre of the sound, there is pitch change according to the size of the edit. One instrument represent one category of data and pitch change represent variation of the data in the category. So consistency of mapping technique enable user interpret the meaning from the sound appropriately. However, sound mapping technique is difficult to generalize. (William W. Gaver, 1993) This type of research need to be extended to provide designers with guidance about their sound design choices. And thereafter, combination of guidelines and usability testing is needed to ensure the message intended to communicate is being received by the listener.

William W. Gaver (1993) What in the World Do We Hear?: An Ecological Approach to Auditory Event Perception, Ecological Psychology, 5:1, 1-29,

2.4. PARTICIPATORY DESIGN WORKSHOP

My literature review and existing project research heavily looked at the theoretical perspective, not with actual usage. Examination of research findings were necessary for identifying practical aspects. For this end, I conducted a participatory design workshop with six participants, which allowed not only generating new design concept and further insights, but also validating research findings.

While my research findings laid the basis of the workshop, conducting an in-depth interview and participatory design workshop with both design and music major participants provided a more contextually rich look at their general experiences in sound interaction. In this section, workshop goal, method and insight will be described.

When is the multi-modal interaction can be effective?

How I can design the sound effectively?

Validation of my research findings

2.4.1. Goal of the design workshop

This design workshop intended to foster discussions around our daily sound interaction and validate what I have found from previous phases. Questions involved in this workshop is the following.

Six participants were in this workshop, and four of them study visual design and two of them study music. Three activities were conducted, and I will briefly describe how I have done and what insights I've got.

2.4.2. Affinity diagram activity

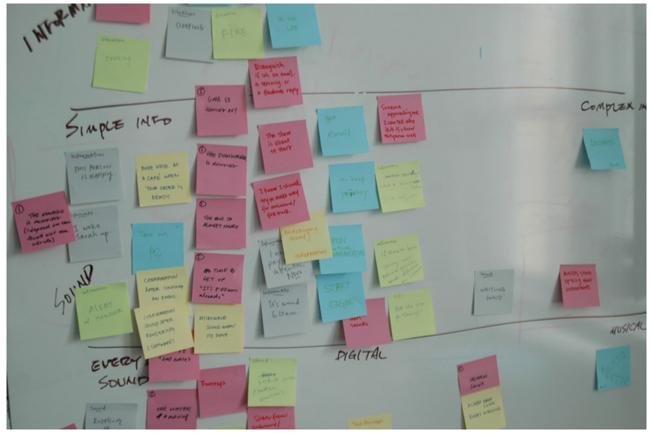
Each participant was asked to write down the situation they got any information from sound in their everyday life. Such as, when we pour a liquid on a cup, close a door, listen to others' footstep, mobile alert sound etc. And then we put post-its on a given diagram. And follow up discussion brought the following findings.

Sound could convey crucial information when user is in the immersive environment that focus one thing. Especially, while user is playing a game or watching movie.

FINDINGS

- Sound conveys information about changing. Especially, when people want to what is going on in the background while they are doing something else, sound can be an effective medium to communicate.
- Sound should be simple enough to contain information that fits the context where there are in.
- Sound can be easily recognized as a very specific type of information after certain number of understanding or confirmation. We train our ears without perceiving it.

"When I was younger, I liked watching the television and not do my homework. But I could hear who's keys was it. So, if it was my dad's key sound, I just kept watching, if it were mom's, I threw everything and then pretend I was doing my homework."



2.4. PARTICIPATORY DESIGN WORKSHOP

2.4.3. Translate sound to abstract visual

I played three different sound samples. Participants were asked to make visual form by listening to those sound samples by using provided geographic forms.

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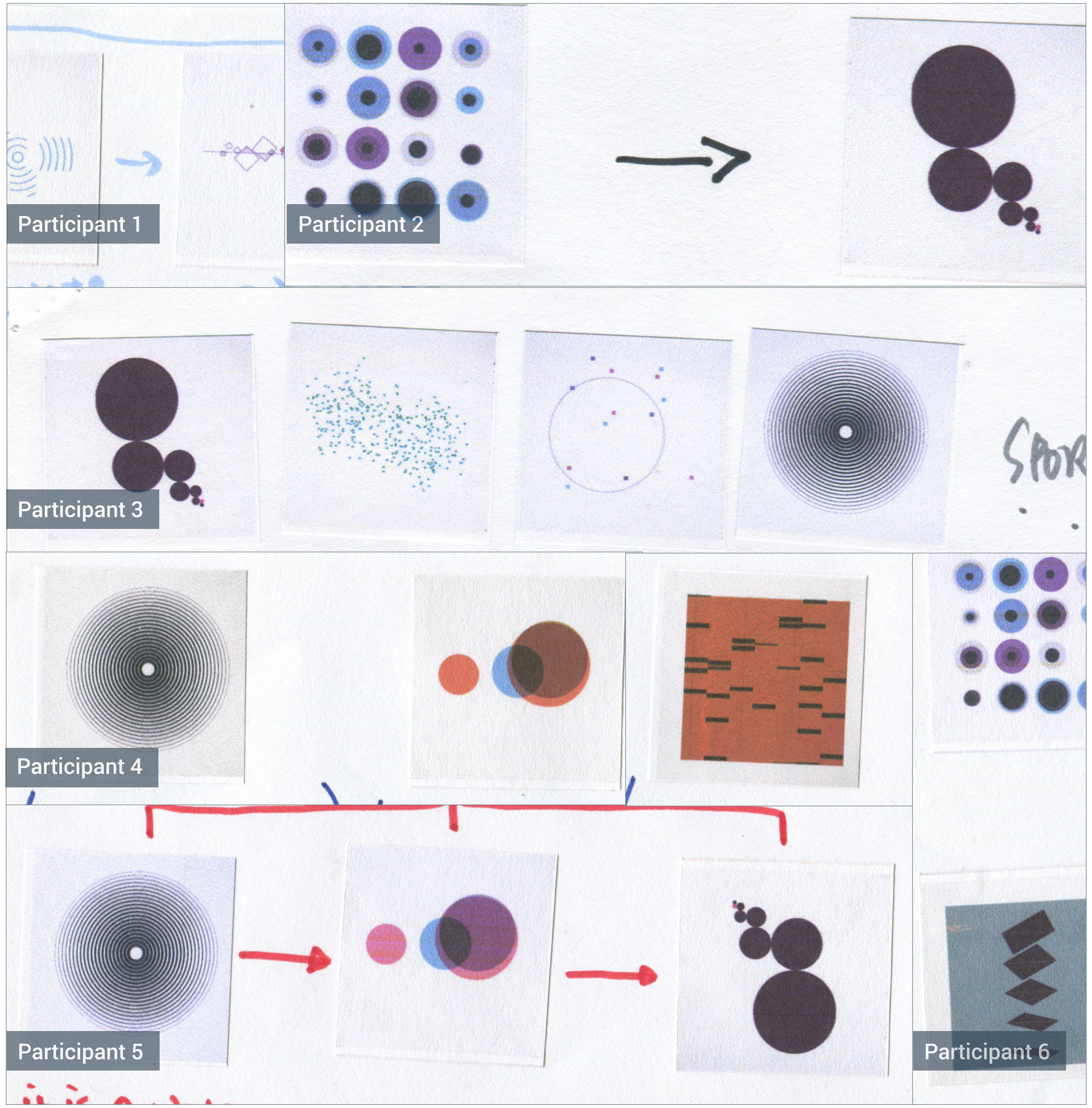
FINDINGS

- People perceive sound in a common way. Participants picked common type of visual form to represent each sound samples.
- Delivering information with sound could be effective only when context is set. Same sound can be interpreted differently according to context.
- Participants could distinguish space of sound, and successfully represent space of sound into appropriate visual form.

"It was hard to gain information from the sound, because they are not set in a particular context. (....) I might get different Information from same sound that sets in different context."



Translate sound to abstract visual session outcome

This is the collage of abstract graphic that created by participants based on sound sample No. 1. Participants picked common type of visual form to represent the sound they heard.

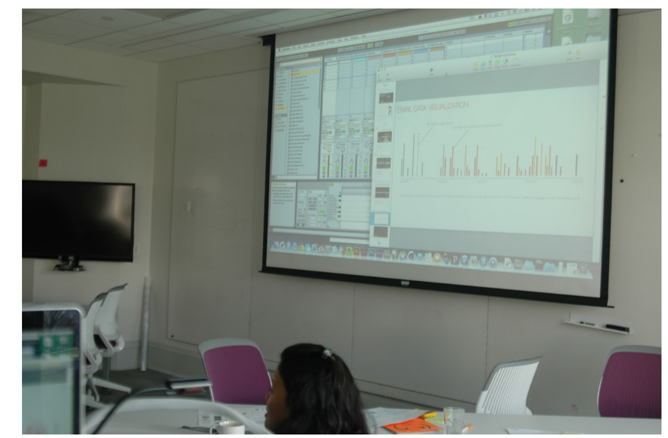
2.4.4. Design sound from given visual

Participants were assigned a task that design sounds for given information by using sound samples. Range of given sound samples is in three categories, rhythmical sound, bright note sound and ambient sound.

FINDINGS

- Information should be represented in sound by using recognizable sound parameters such as pitch, space, noticeable instruments.
- Their process was 1)Divide information category, 2) Prioritize them, 3)Assign appropriate sound for the information.

"The whole point of having sound is enhancing the message. But I feel like if so many sound is happening at once, then, now it's confusing again, cause you have to memorize what each sound indicate."



2.5.5. Synthesis of the workshop

Through this workshop, I could understand how we communicate through sound. Based on those findings and research result from previous phases, I could complete six informational sound design implications that are described in the next section.

3. HOW CAN WE DESIGN INFORMATIONAL SOUND?

3.1. SIX INFORMATIONAL SOUND DESIGN IMPLICATIONS

The nature of data to be presented and the task of the users are important factors for a system that employs sound as a medium of communication. When sound become designers' consideration for more effective communication, designers need to consider those implications described below.
To understand when and how to design sounds for information design, designers should answer these questions at the left.
Answers to these questions enable designers to look at their project in a holistic view.
These questions specify what designers should consider in informational sound design. And this can provide a starting point for designers who are not familiar with sound design. In addition to that, here are six informational sound design implications that designer should be aware of before start designing sounds.

- *What tasks use need to accomplish?*
- *To accomplish the task, what parts of the information help user achieve the goal?*
- *How much information the user need, and what type of information need to be sonified?*
- *What kind of display to deploy?(e.g. simple alert, status monitoring or data exploration)*
- *How to sound should represent the data?(e.g., filtering, transforming, parameter mapping, or everyday sound)*

3.1. SIX INFORMATIONAL SOUND DESIGN IMPLICATIONS

3.1.1. Sound conveys information about changing data.

Mapping data to sound requires a consideration of which types of data to be sonified. The nature of sound is time-based medium that has the beginning and the end. This characteristics of sound means that sounds are well-suited for conveying information about changing events(such as closing doors, pouring liquids, and approaching cars). And it also usually available for a limited amount of time. This implication makes auditory display ideal for monitoring tasks and alerting, where the environment produces noises that result from data and events in the environment. Then we are able to monitor by listening rather than just viewing.

3.1.2. Sound should be simple enough to contain information that fits into context.

In the design workshop, one quote from a participant indicates this implication clearly.
"The whole point of having sound is enhancing the message. But I feel like if so many sound is happening at once, then, now it's confusing again, cause you have to memorize what each sound indicate."
This issue comes together to decide which sound attributes designer should map to the data, and it also present major challenges in sonification design. Incoming auditory signal can be interpreted differently according to listener's prior knowledge, experience, expertise and expectations. I did an experiment at the design workshop, and the result says that music novices, for example, can hardly distinguish subtle pitch change as going "up" or "down". However, most listeners can easily distinguish between fast and slow rhythm. To design the sound understandable, it has to be simple enough before the user familiarizes the meaning of the sound. When sound is complex, people tend to give up decoding information from the sound.

3.1.3. The interpretation of sound is context specific. The same sound can be interpreted differently according to specific context.

Context refers to the tasks that are performed by the user within the system in regard to the user's goal and the functions. Effective sound design requires an understanding of the listener's environment and goals within the system. Even though the general goal involves simply receiving the information through the sound, but the person's goals and the tasks will likely require further action. Designers should concern how sonification help user successfully achieve her or his goal in the situated context. What does the user need to accomplish from auditory display?, How can the sound help the user successfully perform his or her task in the system?

3.1.4. Sound convey crucial information when user is in immersive environment.

Fictional media, in particular film and game, have developed a know-how about conveying meaning through sound. Moreover, sound design in films and game often elaborated rich quality of sound design. The functional use of sound in the audio-visual media can be crucial to delivering information and it plays an important role in this environment. If the user watches horror movie without sound, it will not be interesting than it would be.

3.1.5. Use recognizable sound parameters such as pitch, space, different instruments for important information.

In the sonification, it matters which specific sound parameters are chosen to represent a given data dimension. In order for successful sonification, the dimensionality of the data should be constrained to perceivable sound attributes. Designers should experiment with sound's frequency, pitch, duration, loudness, timbre, direction and rhythm, to examine how close the perceived information matched the to intended message. For example, pitch is generally good for representing temperature, while tempo is not as effective. Walker (Walker, 2002) has evaluated mappings between ten conceptual data dimensions (e.g., temperature, pressure, danger) and three perceptual/acoustic dimensions (pitch, tempo, and spectral brightness). And the sound mapping experiment should be followed by evaluation to check if the sound is delivered to the audience accurately.

3.1.6. Sound design process is the following: 1)Divide information category, 2) Select appropriate information to be sonified, 3)Assign appropriate sound for the information.

The sound design process often separated from other modalities in the design process. And there is an increasing need for systematic approaches and structures process.(Jodi Forlizzi, Paul Robare, 2010) From my research, I suggest this three steps for designing informational sound as represented form of data. (1) Divide information into categories to keep it simple to be perceived by listeners. In this step, designers should consider data types(e.g., continuous flow of information, interval data, discrete pieces of information) and task types(e.g., monitoring, trend identification, point comparison) And then (2) select appropriate information to be sonified according to the characteristics of the information. While sounds are well-suited for conveying changing data that may be heard from all around, visuals are for stable objects that requires user's directed attention. And finally (3) assign sound for selected information. De Campo (2007) researched three broad categories of sonification techniques — event based, model based and continuous — that might useful in this step.

3.2. FRAMEWORK OF VISUAL AND AUDITORY CONSIDERATIONS

Previous research aimed at developing a better understanding of sonification and resulting a wealth of knowledge and implications. And then, participatory design method has been devised, which allowed me to explore real world usage and possible application of auditory display.

Aim of the first half of this thesis project was developing guideline that describes what type of data is suitable to be represented in sound form for effective information delivery. So, I can bring this field to more accessible position to designers. To do that, the first step is building framework that informs designers when they can use sound as a communication medium.

My framework takes an approach of specifying when designers can use sound. It builds on the B.H. Deatherage(1972)'s work that proposed the set of criteria for deciding when to use audio rather than visual displays. The framework focuses on the interaction between information delivery through sound and the user's task. Additionally, it stresses the sound usage opportunities in the context of interaction design. The framework describes three perspectives — environment/ situation, type of task and type of information.

There are three things we need to consider to decide when sound is appropriate to deliver information. What situation/ environment user is in? What type of task user is doing? What type of information need to be delivered to the user? These questions allow us to focus on specific issues in auditory interaction. When the criteria meets the design, the designer should consider using sound as a medium of conveying information. This framework can be a useful starting point for designers considering functional sound in interfaces.

Deatherage, B.H. (1972). Auditory and other sensory forms of information presentation. In: van Cott, H.P., and Kinkade, R.G. (Eds.), Human Engineering Guide to Equipment Design.

Using the framework

Designers can use the framework in concept generation phase to find opportunities of using sound to represent information and generate kinds of interaction and experience that sound design might offer. Once the designer decide sound can have a potential for their design, actual sound design and usability test should be iterated to investigate if intended communication is smooth and natural. In the actual sound design phase, designers can use the guidance that will be described in the next chapter.

3.2. FRAMEWORK OF VISUAL AND AUDITORY CONSIDERATIONS

Criteria	Description	Example
WHAT SITUATION/ ENVIRONMENT IS THE USER IN?		
Wearing headphone	Sound can be heard by only the user.	Using desktop with headphone Walking down the stret with headphone is in Listening music while a user workout
Quiet environment and no one else who can hear sound.	Often this situation is when user is alone at the space. If environment is so noisy, so sound can not be heard, visual representation is more appropriate way than sound.	At home
Need to be hand and eye free	User need to focus on the primary task. Visual sense is already engaged by other task	Walking down the street with heavy package Driving situation
WHAT TYPE OF TASK IS THE USER DOING?		
User's task needs constant moving	The user needs to move constantly, so user's eye can not stay in one position	Factory work Waiter and waitress
Should deliver urgent information	Event that needs user's immediate follow action	Warning information Fire alarm
Need user's attention	While the user is doing something else, this event should grab user's attention	Mobile notification
WHAT TYPE OF INFORMATION IS NEEDED TO BE DELIVERED TO THE USER?		
Short information	Relatively short information such as simple numbers or state change.	Weather information Time information
Simple information	Information that does not contain complex information.	New message notification Cooking complete information from Micro oven
Changing information	Time-based information. Often this type of information deals with events in time.	Radar beeping sound Washing machine sound Car engine sound

3.3. INFORMATION SOUND DESIGN GUIDANCE

Based on sound design implications and framework created in the previous research phases, initial sound design guidance has been developed that helps to inform sound design decisions.

Designers seeking to use sounds should learn about the most basic sound interaction's characteristics and potentials of the sound interaction by answering the following questions. What are the issues in the context when and where the sound will be generated? How can sounds improve the user's current experience? Will the sound be easily adaptable, learnable? Answers to these questions should be found from an objective perspective to the user's experience and interaction.

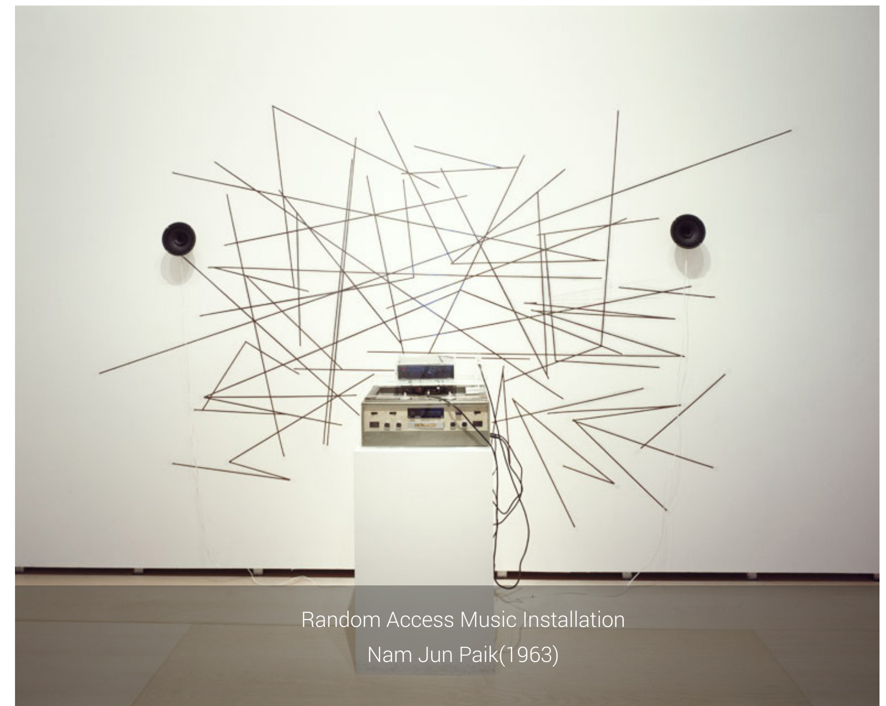
This sound design guidance focus on clarifying those questions. So it starts with the context of sound design, what is the sound for. By simply answering each question, the designer can get a rough guidance for their project.

4. WHERE I FOCUSED AND WHERE TO GO

4.1. SOUND DESIGN FOR INFOGRAPHICS

Sonification, as defined earlier, provides information in an auditory, typically non-speech, form. The most basic question of this subject is ‘what does the pie-chart sound like? How can sound communicate better to reduce complexity of information?’ The mediums I wanted to focus were either static interactive infographic or motion infographic. With this subject, I can pose questions about (1) what information the sound conveys, (2) how exactly sonic interaction depends on relevant data and (3) when and how the sound occur and structure the overall interaction. Mapping data variables to sound parameters is a common approach for this subject. However, such a mapping would be counterintuitive and this could increase learning time. Therefore, I need to balance various factors and adjust designs to find an optimal matching point between data and sound.

4.2. USER GENERATIVE GEOGRAPHIC SHAPES WITH SOUNDS



Random Access Music Installation
Nam Jun Paik(1963)

Random Access Music Installation by Nam Jun Paik(1963) inspired me this design concept. His installation enables visitors generate sounds by moving the audio recorder head over the audio tapes arranged in abstract shapes on the wall. By changing the control of the head from an automatic mechanism to the human hand, a functional piece of technology was converted into an expressive instrument.

This is more of artistic design concept than other two design concepts, which encourage users participation. Questions with this design concept can be: (1) involve non-expert users in sound creation, (2) how to design participatory and collaborative aesthetics of sound, (3) explore collaboration through sound, (4) experiment with interactive metaphors, and (5) novel sound expressions.

This design concept involves both action and listening activity which bridged gap between perception and action. I thought sound making can be considered to be a meaningful aesthetic experience not only for musicians but also for users who do not possess expert musician skills.

4.3. SOUND SYSTEM IN MOBILE DEVICES

Digital technologies have enabled new possibilities in using sound in interactive products. It potentially brings values when auditory channel is superior to the visual one in situated context, particularly when users are moving. In this design concept, the question becomes what type of information can be delivered more effectively than what visual does, and which situations are appropriate to use sound as a communication medium. This field is pretty mature in terms of musical sound, but the design of non-speech , non-musical sounds is quite young. (Sonic Interaction Design, Serafin, Karmen , 2010)

In the appropriate context, sonic interaction design can carry a large amount of information, which designers can shape and refine. This information-carrying aspect should not be underestimated. What if the urgency level of the alarm clock depended on the time until the first appointment in the user's calendar? What if notification sound can let users know what type of message and how many new notification the user got?

I ended up developing and flushing out the third concept — sound system in mobile. Why I choose this concept is described at the following, but other two concepts are intriguing enough subjects for further exploration.

Nomadic Radio: Speech & Audio Interaction for Contextual Messaging in Nomadic Environments, Nitin Sawhney and Chris Schmandt, MIT Media Lab, 2010

Why did I choose sound system in mobile devices?

I decided to push forward with third design concept, sound system in mobile. I particularly thought there are more potential than other two concepts based on the following reasons:

First, having to keep their eyes and hands to check information is irritating and distracting. Sound can enable users to focus on primary task without being distracted.

Secondly, sound should be context specific to convey accurate information to users through sound. Meanwhile, contextual auditory information has lots of potential to be a new type of interaction that has rich information about peripheral awareness, such as notification, augmented auditory reality, and navigation information.

Last but not least, wearable mobile devices need to look at other potential. The current model — wrist smart watch and wearable glass — is not flexible enough to provide contextual information at the right time, since it still need visual attention. The latest research done by MIT media lab discovered how different sound frequency detect where the user is situated. (Sawhney, Schmandt, 2010)The new model of wearable device that uses multi-modal interaction should be able to support users' better interactive experience.

5. BEYOND VISUAL CENTRIC INTERACTION: WEARASOUND

When is the multi-modal interaction can be effective?

How I can design the sound effectively?

Validation of my research findings

These ideas and findings from the previous phases, is instantiated in the Wearasound, an auditory wearable device in which information is conveyed using auditory interaction. This design concept address several questions about possibilities and usefulness of auditory interface.

As a starting point, I investigated information that is available in the existing mobile interface. And I analyzed and filtered appropriate information to be represented as sound. Thus, the Werasound extends the visual(information on the screen) into the auditory dimension(information from the headphone).

5.1. WEARABLE AUDIO COMPUTING

Before I dive into actual design concept development, research about current wearable audio computing was necessary to find out what is the current status in this field and what kinds of technologies I can apply to this design concept. Keywords I have used for this phase are the following:

5.1.1. 3D audio

Experimentation about how users recognize distance and direction from the source of sound and how 3D sound contains information.

5.1.2. Audio augmented reality

Provide one layer of information onto real world. There were attempts overlaying audio enhancement and how sound can combine with graphics. J. Sodnik and R. Grasset(2006) built AR application with visual augmented reality environment (tracking and display) and the 3D sound reproduction. They explored the possibility of localization in a tabletop augmented reality environment, based on sound and visual cues.

Sodnik, Jaka, et al. "Spatial sound localization in an augmented reality environment." Proceedings of the 18th Australia conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments. ACM, 2006.

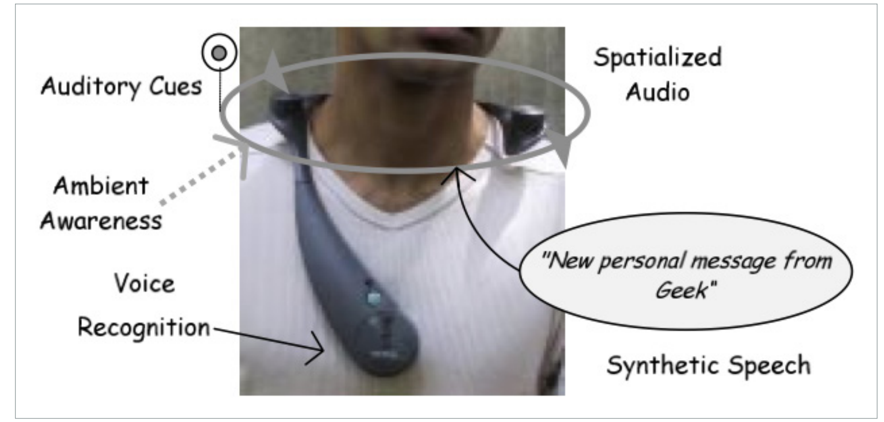
Clarkson, Brian, Nitin Sawhney, and Alex Pentland. "Auditory context awareness via wearable computing." Energy 400.600 (1998):

Sawhney, Nitin, and Chris Schmandt. "Nomadic radio: speech and audio interaction for contextual messaging in nomadic environments." ACM transactions on Computer-Human interaction (TOCHI) 7.3 (2000): 353-383.

5.1.3. Contextual interface

How different sound frequency can recognize user's surrounding environment, and provide contextual information. Several recent projects utilized speech and audio interface on wearable devices to present information. Normadic radio (N. Sawhney and C.Schmandy, 2010) developed a prototype that is adaptive and context sensitive auditory wearable device. It employs an auditory user interface, which uses speech recognition, speech synthesis, non-speech audio and spatial presentation of digital audio, for navigating among messages.

And B. Clarkson and N. Sawhney(2009) built a system for obtaining environment context through audio. They successfully identified specific auditory events such as cars, shutting doors, and auditory scenes such as the office, supermarket, or busy street.



◀ **Normadic radio**

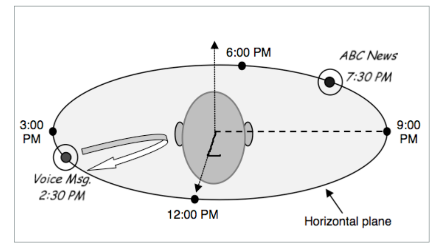
(N. Sawhney and C.Schmandy, 2010)

the Soundbeam Neckset, with directional speakers and microphone.

▲ **Spatial Sound Localization in an Augmented Reality Environment**

(Sodnik and R. Grasset, 2006)

Virtual scene was overlaid on a real piece of paper with tracking markers drawn on it. The user could move the object in the table top in any direction, and rotate their head or body in order to move around in the virtual scene.



◀ **Normadic radio**

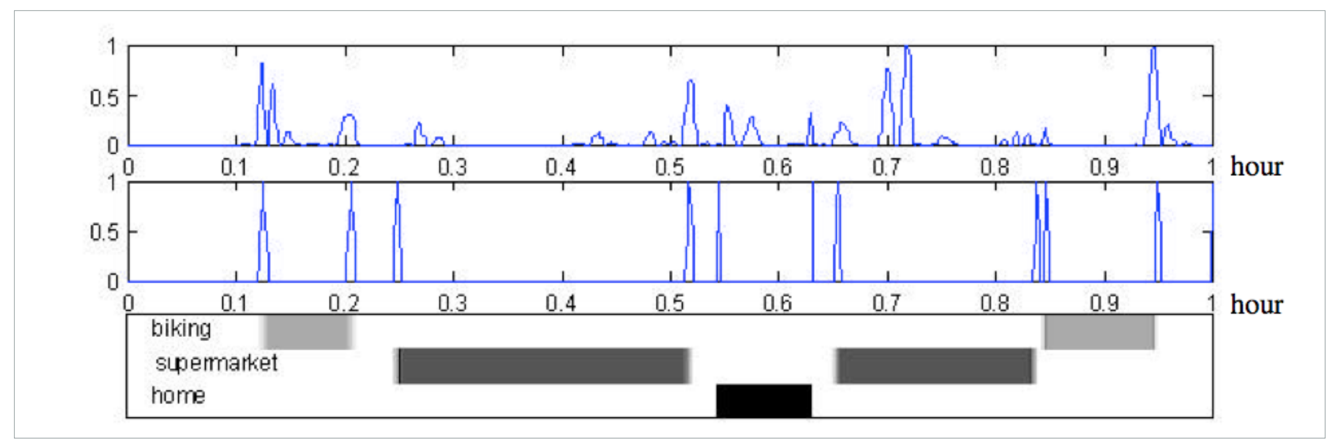
(N. Sawhney and C.Schmandy, 2010)

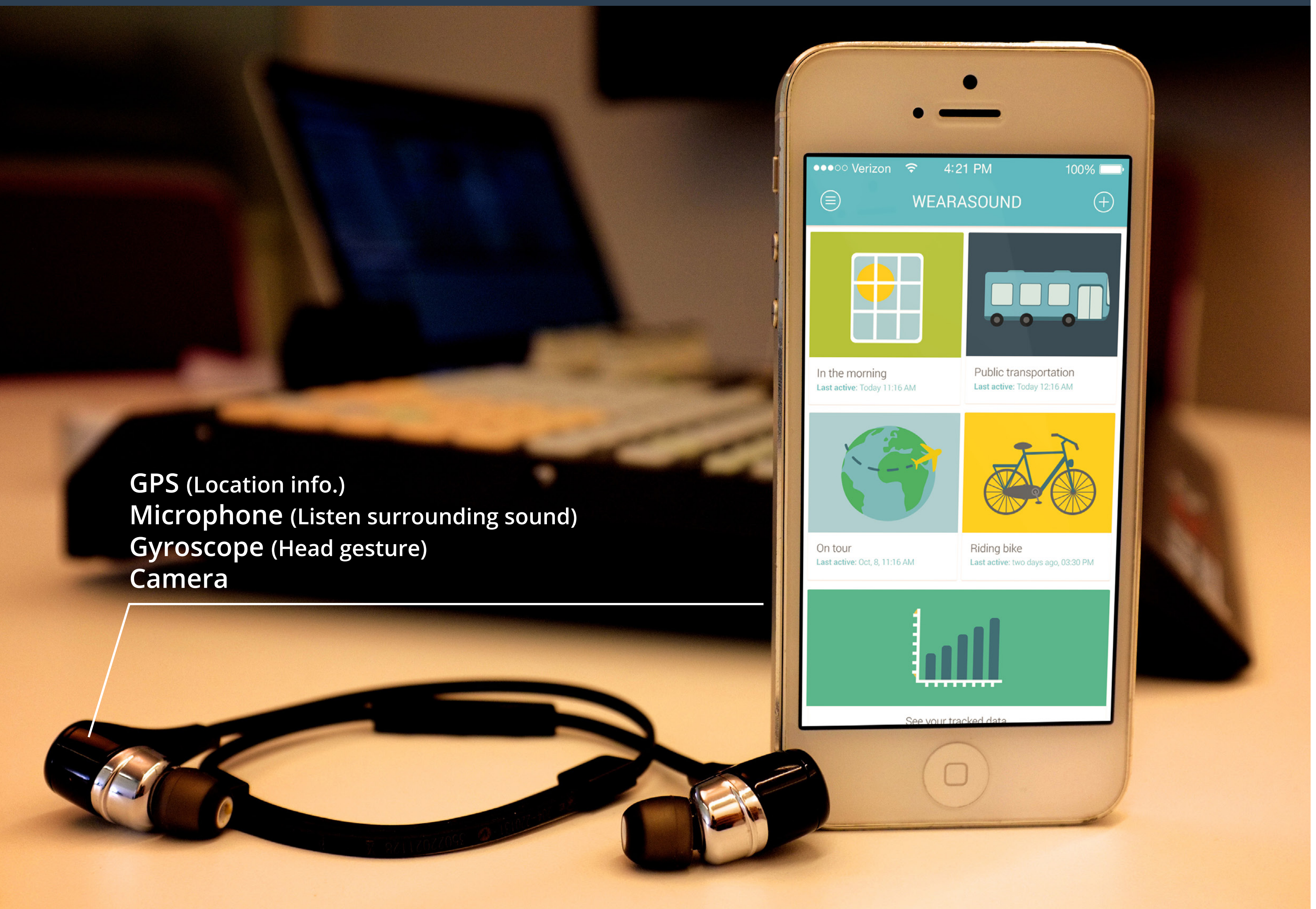
Audio messages are positioned around listener's head by using 3D sound technique. While the user is listening to an ABC news broadcast in the background, an incoming voice message begins to play, gradually fading in and out of the listener's foreground.

Auditory scene change detection technique. It detect which context user is in by listening surrounding sound. In this graph, it indicate surrounding sound is different from each contexts — biking, supermarket and home

(B. Clarkson and N. Sawhney, 2009)

▼ **Auditory Context Awareness**





5.2. THE WEARASOUND

Wearasound runs on the smartphone platform and paired with Bluetooth headphone. One of the goals of this device is that enable users do peripheral interaction(e.g., navigating on the street, get notifications) without shifting their focus of attention. Users, therefore, interact with the Wearasound passively as they are on the moving situation around a physical location. Information is directly and indirectly presented through a spatialized auditory display via Bluetooth headphone. This headphone works in two modes that are audio transparency mode and noise isolation mode. In audio transparency mode, it does not block out surrounding sound. These two modes are switched according to context of usage. For example, noise isolation mode is activated when user is listening media contents, and when audio transparency mode is turned on when user is walk down the street.

Wearasound users can access to relevant information using natural and unobtrusive interfaces. It provides contextual information such as weather information, notification, media contents and personal calendar events by filtering information based on the user's situated context. To provide a hands-free and unobtrusive interface, the system primarily operated as an audio-only wearable device, although a visual interface is used for setting user preference. Textual messages such as email and calendar events are spoken, whereas another information is presented as non-speech sound. Users can control the interface using voice command along with button input for situations where it is socially awkward to speak such as in the public spaces.

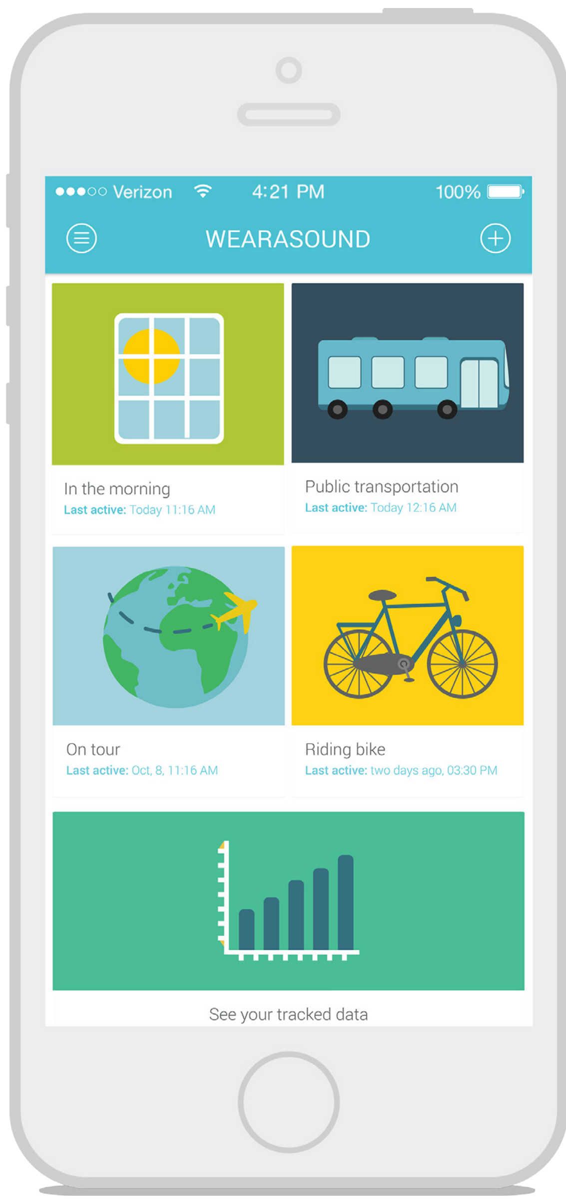
In this system, audio output is provided via headphone. It consists of two ear plugs, remote controller, GPS censor, camera and two microphones. User can active functions by pressing a button on the remote controller instead of speaking to the device. The GPS censor and two microphones are dynamically detect user's situated context. If surrounding sound and location data meets pre-defined criteria for each context, the device activates each context mode.

Table 2.
What sensors are in the Wearasound and what is does.

Sensor	What does it do
GPS sensor	It tracks the user's moving location and speed to detect the user's context. So it can provides timely information that is appropriate in the user's context.
Two microphones	It listens user's surrounding sound to identify the user's context such as the office, riding a bus, supermarket, or busy street.
Remote controller	User can activate function by pressing button on the remote controller. When user press the button, it provides contextual information based on the user's situated context. And also users can activate functions by using voice commend.

5.3. SOUND PRODUCING EVENTS IN THE WEARASOUND

5.3. SOUND PRODUCING EVENTS IN THE WEARASOUND



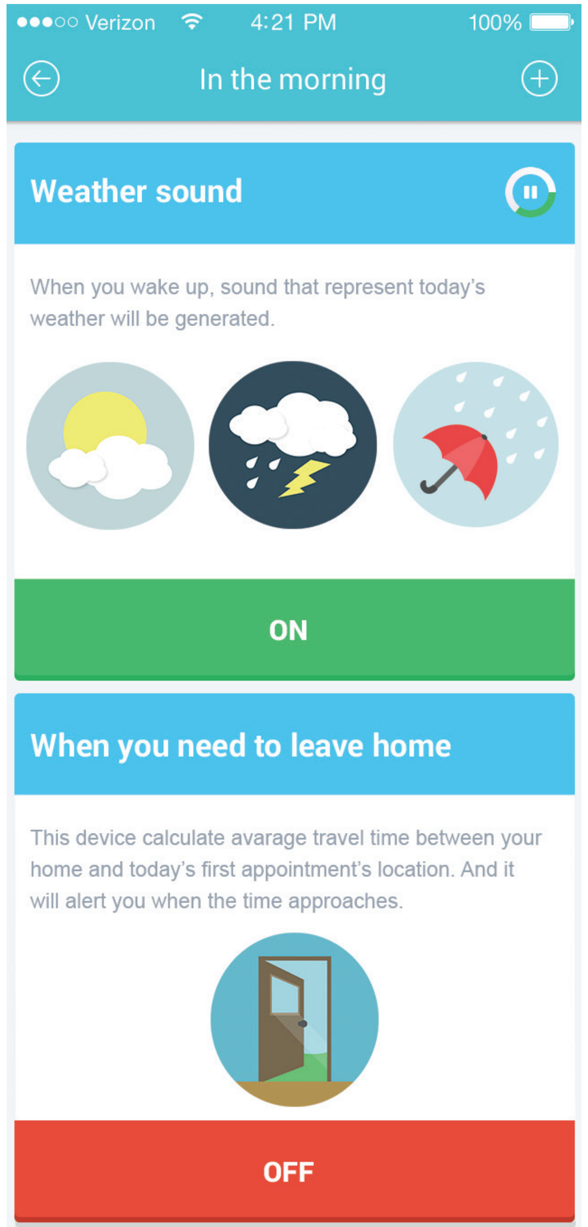
In Wearasound, providing information(such as weather information) are paired to the context(such as in the morning context). Table — summarizes information in the Wearasound that are mapped to contexts and sounds.

Goal of this wearable device is providing contextual information in a timely manner. Contextual information is coupled with pre-designated contexts, which include in the morning, riding a bike, riding public transportation and on a tour. Information is dynamically provided within the context by identifying surrounding sound and location data from the headphone.

I recommend to watch attached video in this document for the clearer understanding.

Table 3.
Sound producing events in the Wearasound. It shows how the information is mapped to sound.

Context	Information	Sound representation
Wake up in the morning	Today's weather	Bird chirping sound
		Raining sound
		Wind sound
	Temperature	*How many birds are chirping*
	precipitation	*Intensity of raining sound*
	How windy	*Intensity of wind sound*
	Today's schedule	Speech sound
	Popular today's article	Speech sound
On tour	Further information of the spot	Speech sound
	Music matched with the surrounding sound	Music play
Riding public transportation	The best route recommendation	Speech sound
	When does the bus will arrive	Speech sound
	Music play while on the move	Music/ Article/ Unread notification
	When the user need to get off the bus	'Ding' sound
	How many stops away from the destination	*Number of 'ding' sound*
Navigation	Direction information	Signal sound
	Distance between where the user is and the corner she or he should make turn	*Frequency of the sound*
	Turning direction	*Direction of the sound*



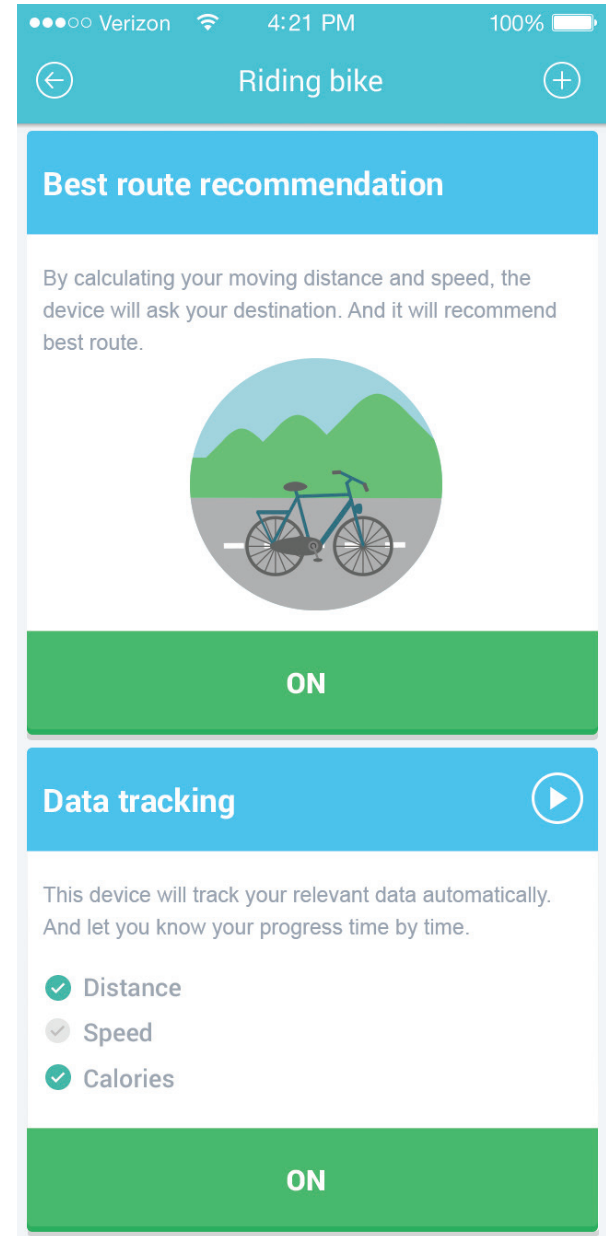
5.3.1. In the morning

First, the user wakes up in the morning. Sound that represent today's weather is played from a speaker with morning alarm sound. For example, if it's a sunny day, birds chirping sound or if it's rainy day, raining sound will be played. In this case, weather sound from the real world makes this information feel closer than visually represented information. Because the user does not have to process the information cognitively, but take it naturally. This information directly mapped to the sound. The temperature of today's weather changes how many birds are chirping. And intensity of raining sound would be changed depending on today's rainfall forecast.

Once the user get out of his bed, weather sound stops and s/he can listen media contents that he set through visual application. Contents he can select are popular article, today's schedule or unread email and SMS.

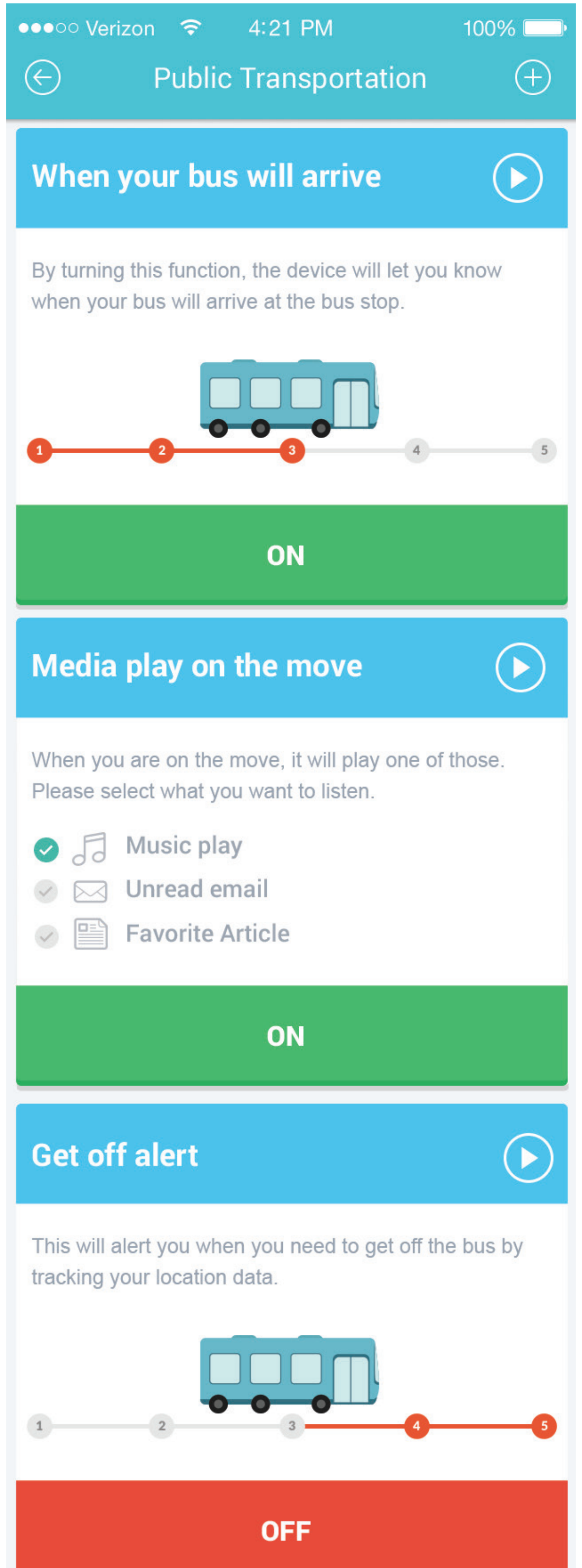
And then, it alerts the user when he should leave home to get to the first appointment's location that is stored in his personal calendar.

5.3. SOUND PRODUCING EVENTS IN THE WEARASOUND



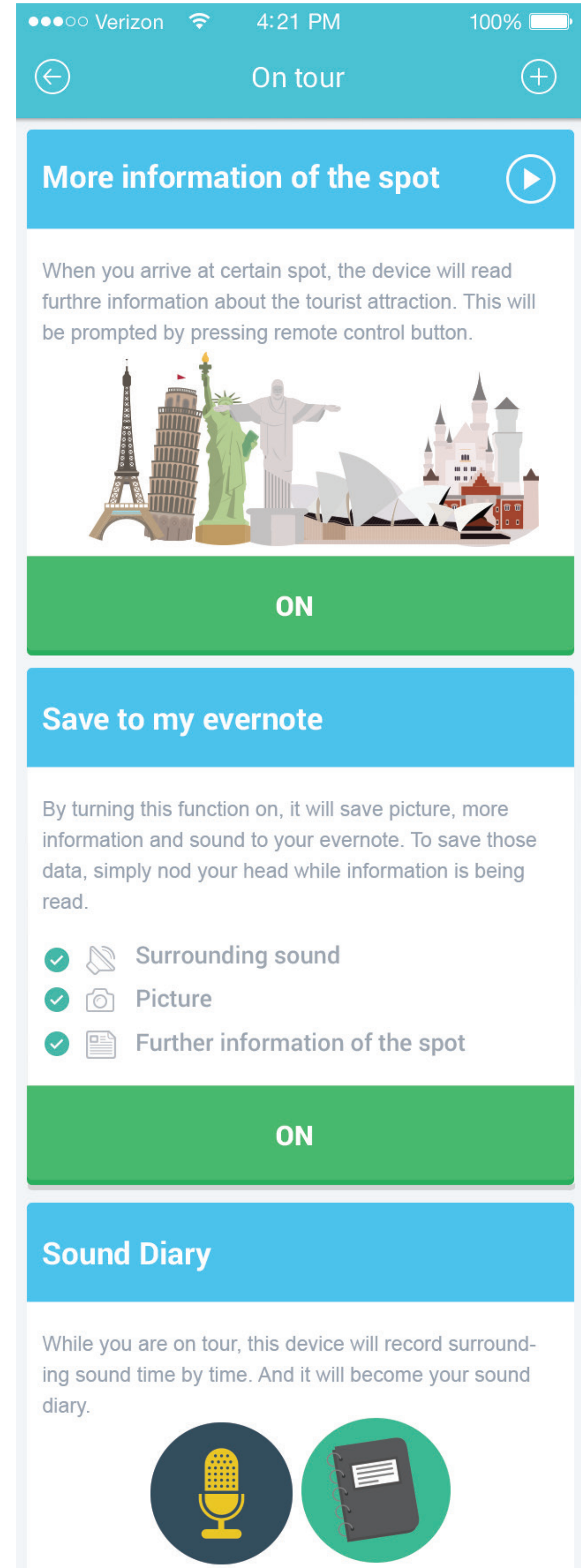
5.3.2. Riding a bike

Secondly, once the user starts to ride a bike, it activates riding a bike mode by calculating the user's moving speed, location and the sound from the street. The headphone's mode is changed to the audio transparency mode so the user can hear the traffic. Sound is associated with the direction and proximity of the corner the user need to make a turn. The mapping of frequency reflects the distance between the user and the corner to make a turn. And the direction of the sound represents if the user need to make left or right. In this example, such information is delivered more effectively than visual information by using direction of the sound. And also user can focus on driving a bike without distraction from visual information.



5.3.3. Riding a public transportation

Thirdly, sounds provide contextual information before the user ride the bus until you get off. The device detect the context with two criteria. When the device hears car approaching and mundane street sound and the user's location is staying near a bus stop. When the user arrives at the bus stop, it provides when the bus will arrive at the bus stop if she set a destination on a map. While the user is moving on the bus, pre-selected media content is playing. And when the user is approaching to the destination, 'ding' sound that represent how many stops away from the destination is played.



5.3.4. On a tour

Last but not least, Device can detect the tour situation by analyzing GPS information and surrounding sound. when user is near tourist attraction, it gives the user further information of the spot. While it is being read, music matched with surrounding sound is playing on the background. So, it can create emotional aspect of the user.

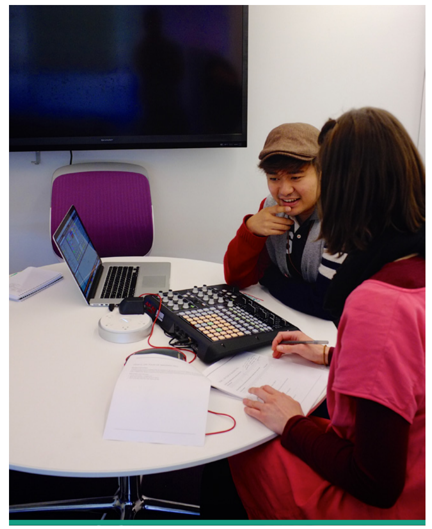
5.4. EVALUATION FOR THE WEARASOUND

5.4. EVALUATION FOR THE WEARASOUND

Evaluation of auditory display is a crucial part of the design and implementation. The Wearasound was tested with four participants in order to get general feedback and refine the interaction to make it more natural. The participants conducted five tasks and discussed the auditory interaction after each task's completion. And they were also asked how the sound convey information in each context effectively. However, I thought evaluation could not capture all of the problems because the system must be used in a real environment, and hence social constrains as well as system's usefulness and robustness become critical. However, real implementation was not possible, and I had to rely on the participants' subject experiences. For the evaluation, I focused on how the sound is more effective than visual to convey the information.

At the beginning of the session, the conceptual and contextual background was explained, making sure that the overall purpose and context of this design concept understood. As I was playing relevant sounds for each task, I checked if the participants were getting the information. Then, the participants were asked, how much they satisfied with this auditory interaction and if it is more effective way to deliver the information than using visual. And followed by follow up discussion about the interaction.

I recognized that even limited study allowed me to obtain meaningful insight for improving system.



5.4.1. Wake up in the morning

Generally participants satisfied with today's weather sound because it is more natural and smooth way of telling today's weather. However, one user pointed out limitation of it: (1) how the sound can convey today's exact temperature? (2) I could not hear how the weather will be changed throughout the day. This was one of the insights in this session that those detailed information is more effectively represented with visual graphic, because users can skim through exact information and forecast visually, rather than waiting for the information to be heard. However, sound can still play as a medium to convey overall abstracted information.

And for the listening today's event while the user is doing something else, most of the participants responded it is too much information to digest by only listening to it. As a solution of this, abstracted sound that represent today's schedule could leverage advantage of sound, that let the user know quick glance of the information.

"I want it to not just tell me what's happening at the moment, but may be tell me what will happen later on. Weather sound could be helpful instead of someone says it's raining. It is nice smooth background noise. It's more natural then telling me directly."

"It is nice that I can do multi task while I hear the information."

"For schedule information, I feel it requires lots of attention to get the time/ people/ location information"

"Sound can not tell me what exact time I have appointments. What about abstraction of sound? Sound is good for abstracting the information."

5.4. EVALUATION FOR THE WEARASOUND

5.4.2. On tour

One of the scenarios in this context was that when user approaches Niagara fall, the Wearasound read further information of the spot. Participants had an ambivalent attitude towards this interaction, because further information is always good to know, but lots of social situations should take into consideration. For example, what if I am with other people? What if I just want to hear the sound of Niagara Fall? From this comment, I revised the information to be triggered when the user wants it by pressing a button on the remote controller. However, participants said listening to further information is much better than reading long text in a small screen. In addition to that, the auditory information does not distract what the user is seeing at the moment.

"I don't want to look at the information on the small screen. I want to enjoy the scenery of the tourist attraction. In that sense, sound will help me a lot."

"I want toggle the interaction. I don't want it to talk to me without any previous notice."

5.4.3. Riding a public transportation

In this task, I tested three sounds contain different information — (1) when the bus is arriving, (2) media play on the move, (3) how many stops away from the destination. Participants generally liked this interaction since those sounds can eliminate most of the screen interactions. However, two participants missed the getting off alert information. The number of 'ding' sound depends on how many stops away from the destination. For example, when the user is three stops away, three 'ding' sound is generated. In contrast to speech only feedback, the participants were more willing to listen to important information more distinctively. In this case, where the user should get off is the most important information, so it should be different from others. In overall, participants felt the system provided appropriate awareness relevant to what the user is doing.

"When let you know how many stops away, last alert message should alert more. It should be little bit more significant. Because it is the most important information."

"I personally like this interaction. Since when needed information can be conveyed through the sound, you are eliminating screen almost."

5.4.4. Navigation and close proximity

Three participants commented that having audio navigation would be helpful when they cannot use their hands. And they liked the mapping of direction of the sound to actual direction, so it reduces cognitive load to think about where is left and where is right. Listening to the sound from the right conveys information intuitively that the information is something about right. Through the sound, however, it is hard to see the big picture of the route. Again, auditory interaction is not for replacing visuals, but for complementing visuals. Visual and auditory should simultaneously be used and complement each other. In this case, overall route information can be shown on the screen, and once the user start move, sound will guide the user. If the user is confused where the sound guides me, they can check the screen and get detailed information.

In order for the sound interaction to fully achieve tis potential benefit, it has to provide good sound quality that contains appropriate information in the right time. As a general direction, illustrative sounds should be designed to reflect the information in a very precise way.

"Sound is almost like picture. Sound is creating emotional aspect such as alerting or relaxing. But spoken speech, there was no emotional aspects involved. This could be boring. Sound itself can contain multi-dimensional information. Each characteristic of sound makes me feel differently, and pay attention differently. This speech is mono tone, so this is not that arising emotional aspect. I believe sound can contain more information than that."

"It is useful if I am walking in the situation that I can not use my hands. And direction of the sound can let me know which direction I should go intuitively"

5.5. SCENARIO

Kat is visiting France. It is her first visit to the country, and she is exploring new places. She puts in her Werasound Bluetooth headphone, starts the Wearasound application, and puts the phone back into her pocket. By analyzing surrounding sound and location information, it detects her situated context. As she is on the way to Eiffel Tower, she does not know the exact way to get there. She press a button in the remote controller and the device asks, “where are you heading to?.” The device asks contextual question to her according to her context. She answers Eiffel Tower, and the device recommends the best route to her. As the device guides her, she approaches the bus stop to ride a bus to Eiffel Tower. As soon as she arrives at the bus stop, the device gives her information of estimated time of the bus arrival. Kat gets on the bus, and the device plays a media content that she set through the mobile application previously. After for a while, it let her know when she should get off from four stops away. She get off the bus and arrives at the Eiffel Tower.

She arrived at the Eiffel Tower, and activate the device by pressing a button on the remote controller to listen further information of it. While she listens the further information, the device saves contents about the location include location, photo and further information to her note application.

Next morning, the sound from the speaker gently wakes up with weather sound in the background. While she is preparing go out for today’s tour, it plays one of contents according to her preference. She is planning today’s tour while she is eating breakfast. And the device also provides open hour information of those tourist attractions she wants to visit according to information from her calendar. Then, it advises her when she needs to leave the hotel. She leaves the hotel; Kat continues her exploration with the Wearasound.

5.6. BENEFITS OF THE WEARASOUND

Despite its present limitations, the Wearasound is successful in demonstrating some of the potential of auditory wearable mobile devices. It deliver values both as an alternative to their existing visual display(e.g., navigating with sound, providing further information of the spot) as well as a secondary modality to complement their functionality (e.g., brief weather sound, best route information). I recognize that an auditory modality may not serve general-purpose interface for all mobile applications; however, audio may be better suited within certain domains of information (particularly for content that is intrinsically voice/audio) and in specific usage context (when the user’s hands or eyes are busy). Four major advantages of this interface are involved in the Wearasound.

5.6.1. Unobtrusive interaction

Wearable wrist watch or glass type displays demand a certain level of perceptual load on the user. There are situations in which the user's eyes are busy although she can attend to information from her wearable or mobile device, such as when walking or driving. A "hands and eyes-free" approach, using audio-based augmentation allows the user to simultaneously perform other tasks while listening.

5.6.2. Efficient interaction

Voice and audio are more efficient than written text, as it places less cognitive demand on the speaker and permits more attention to be devoted to the content of the message. In this project, I could not explore how users feel the information differently according to tone of the voice, but I believe the intonation in speech also provides many implicit hints about the message content.

5.6.3. Peripheral awareness

People using wearable devices can primarily attend to tasks in their environment and can be notified of background processes or messages. Speech and music in the background and peripheral auditory cues can provide without requiring one's full attention or disrupting their primary task. Audio easily faded into the background, but users are alerted when it changes.

5.6. BENEFITS OF THE WEARASOUND

5.6.4. Increased flexibility

The getting off the bus alert may illustrate this advantage more clearly. When the user approaches the destination, the number of 'ding' sound represent how many stops away from the destination. In the current version of visual oriented interaction, user should pull out the phone from her or his pocket to check the information. This interaction requires the user to attend to the screen, while the sound does not.

Gains in those advantages make the Wearasound an appealing interface. But such advantages appear difficult to demonstrate empirically, and no real world user testing has been done as of this writing. I have got good positive responses from the thesis poster session so I could believe the Wearasound is more likely to increase user satisfaction after further exploration and iteration. Finding situations in which sound can convey information better than graphics is more likely to lead to measurable influences. And the Wearasound demonstrates the potentials of auditory interaction in mobile wearable device.

6. FUTURE DIRECTIONS AND CONCLUSION

6.1. FUTURE DIRECTIONS

The findings in this project provides rich resources for further investigation. Informational sound design guidance will be refined and newer holistic guideline, which could not address in this project, may still emerge in further analysis of sound interaction. It will be valuable to leverage the knowledge in the field of design, music and computer science for better sound quality and detailed refinement that designers should consider.

Another next step is that evaluation of the suggested guideline in this project. The application of the framework and guideline in the design process, if possible in real-world industrial situation, should be carefully evaluated with the aim of how this guideline fit into each design processes and how this idea can be integrated with designer's familiar tools.

This leads to another topic for future work, the development of suitable design tools. This tool should support design decision making and help designers access sound design skills easily, like sketching skill. The tool should offer some real-time sound making possibilities with playful experimentation. But it has to be considered if the real-time control carefully prepared beforehand. And the prototype tool should enable designers control sound parameters such as frequencies, envelopes and timbre. Therefore, the tool should facilitate real-time sound prototyping seamlessly. This research will allow interaction designers who are not technically trained to easily produce auditory interaction.

Along with the issue of guideline evaluation and sound prototyping tool, another future direction is how to design the sound with the balance between pleasantness and annoyance, artistic expression or understandability of the sound that convey the message. This direction is mainly focused on the ways in which designers may successfully create meaningful, engaging and aesthetically pleasing auditory interactions.

The designers will benefit from advances in knowledge including a better understanding of the role of sound, improved sound synthesis and design methods and tools, finally evaluation methods to assure quality of sounds. To enable designers capable of addressing sound as one of the design elements, a more solid foundation and methodologies needs to be developed.

Design recommendations

- **Evaluation of suggested guideline** - How this guidelines fit into design process that designers are already familiar with
- **Development of suitable design tools** - How designers can quickly and easily make sound prototypes like sketching
- **Designing sound with the balance between artistic expression and understandability**

6.2. CONCLUSION

This thesis began by questioning how sounds can enhance visual contents and by considering the key affordances and limitations of sound to deliver appropriate information. As a first final outcome, I developed sound design guidelines along with a framework that can provide a starting point for designers who are not familiar with sound design. The results can be used to address problems associated with the beginning and the various evaluation steps of the sound design process.

Secondly, I demonstrated the combination of how a non-speech sound, everyday sound, coupled with voice output can be used in mobile situation with wearable headphone. A key focus was determining when the informational auditory interaction is more beneficial rather than screen based interaction. Preliminary evaluations indicated that users find auditory awareness and contextual information delivery beneficial rather than visual information in certain situations, particularly, riding public transportation and navigating situation.

My efforts have focused on wearable audio platforms, and these findings can be applied to bring current wearable devices to the next level to minimize disruptions while providing timely information on the move. It is important to designing interaction within possibilities and limitations of sounds, keeping in mind the characteristics of changing physical and social environments within which such devices are actively used.

Furthermore, future steps of research were proposed, that could further contribute to a better integration of sound and visual contents. I strongly believe that, if the sound design of interactive commodities was executed on a quality standard comparable to film sound, with a holistic consideration of situational aspects of interaction, functional sounds would be acceptable and even successful.

6.3. REFLECTION

During this project, I faces two challenges. First of all, it was challenging to explore such diverse fields relevant to this subject. Sonic Interaction Design is such an interdisciplinary field which has recently emerged as a combined effort of researchers and practitioners working at the intersection of sound and music computing, interaction design, human-computer interaction, product design, music psychology and cognition, music composition, performance and interactive arts. Because of those diverse realm of research subject in each professional field, I found it difficult to digest basics of sonic interaction design at the beginning of this project. And I needed to keep myself to see this subject with a designer's perspective, which is shaping things for people. Through this challenge, I learned to choose the best solution considering a vast array of knowledge and possibilities in a complex design problem.

The second challenge was finding sound design guidelines and principles for interactive commodities. From designer's perspective, this requires novel perspectives that move away from the rigid guidelines and techniques which have been traditionally adapted in the auditory research community. Strict engineering guidelines and formal listening tests are not valid as such in the interaction design field, but need to be replaced by design and evaluation principles which are more exploratory in nature. I needed to approach more deeply to a holistic sound design process such as participatory workshops and active listening experiences, which support the importance of an ecological approach to sound design.

This was a good opportunity to challenge myself to dive into new field of research as a designer, where I should be positioned in raising the right questions. The subject of this work focused on revealing possibilities of using sound as a design element. I believe this project opens the door for other designers to explore sounds for their design. Through my research process, I uncovered unique design opportunities and implications that make this topic a contextually rich area to explore.

Additionally, my thesis really expanded my boundary as a designer who can design not only graphics and interactions but also sounds. As a designer, it is easy to get caught up in creating aesthetically appealing visuals, but this project throughout the year taught me several important lessons about seeing other mediums to achieve the goal of the design.

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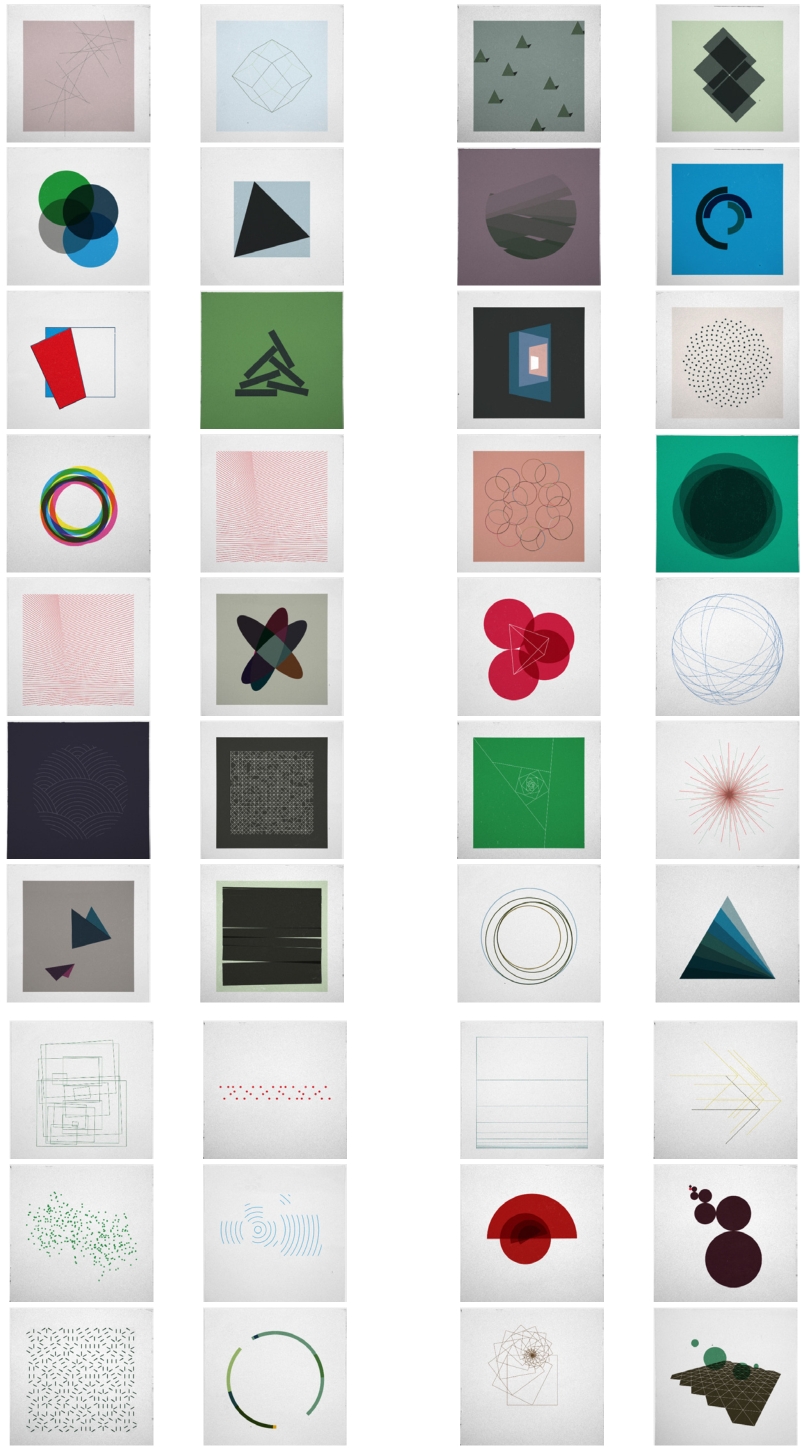
APPENDIX

Appendix A

Prepared graphics for participatory design workshop session 2 — *Translate sound to abstract visual.*

All graphics are from *Geometry Daily — http://geometrydaily.tumblr.com/*

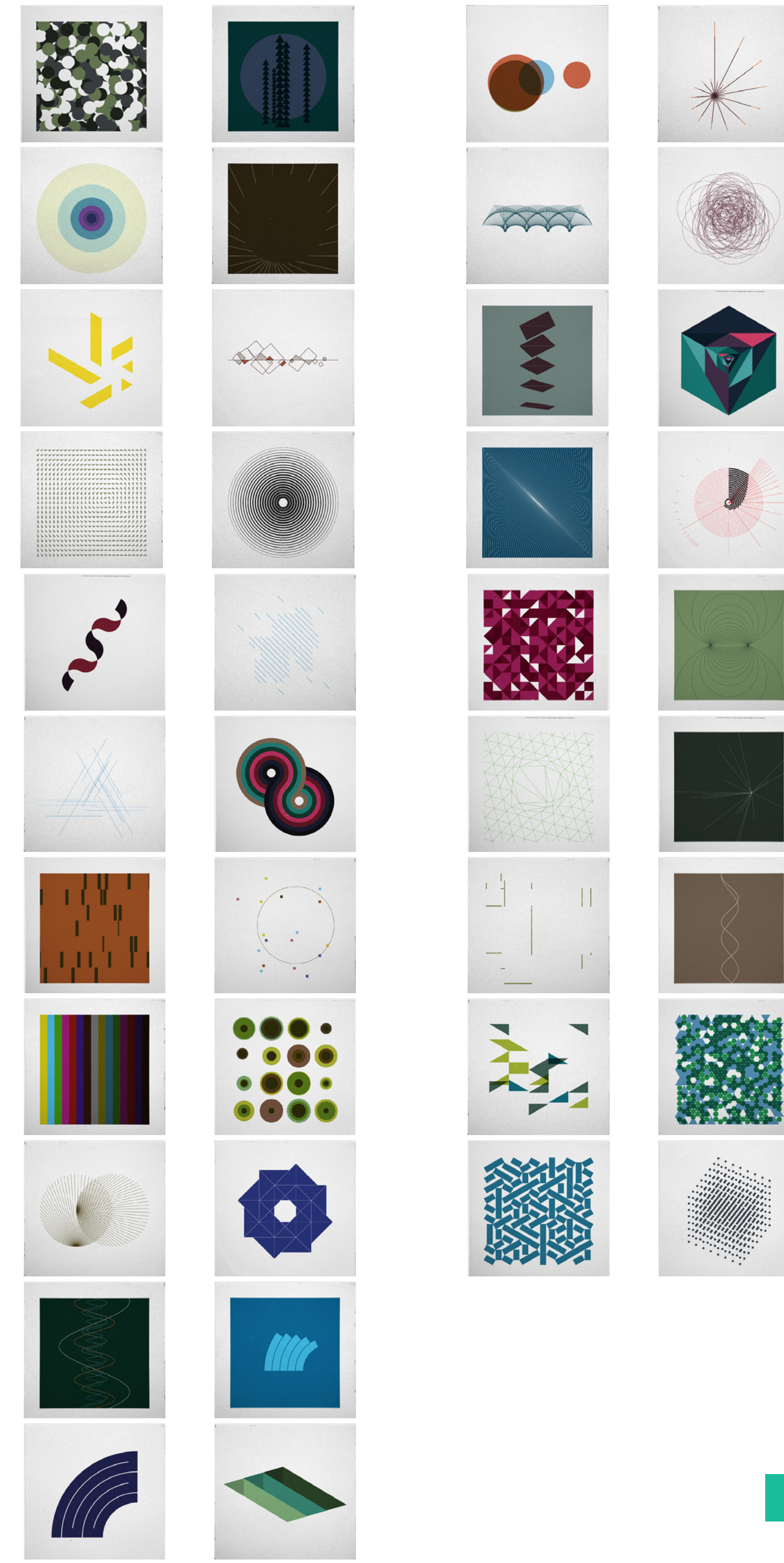


APPENDIX

Appendix A

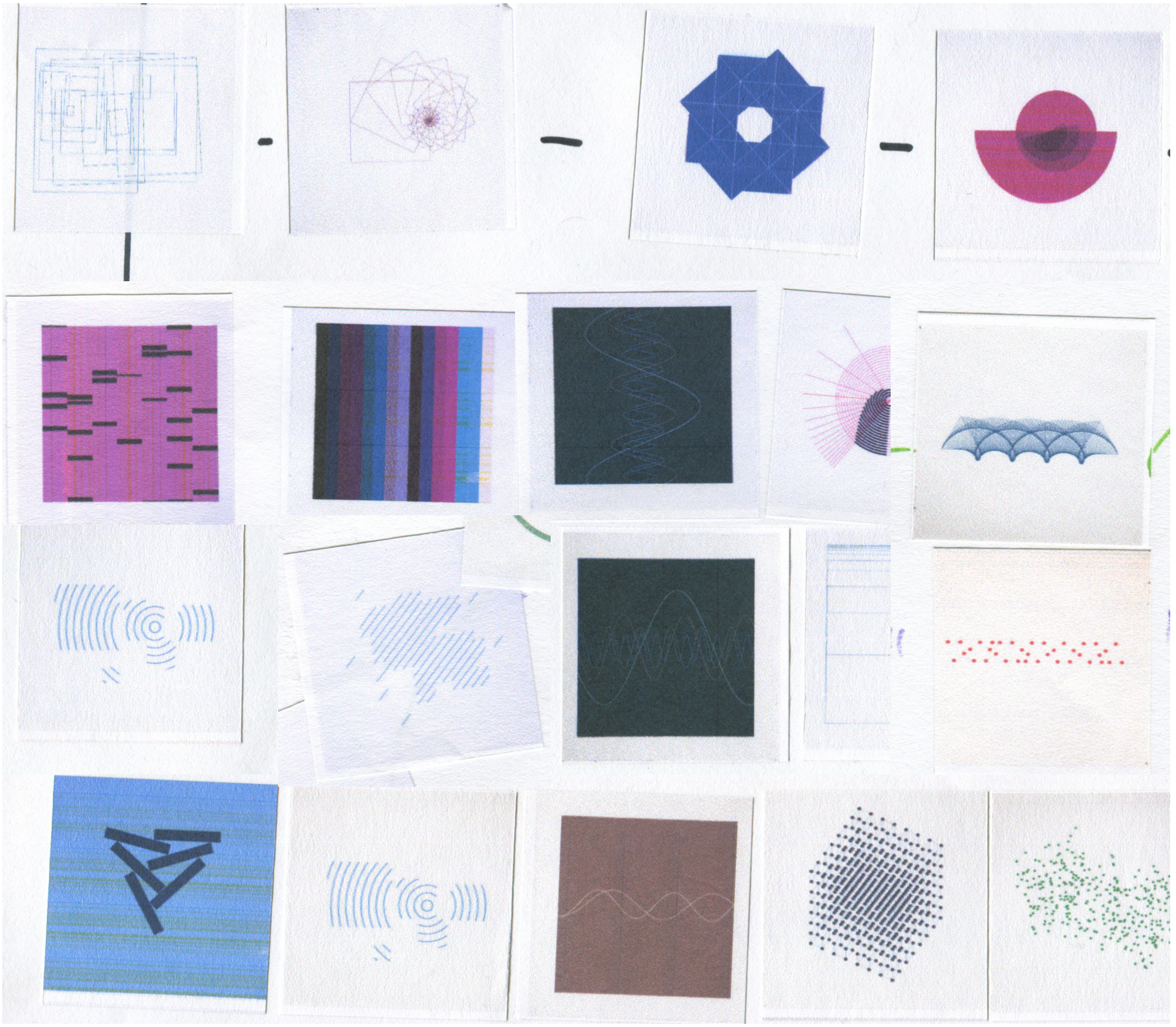
Prepared graphics for participatory design workshop session 2 — *Translate sound to abstract visual.*

All graphics are from *Geometry Daily — http://geometrydaily.tumblr.com/*



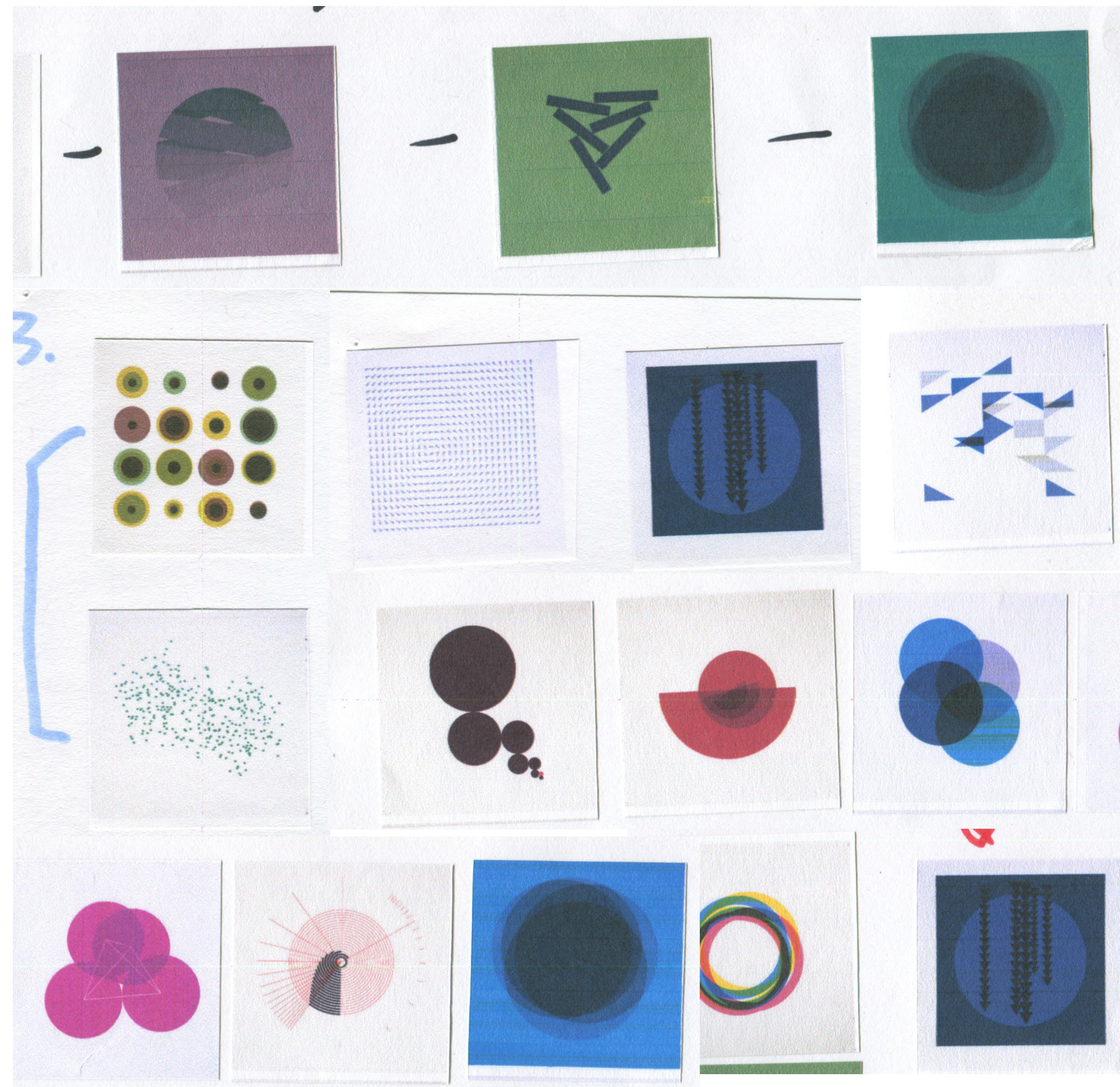
Appendix B. Translate sound to abstract visual session outcome

This is the collage of abstract graphic that created by participants based on sound sample No. 2.



Appendix B. Translate sound to abstract visual session outcome

This is the collage of abstract graphic that created by participants based on sound sample No. 3.



Auditory Wearable Device Evaluation

Multi modal interaction: How sonification can enhance visual information

Gilbert Han, Interaction design, MDes 2014
Carnegie Mellon University
School of Design

2014 THESIS PROJECT DESIGN EVALUATION

SESSION GUIDE

Thank you for participating in my usability test. During 30 minutes we will have a closer look at the auditory wearable device interaction. I will have you listen sound samples that I will use. These tasks are not intended to test your listening abilities, but to evaluate the interaction is right. These sound samples you are about to test is prototype. Please understand even if you feel the interaction is unnatural.

Warming up questions

1. What do you study?

____

2. Have you had official musical education in your life?

____

3. How much information do you think you get from your eyes and ears in your daily life? Please mark each percentage of 'visual' and 'sound'.

0%	100%

4. Have you used wearable device?(Fitbit, Nike Fuelband, Google glasses, etc)

____

5. If #4's answer is 'yes', what is the objective of your wearable device?

____

6. If #4's answer is 'no', do you think you will use in the future? What are you going to use it for?

____

TASK 1. WAKE UP IN THE MORNING

Background context

You just woke up and you are staying on the bed. You just turned off the alarm, and put this auditory wearable sub-device on the ears. You just listen those information below while you are lying on the bed. After 10 mins, you get out of the bed, and prepare to go out.

Information you will hear

- Today's weather.
- Today's schedule and to dos
- When you have to leave the home to get the first appointment's location on time.
- Popular article reading or music.

TASK 1. WAKE UP IN THE MORNING

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

Little bit more specific questions

1. If it was difficult to get information, what made you difficult?

2. If you missed certain information, what information did you miss? And why?

3. To make it better, what should I do?

TASK 2. ON TOUR AT NIAGARA FALLS

Background context

Imagine you are on a tour of Niagara Fall. You parked your car, and you just arrived at Niagara Fall. You are seeing one of the greatest nature in the world. And the device is delivering information to you while you are amazed by the scale of Niagara Fall. Device would know your situation according to GPS information and surrounding sound.

Information you will hear

- Further information of Niagara Fall
- Music that matched with the sound of nature
- Recommended restaurant near where you are

TASK 2. ON TOUR AT NIAGARA FALLS

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

Little bit more specific questions

1. If it was difficult to get information, what made you difficult?

2. If you missed certain information, what information did you miss? And why?

3. If there were anything bothered you, what was it?

4. To make it better, what should I do?

TASK 3. IN PUBLIC TRANSPORTATION

Background context

You are on the way of going to school, and you are heading to bus stop. When you arrived at the bus stop, device detects what situation you are in by analyzing surrounding sound and GPS location info. The device will provide information according to the context.

Information you will hear

- The best route or your routine way to your destination
- When does the bus will arrive
- Music play when you are moving (User can select what the device do in the bus or subway)
- Approximate ETA to the destination and do appropriate action
- When you have to get off the bus

TASK 3. IN PUBLIC TRANSPORTATION

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

___

Little bit more specific questions

1. If it was difficult to get information, what made you difficult?

___

2. If you missed certain information, what information did you miss? And why?

___

3. If there were anything bothered you, what was it?

___

4. To make it better, what should I do?

___

TASK 4. NAVIGATING AND CLOSE PROXIMITY

Background context

You are wearing the auditory sub-mobile device, so you can hear the sound from the device. You will do two kinds of tasks that 1) navigating the road and 2) finding an object by listening the sound from the device. For the first scenario, assume one block is one tile on the floor. And for the second scenario, I will adjust the direction and frequency of the sound according to your position and object's location.

Information you will hear

- Which direction I should go
- How close you are from the object you are looking for
- Direction of the object

TASK 4. NAVIGATING AND CLOSE PROXIMITY

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

Little bit more specific questions

1. If it was difficult to get information, what made you difficult?
2. If you missed certain information, what information did you miss? And why?
3. If there were anything bothered you, what was it?
4. To make it better, what should I do?

TASK 5. SOUND DIARY

Background context

You have been multiple places today. This device records sound from surrounding environment. So, you can hear the sound of places where you have been.

Information you will hear

- Location where you have been.
- Sound from the each locations.

TASK 5. SOUND DIARY

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

Little bit more specific questions

1. In this interaction, what kinds of occasions you may use?

2. If you missed certain information you may wanted to have, what information did you miss? And why?

3. To make it better, what should I do?

TASK 6. DURING MEETING

Background context

You are in the meeting, and you focus on the meeting agenda now. And facilitator will have you listen SMS and email notification sound.

Information you will hear

- Ambient mobile notification
- How many and what kinds of notifications you've got.

TASK 6. DURING MEETING

Overall, I am satisfied with this auditory interaction

Strongly disagree				Strongly agree
1	2	3	4	5

Do you think this way of delivering information is better than in visual way?

Strongly disagree				Strongly agree
1	2	3	4	5

- Why?

Little bit more specific questions

1. If it was difficult to get information, what made you difficult?

2. If there were anything bothered you, what was it?

3. To make it better, what should I do?