Enhancing Design with Sound

by

Dongju In

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Arts

Humanities Computing

University of Alberta

Abstract

Over the past few decades, our computing environment has changed dramatically. As computing has become more prevalent in every part of daily life, so has using computers to understand the humanities become more commonplace. Digital Humanities has provided people a unique, broad perspective by which to further understand social phenomena using computers.

Just as the appearance of the Personal Computer (PC) changed the world, we are once again experiencing a revolutionary shift with the ubiquity of mobile computing. Computing is no longer constrained to only certain locations, and much more data is thus being generated as we spend more time computing, everywhere. Today, data is unfixed and enormous. As computers grow in power and the extent to which they are integrated into our lives, the need for better usability, for as many people as possible, also grows. Without ever more efficient ways to interact with the data we are producing, we risk floundering around in a uselessly large pool of expensive information.

Although hearing is an important sensory system for the perception of information, the use of sound in computing considerably less developed than the use of graphics. Sound has huge potential as an interactive computing medium, the appropriate use of which can offer a supplementary way to enhance usability.

Features of sound and their possible use in computing are examined under four broad headings in this thesis: usability, interactivity, accessibility, and

universality. It ends with a discussion of the potential significance of the appropriate use of sonification in advancing both our engagement with, and the efficiency of, our computing experience.

Sound studies is broad, and this thesis will not cover the entire field. The objective of this thesis is to start a conversation in Digital Humanities around the use of sound in digital projects, offering a new perspective that will expand the effective utilization of sound in Digital Humanities and the digital world in general.

Table of Contents

List of Figures

Introduction

"It's not good enough to just keep producing technology with no notion of whether it's going to be useful. You have to create stuff that people really want, rather than create stuff just because you can."
– Genevieve Bell -

In 2009, Volkswagen introduced a new campaign called "The Fun Theory." One of their popular advertising experiments is a set of Giant piano stairs in a subway station, in Stockholm, Sweden. They built musical black and white piano keys on stairs beside an escalator. According to Volkswagen, 66% more people chose the stairs rather than escalator after the installation. The sound used for the giant piano stairs was just the simple sound of musical notes, however the story of this entertaining experiment has spread quickly both online and off; the video of Piano Staircase has been viewed over 20 million times on Youtube. The *World's Deepest Bin*, another experiment of Volkswagen's, is a trash can designed to make sound when it collects garbage. During one day, this bin collected more than twice the garbage collected by a normal bin just a small distance away. These experiments suggest two things; sound has the potential to enhance people's enjoyment of otherwise everyday activities, and the right use of technology can change people's behaviour.

Determining a user's motivation is key to improving their experience. According to Shneiderman, user-interfaces that evoke emotional response and a feeling of fun are important qualities identified by adult users; "fun" can encourage users and increase their interactivity and engagement since users *like* having fun (Shneiderman 48). As technology develops, we can implement an ever wider variety of effects in computing to engage users. However, for user satisfaction, we need to prioritize, as Bell states, what motivates user participation rather than simply what we are capable of building (qtd. in Flynn). While technology has the power to affect change, the importance of determining the most effective time, place and method of implementation can not be overstated. This is why we need a humanistic approach to using technology effectively; knowing what people want and how best to provide it are crucial to success. If we approach the examples above traditionally, we might simply design a faster escalator to solve congestion and install more garbage bins to keep parks clean.

Striking a balance between what we *can* do and what we *should* do is rarely simple due to competing motivations. Science for instance, will often develop technologies simply because they can be developed, with little concern for human needs, while humanists often lack the skills to develop what they identify as necessary or desirable. The *Newton,* for example, was introduced in 1993 by Apple, and offered a new technology: handwriting recognition. Although the *Newton* presented users with an impressive new technology, it did not reflect people's needs at the time, and so presented no engagement or efficiency gain. Many people were not yet familiar with using desktop computers, and though technically portable, the *Newton* was nonetheless bulky; it failed to convince potential users that the few minor functions it offered were enough reason to carry it around. *Google Glass* offered several groundbreaking new technologies, however people identified several concerns that limited interest, ranging from privacy to fashion.

The examples above suggest the importance of understanding users, their needs, and how best to engage and enable them. As a field of intersecting studies between computing and humanities, Digital Humanities (DH) has helped further this understanding. Visualization tools in DH are an outcome of the collaboration of data analysts, programmers, and graphic designers. Tools such as these provide users not only the ability to understand data but also an engaging way to explore it.

Many fields remain underrepresented in DH. Music is a major discipline in the humanities, however while literature, visual arts, and philosophy play important roles in much Digital Humanities work, music remains greatly absent. Music is a powerful tool that reflects time and place, evoking personal experiences and memories in the humanities (Lam 1). These impressive features apply not only to music, but to sound as a whole. Sound studies can thus offer unique benefits to multi-disciplinary humanities projects. As visual studies developed from fine arts, and performs a great role in DH, sound studies can take an important role in DH by incorporating unique disciplines from traditional music.

Schafer argues that aesthetic education by The Bauhaus was the most significant revolution in the twentieth century. The Bauhaus was focused on interdisciplinary skills while other art schools paid attention only to fine arts. As a result, The Bauhaus aesthetics were conveyed to industry, marking the birth of industrial design (Schafer 96). Schafer describes the invention of industrial design as the result of collaboration of the fine arts and the industrial crafts. The dawn of acoustic design is greatly similar to the revolution of industrial design. Schafer argues, “An equivalent revolution is now called for among the various fields of sonic studies. This revolution will consist of a unification of those disciplines concerned with the science of sound and those concerned with the art of sound” (205).

Sound studies offers a greatly untapped potential for DH, and for digital users’ experience in general. Sound has unique, distinctive features which, alone or when integrated with appropriate visual cues, can significantly impact user experience for the better, as is the case for instance with many tools for the visually impaired. As our experience with computers is no longer limited to the home and office, the use of sound will likely also play a huge role in mobile computing, as sound helps us perceive the space we are living in; it provides us not only what we can hear and identify, but also a sense of environment.

In this thesis, my focus is on examining the potential use of sound in DH in order to make usability enhanced and interactive. The use of sound can not only directly benefit users, it will also be a benefit to DH researchers. Providing users a more intuitive and interactive computing environment will likely increase users' overall computing activities, providing researchers with more diversified tools and data. I will examine several existing examples of sound as a component of usability in computing. A number of sound based studies were produced in the 1990s, but with the proliferation of smartphones, tablets, and wearable devices, contemporary computing is very different from the recent past. I will thus re-examine the utility of sound and suggest new possibilities for Digital Humanities work.

In the first chapter, I will discuss the significance of the appropriate use of technologies. I will examine the history and evolution of DH, from its inception as Humanities Computing to the current state of Digital Humanities, and discuss the values suggested by Lisa Spiro, as a means of allowing DH to move forward as a more cohesive discipline (Spiro 1).

In the following chapter, I will explain the features of sound in order to understand their potential use in DH. I will also explore some examples which demonstrate unique features of sound such as evoking emotion and spatial visualization. We often use the term "design" as a way of describing exterior appearance in the visual arts. However, design is not nessecary limted to only visual elements; design can be interpreted more widely. The term “design” in my thesis will be used in a broader concept as Ralph and Wand suggest.

> (noun) a specification of an object, manifested by some agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to some constraints (Ralph and Wand 6).

In the next section, I will address the importance of usability, interactivity, accessibility, and universality using existing examples to discuss how sound can improve these four aspects. Even though “usability” and “user experience” are slightly different, we often use them interchangeably. According to Nielsen, “Usability is a quality attribute that assesses how easy user interfaces are to use. The word ‘usability’ also refers to methods for improving ease-of-use during the design process.” User experience “encompasses all aspects of the end-user’s interaction with the company, its services, and its products.” I will be using the term “usability” rather than ‘“user experience” since my thesis focuses more on improving the working process rather than examining the larger, overall experience.

In the last chapter, I will examine the role of sonification, a technique that can be useful in a wide range of activities such as analyzing data, informing users, and even creating art. Both current and former DH projects will be examined in order to show sonification’s possible impact on usability and interaction; I will present a prototype I created called “Sonifyer of Visual Data” to demonstrate how sonification can combine effectively with visual data, as well as demonstrate the importance of expert collaboration. Finally, I will argue in favour of specific sonification techniques that can be applied to DH projects as well as computing in general.

Chapter 1. Digital Humanities

1.1 Humanities computing to Digital Humanities

"It's in Apple's DNA that technology alone is not enough — it's technology married with liberal arts, married with the humanities, that yields us the result that makes our heart sing and nowhere is that more true than in these post-PC devices."
- Steve Jobs -

The first generation of iPhone was unveiled in 2007, and it was an immediate hit. While many cellular phone companies competed with each other on performance metrics such as the number of pixels captured by their camera, what Apple introduced was beyond simply "the latest technology." While iPhone did not have notably superior hardware, it had an answer to the question "how can technology best be used for people?" The intuitive OS and touch screen were huge conveniences for users both young and old, with very little effort required to learn this new gadget. The total sales of iPhone proved what people were looking for was an intuitive, easy and fun to use technology.

The iPhone example shows us the importance of employing a humanistic approach to finding the best answer to people's needs; science and technology has the power to make things happen, however we need human-centric examination in order to determine the most *appropriate* solutions. "[Interdisciplinary research can] not only fill existing gaps or take advantage of new possibilities but sometimes, quite overtly, seek to remedy, redress, respond to or in other ways compensate for lacks, problems, rigidities, blindspots, and incapacities inherent in existing or traditional disciplinary structures, omissions made evident by the infilled needs at a specific historic moment" (Davidson 209). In other words, interdisciplinary studies can enhance the effectiveness of studying the humanities traditionally, in isolation; an interdisciplinary approach can suggest a greater number of appropriate answers to complex questions.

At the intersection of traditional humanities disciplines and computing, DH (traditionally called Humanities Computing) has received steadily more attention with the increasing ubiquity of digital technology in our daily lives. The development of tools in Humanities Computing began in the 1970s. The 1970s to mid-1980s can be described as the "consolidation" of Humanities Computing, an important period that recognized the need for semi-standardized software in order to maintain and archive texts (Schreibman et al. 4). This research need drove the industry to have more developed computing systems.

> More people were using methodologies developed during the early period. More electronic texts were being created and more projects using the same applications were started. Knowledge of what is possible had gradually spread through normal scholarly channels of communication, and more and more people had come across computers in their everyday life and had begun to think about what computers might do for their research and teaching (4-5).

Humanities Computing exemplifies how the evolution of technology and humanities are tied together. “neither humans or tools are fixed; they influence each other and thereby *coevolve* over time. In particular, humans develop new tools, which influence the mental and physical processes that humans apply to those tools, which in turn influence the development of yet further tools” (Plotkin 93). The development of digital tools and methodologies are invariably influenced by the needs of the humanities disciplines, as are notions of how one might proceed in disciplinary research necessarily influenced by the available tools.

The appearance of the personal computer in the mid-1980s to early 90s represented a significant development for Humanities Computing (Schreibman et al. 6). The *Apple Macintosh* for instance, offered one of the first widely disseminated graphical user interfaces (GUIs) and a program which helped users create hypertexts (see Figure 1.). GUI’s ease of use increased work efficiency, and reduced the learning curve typically associated with computers. Furthermore, these intuitive computing environments provided humanities scholars the ability to write programs in a relatively easy way. This environment not only helped researchers use programs but also to develop programs for their use. However, development was limited initially since people could share their knowledge with people only within a short physical range.

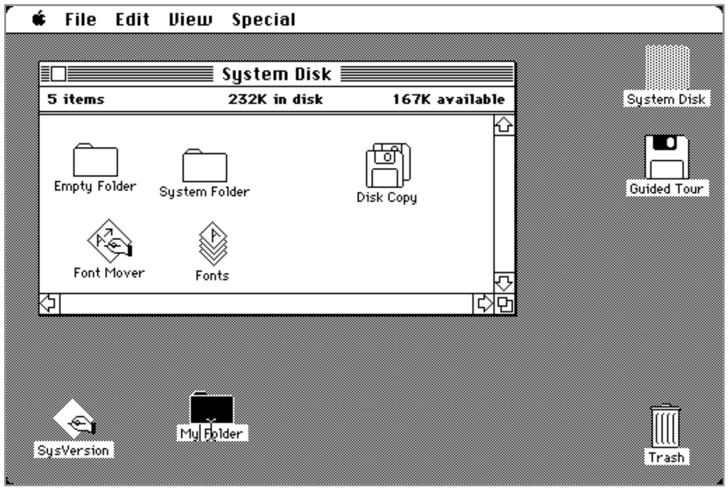

Figure 1. Macintosh Desktop (1984)

The development of the web brought a big change in computing, having a particularly large impact on knowledge sharing. The Internet allowed people to work on collaborative projects regardless of geographic space. Furthermore, the need to handle electronic resources such as images, audio, and video in the early 1990s drove the development of multimedia.

DH has experienced a significant shift since the early 1990s, changing the name from "Humanities Computing" to "Digital Humanities" and expanding the field to include more advanced and varied areas of study, applying technology to a wide range of traditional humanities such as philosophy, history, linguistics, and cultural studies. Consequently, DH has developed many computing tools such as text and image digitization, text mining, topic modeling, digital mapping, and visualization. These tools have helped DH expand how the humanities are practiced. DH is often described as “the next big thing,” however practitioners continue to debate what it is, and what it is not (Spiro 1).

Digital Humanities Manifesto 2.0 describes Humanities Computing as the first wave of this field (Schnapp et al. 2). A lot of quantitative work such as text mining and visualization was done in this early period, which is described in *New Developments* of humanities computing as the mid-1980s to early 1990s (Schreibman et al. 6). These text-mining and visualization tools help researchers not only analyze massive texts digitized from traditional material sources, but also to modify data for their own purposes.

At the crossroads of computing and the humanities, DH should always maintain a focus on humanity. In order to identify and produce solutions that really benefit people, we need a comprehensive understanding not only of technology, but also of people’s needs and desires. “[Interdisciplinary studies is] a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession...and draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective” (Klein and Newell 393-394). In the arts for example, educators study game theory in an effort to deliver knowledge to students more effectively. In science, interdisciplinary studies are self-evident in biomedical engineering, neuroscience, and biochemistry.

Interdisciplinary collaboration is a key to benefiting from sometimes vastly different expertises. Social media for instance, offers a new perspective from which sociologists can examine behaviour and relationships. Without programming skills to collect and analyze data however, their examinations would be impossible. Furthermore, without the skills of a graphic designer, it might be difficult to effectively communicate the sometimes massive amounts of data.

As DH has grown and technology has advanced, the nature of the field has also changed. "As DH have come to be practiced, we are no longer talking about processing and statistically analyzing large collections of text, but rather about the changes that digital technologies are producing or generating across the many fields of humanist inquiry" (Porsdam 5). A further change with the growth of DH is the inclusion of design thinking in order to increase the utility of works; how we best display the outcome of research can be as relevant a consideration as how we collect and analyze large sets of data. Resulting visualization tools have significant advantages, allowing users to understand research results, even with little knowledge of the process.

As more disciplines adopt new technology-based strategies, the role of DH becomes more central in the search for new and effective practices. Debate surrounding what exactly DH is, and who can call themselves a practitioner, has existed for decades. Without a clear understanding of itself, DH as a field is likely to encounter problems in the future. In the next section, I will discuss values Spiro suggests Digital Humanists ought to pursue in order to effectively move the discipline forward.

1.2 Expanding the Field

In the previous section, I introduced the importance of interdisciplinary work and collaboration in developing and expanding the field of DH. In this section, I examine how interdisciplinary collaboration applies to another item which DH needs to explore and embrace as the field expands; the ubiquitous nature of mobile computing.

The key-words of the second wave of Digital Humanities: qualitative, interpretive, experiential, emotive, and generative. "harnesses digital toolkits in the service of the Humanities' core methodological strengths: attention to complexity, medium specificity, historical context, analytical depth, critique and interpretation" (Schnapp et al. 2). It has been less than a decade since the introduction of smartphones, and the mobile computing industry has grown at a remarkable rate. We can and do check emails everywhere, and composing new documents is a task no longer tied to a desk. We interact with our computers almost anywhere, and are thus exposed to a wide variety of rapidly developing computing environments.

Augmented Reality (AR) is a system that “supplements the realworld with virtual (computer-generated) objects that appear to coexist in the same space as the realworld” (Azuma et al. 34). AR, though still in its relative infancy, no longer requires specific locations and tools; it is now within the average researcher’s grasp. *Layar,* for example, a free smartphone application, allows users to experience an AR environment virtually anywhere. As can be seen from Figure 2, AR environments have become convenient and accessible, increasing their use in areas of our lives like education, marketing, and tourism.

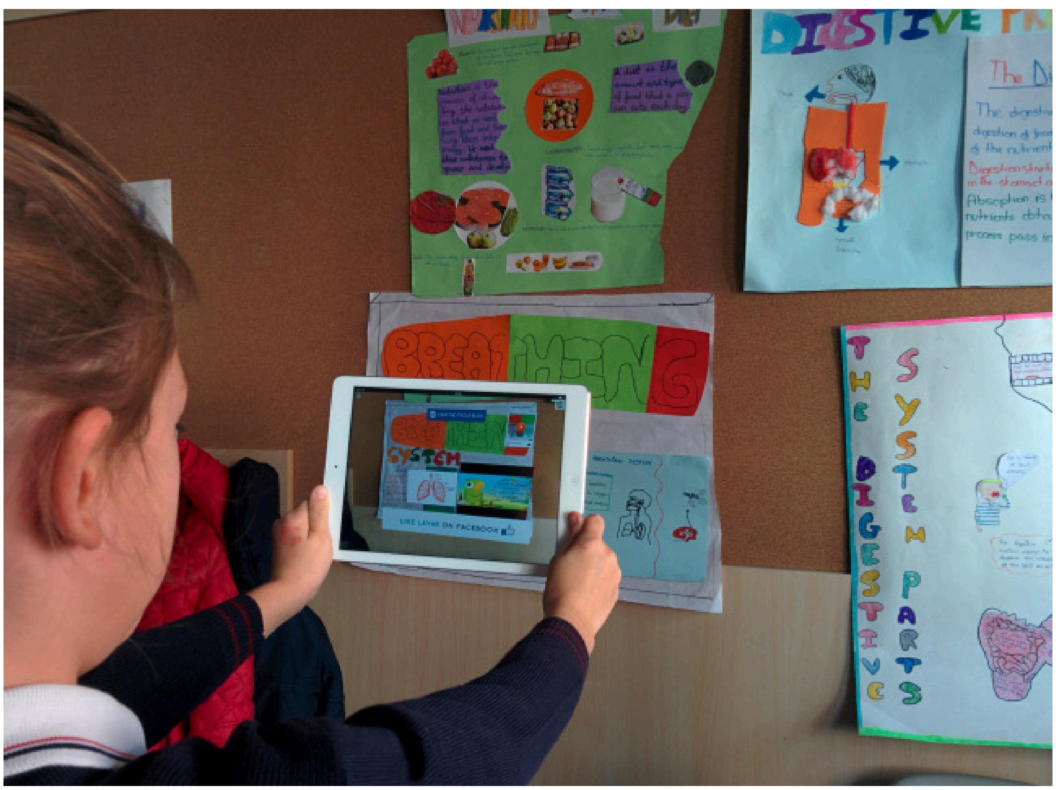

Figure 2. *Layar* use in education

In the past we received information via computer monitors in dedicated spaces, whereas with mobile computing, we can now enjoy a comprehensive experience which includes factors unique to the space in which we have the experience. A broad, interdisciplinary perspective will help us understand this still relatively new phenomenon which often requires more than one discipline to effectively explore. Collaboration, as suggested by Spiro, is an important value DH needs to embrace. The free flow of varied information helps us think and build ideas in new ways. Johnson says that a "majority of breakthrough ideas emerge in collaborative environments" (qtd. Spiro 10). This change is very natural since digital humanists realized a lot of projects cannot be done successfully without text encoders, project managers, and visionaries in order to develop effective multimedia projects. Collaborating not only affords people the opportunity to learn from others but also integrates various specialized areas of knowledge, potentially revealing different perspectives with which to approach a problem.

Many tools developed by Digital Humanists are the result of a collaboration between different areas of expertise. Text mining tools, for instance, which play a significant role for the literary scholar in the analysis and understanding of massive texts, require a lot of computer code, complex algorithms that are magical to the average humanist, but no big deal to a computer scientist or mathematician. Visualization tools, as another example, developed to help users understand abstract data, are a result of the combined efforts of graphic designers, computing scientists, and humanist specialists to improve the utility of traditional visualizations. Collaboration between fields is an important component of the future success of DH. The power lies in exploiting the possibilities offered by new and different perspectives, as exemplified in the Volkswagen experiments.

As technology has developed, DH has developed alongside it. The nature of digital data, for example, is much different from its relatively static, analogue past. New information is generated every second, and the amount of data we handle is larger than ever. “A full 90% of all the data in the world has been generated over the last two years” (“SINTEF”). With this massive increase in data, usability has become a more and more pressing issue for digital humanists. Good usability helps users not only understand data effectively but also provides a pleasant digital working environment. A well-made visualization on the web, for instance, gives an understanding of data and can be a playful pleasure to explore.

Human-Computer Interaction (HCI), one of the fields studying the interaction between humans and computers, and one of their key areas of concern is usability. Interactivity is an important aspect which can positively influence usability. Interactivity helps engage users, and can make them more invested in the process of exploration, particularly if the interactivity is intuitive and clear. For example, when users click an icon, they have no idea whether their request is processing or not. However if the computer offers a sign, visual or audible, that the user's request has in fact been processed, the user's experience will likely be more satisfactory.

Most HCI studies are based on GUIs, but using other sensory systems can significantly improve current vision based interactivity since each sensory systems offer its own unique benefits. Sound for instance, has been recognized as a significant component of computer graphics and interaction. "Sounds are known to be useful for human-computer interfaces in general" (van den Doel et al. 1), and Buxton points out that sound can be used for alarms and warnings, status and monitoring indicators, and encoded messages (qtd. 1). Touch screens allow people to use their fingers in an intuitively comfortable way instead of using traditional input devices such as mouse and keyboard, and have notably changed our computer using environment. This new interaction paradigm offers significant benefits to users, including those who struggle with traditional interfaces. The use of touch screens demonstrates not only how better interactivity and usability can benefit the user, but also the potential of immersing the user via sensory systems in addition to vision.

In terms of interactivity and usability in computing, the potential of hearing is as huge as that of touch, though its implementation via sound studies has so far been relatively limited. While sound studies have become a significant part of higher education in new media studies, visual studies has historically received more attention than sound studies (Tahiroğlu et al. 1). Sound studies is often misunderstood as a field concerned with only researching artistic uses of sound, but it is frequently an important, and taken for granted, component of many parts of our lives. In urban planning for instance, sound studies provides solutions to control noise pollution; a city fountain will often function not only aesthetically, but also as a noise-masking tool.

Sound studies is "an emerging interdisciplinary area that studies the material production and consumption of music, sound, noise, and silence" (Pinch and Bijsterveld 636). With the prevalence of multimedia, sound studies has become an important component of design. As more people use new computer technologies to express their thoughts and ideas, the role of new media has become more central (Tahiroğlu et al. 1).

Developers can increase usability, engagement, and the quality of communication with a better understanding of sound as a potential design element. Spreading the cognitive load over different sensory systems, will allow some visual information to be replaced by sound. Furthermore, because sound can convey information spatially, sound can deliver information in a way which vision cannot. For example, when data represents as stereo sounds, users can identify not only the pitch and velocity of the sounds but also their direction (see Figure 3.). This offers a way to augment the data presentation possibilities of the 2D computer screen.

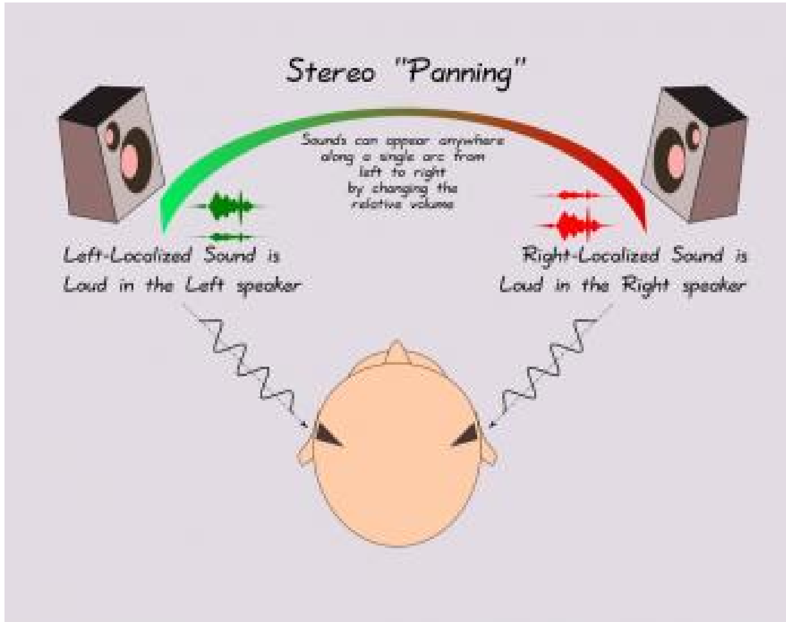

Figure 3. Feature of stereo sound

Sound studies has the potential to work within a variety of interdisciplinary study areas. Revealing this potential will provide users a new way to experience computers, and contribute to the overall development of DH. Breaking the wall to sound studies will help DH embrace more diversified work, and applying various specialized areas of knowledge to problems both old and new, can help discover completely different answers.

Chapter 2. Why Sound Matters

2.1 Feature of Sound

"Sound is not only a guide to the practicalities of living….it is also an aesthetic pleasure."
- Tomi Keitlen -

In this chapter, I argue that the role of sound in our lives is a benefit to us. I look at some sound examples in order to demonstrate how sound has the power to make people pay attention. Comparing hearing to vision provides us an opportunity to understand the distinctive features of sound, and how sound can provide benefits in ways which vision cannot.

Sounds can be described as frequency and intensity, measured in hertz (Hz) and decibels (dB). Frequency is measured by the number of sound vibrations in a second. Sound wave frequency allows us to identify the pitch of sound; 440 vibrations in one second, a frequency of 440 Hz, is A above middle C. Humans can hear a range from 20 Hz to 20,000 Hz in frequency on average, and the important sounds in our lives appear in a range between 250 Hz and 6,000 Hz (see Figure 4.). Decibel is used to measure the loudness of sound. We can identify the level of sound in a range from 0 dB to 140 dB in intensity, however over 120 dB sounds can be painful for humans, and can cause hearing loss (see Figure 5.).

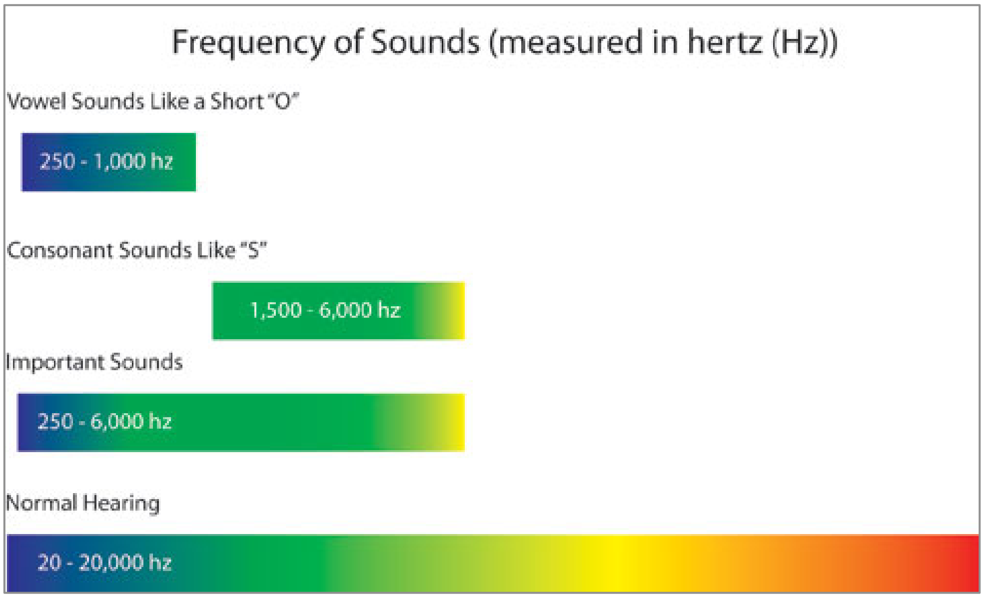

Figure 4. Frequency of Sounds

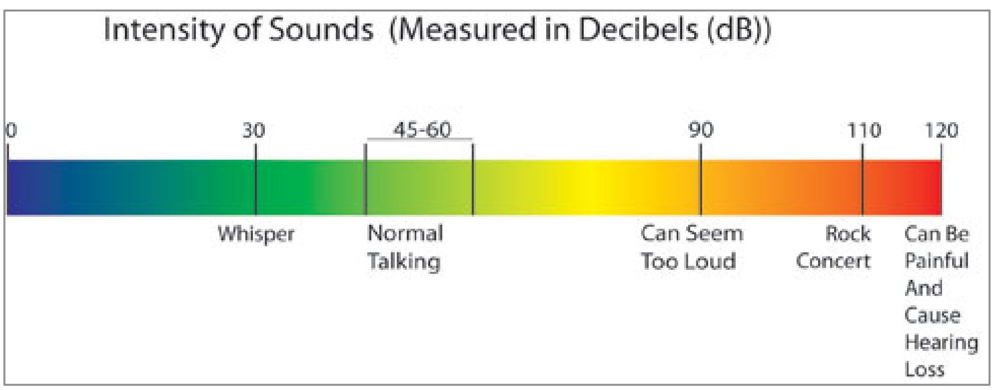

Figure 5. Intensity of Sounds

As "the primary advantage of having two ears," we can identify the direction of incoming sound; when we hear the siren of an ambulance, we can discern not only which direction the sound comes from but also whether it is coming or going. As Figure 5 shows, we have a good ability to hear in a wide range, but we use only a small part of our ability; while we use a huge range of colors, the use of pitch variety in our daily lives is very limited.

The embodiment of a person's experience of a space occurs through different sensory perceptions such as sight, touch, taste, smell, and sound. While our use of visual cues is well developed, other sensory perceptions are historically regarded as less important. In "Sound Studies: New Technologies and Music," Pinch and Bijsterveld argue, "Visual metaphors dominate our language...we *see* the new *vista* of sound studies but don't hear it! The visual is the known" (Pinch and Bijsterveld 637). People have begun to pay attention to each sensory system's unique features however, and to develop effective ways to use these features.

Abercrombie & Fitch has developed a unique marketing strategy which uses smell. While other clothing shops focus only on their interior decor, Abercrombie & Fitch uses a specific scent which both makes customers feel comfortable, and is inherently memorable, making the scent become an identity of the brand. We can find similar examples using sound; we all remember the melody "jingles" of Mcdonald's commercials, for instance. The effectiveness of these marketing strategies is made possible by the unique features of sound. Sound is memorable. Even if you do not listen to a specific song for a long time, you are likely to remember it in with only a few seconds of exposure.

Sound's unique features offer a lens through which we might gain knowledge of a place or event, one that can incorporate additional significance which might be silenced in an exclusively visual study of the land. Hearing and seeing are often compared since they have very different features. Dombois argues, "From philosophical point of view the eye is good for recognizing structure, surface and steadiness, whereas the ear is good for recognizing time, continuum, remembrance and expectation" (Dombois 227). In "The Sound Studies Reader," Jonathan Sterne also states,

- hearing is spherical, vision is directional;
- hearing immerses its subject, vision offers a perspective;
- sounds come to us, but vision travels to its object;
- hearing is concerned with interiors, vision is concerned with surfaces;
- hearing involves physical contact with the outside world, vision requires distance from it;
- hearing places you inside an event, seeing gives you a perspective on the event;
- hearing tends toward subjectivity, vision tends toward objectivity;
- hearing brings us into the living world, sight moves us toward atrophy and death;
- hearing is about affect, vision is about intellect;
- hearing is a primarily temporal sense, vision is a primarily spatial sense;
- hearing is a sense that immerses us in the world, while vision removes us from it (Sterne 9).

Because our hearing has significantly different features than our vision, sound offers several supplementary benefits to vision.

Figure 6, Sonification of Tohoku Earthquake shows how sonification techniques can offer additional, supplementary benefits over the visual by allowing us to hear seismometric sound which is well below the range of the human audio spectrum. [1] Traditionally, earthquakes are visually studied since they are unhearable to human ears. This example demonstrates the huge potential of colllaboration between science and the arts to not only broaden the research scope in DH, but also to provide users a unique opportunity to understand scientific phenomena in an artistic and compelling way.

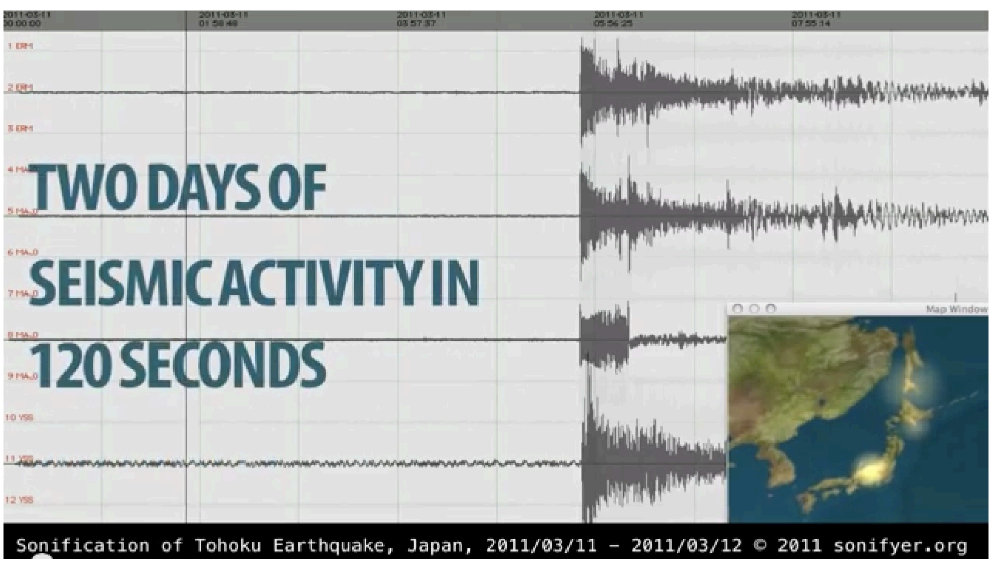

Figure 6. Sonification of Tohoku Earthquake / Sendai Coast, Japan

[1] https://youtu.be/3PJxUPvz9Oo

Dombois also states, “Nevertheless if one compresses the time axis of a seismogram by about 2000 times and plays it on a speaker (so called 'auralisation'), the seismometric record becomes hearable and can be studied by the ear and acoustic criteria” (Dombois 227). This sonification has a significant impact on its accompanying visualization. In DH, there are very few experts in sound. Due to this lack, there exist only a small number of research projects which require sound techniques. As this example demonstrates however, sound techniques can be very effectively used to help people understand the otherwise invisible data in this type of project. Furthemore, this example demonstrates the positive effect of combining sonification and visualization. DH has already begun successfully utilizing visualization. Incorporating sound techniques into current and future projects has the potential to remarkably enhance the results.

Sound can also suggest new and unseen ways to solve problems. As can be seen from Figure 7 and Figure 8, Volkswagen’s The Fun Theory demonstrates how people often immediately react to sound, exploring and playing with it. According to Volkswagen, thefuntheory.com is “dedicated to the thought that something as simple as fun is the easiest way to change people’s behaviour” (“Volkswagen”).

Figure 7. Giant Piano Stairs

Figure 8. The World's Deepest Bin

As expressed earlier, the experiments clearly demonstrate how fun sound can actively change people's behaviour; the use of stairs increased 66% when using the stairs generated piano-like feedback, [2] and twice as much garbage was collected with the installation of amusing, interactive garbage cans. [3]

Gresham-Lancaster and Sinclair argue that unlike with sight, our minds are actively hearing whether the world is awake or asleep; hearing does not go away since we cannot close our ears. Sound envelops us, greatly determining our sense of the environment and providing us a sense of space (Gresham-Lancaster and Sinclair 70). de la Motte-Haber also says, "We do not walk into walls and can 'feel' someone behind us. With our ears 'we can see in the dark, because the reflection of sound gives us information about the volume of a given space'" (de la Motte-Haber).

As sound has such a close relationship with space, *soundscapes* have the potential to help us better understand our immersive environment. R. Murray Schafer, a Canadian composer who coined the term "soundscape," defines the soundscapes of specific areas as natural "keynotes," and particular sounds in a community as "soundmarks" (Schafer 1993). If I record the sound of a coffee shop for 10 minutes using a phone while I am drinking coffee, this is also soundscape. This is no different from other creative activities such as drawing something on a piece of paper or shooting a photo a camera. The only difference is "a soundscape consists of events heard not objects seen" (1993). Although the

[2] https://youtu.be/2lXh2n0aPyw
[3] https://youtu.be/cbEKAwCoCKw

creation and use of soundscapes is more prevalent than it once was, compared to photography for instance, it remains a relatively narrowly known and practiced activity.

Understanding sounds in our environment is an important part of plan our future environment. Schafer argues that noise pollution is a worldwide problem which disrupts listening to environments, and he suggests soundscape as a way to control noise. According to Schafer, “the only realistic way to approach the noise pollution problem was to study the total soundscape as a prelude to comprehensive acoustic design” (1993). Schafer imagines soundscape being used to provide new answers to noise control problems, proposing “an interdiscipline in which musicians, acousticians, psychologists, sociologists and others would study the world soundscape together in order to make intelligent recommendations for its improvement” (Schafer 1993). Today, more and more widely, what Schafer suggested appears in our lives as “acoustic ecology.”

As I mentioned in the previous chapter, an interdisciplinary approach to research offers the potential of a wider perspective. The practice of sound is not limited to a particular field. Sound studies can be applied broadly to many other fields. In the same way that other DH disciplines have offered one another new solution directions, sound studies has the potential to offer important new perspectives in DH.

A soundwalk is an activity to listen and feel surrounding environments while we are walking. Schafer defines, “soundwalk is an exploration of the soundscape of a given area using a score as a guide. The score consists of a map, drawing the listener's attention to unusual sounds and ambiances to be heard along the way" (1993). For this reason, a soundwalk has a close relationship with geographical location.

Sound can function as audible landmarks, and sound artist Andrea Polli attempts to use this feature of sound to provide environmental information. In "Soundscape, Sonification, and Sound Activism," Polli uses examples from NYSoundmap, a unique digital map that abstractly displays audio/geographic data, to demonstrate how *soundwalking* can provide us an alternative way to understand the natural and man-made environment (see Figure 9.). This audible landmarks idea suggests not only a new way to perceive the world, but also the impressive potential of human pattern recognition. According to Polli, "ears collect information from all directions at once constantly, and repetitive sound can be tuned out." Humans have strong sound pattern memory; we easily remember songs for decades, for instance (Polli 266). The advantages of sound pattern recognition can be applied to a variety of research, and it can provide us a completely new way to understand data.

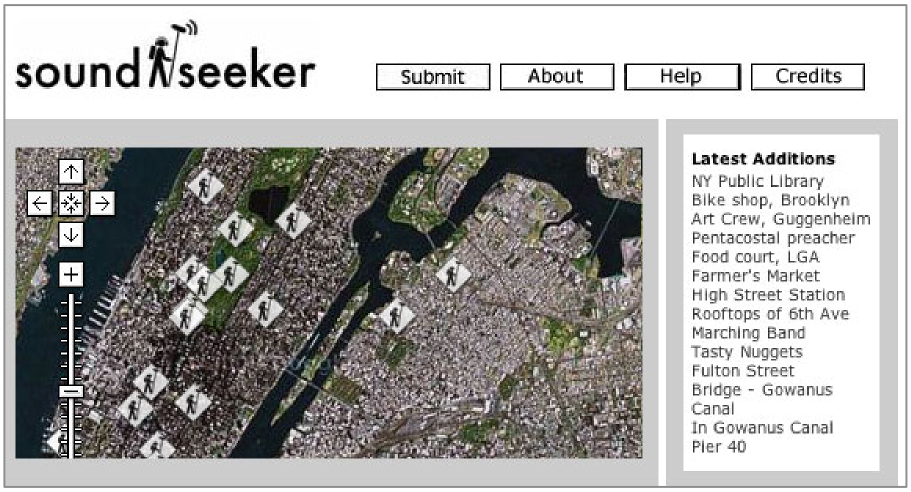

Figure 9. NYSoundmap

In the past, recording and sharing sounds required a lot of effort. People had to bring a microphone and recorder to the field, and allocate further time to digitize the sound. Today however, with computers now everywhere, designed, digitized sound is likely to become an ever more common ingredient when experiencing one’s environment. Users can record, edit, and share sound using their mobile devices regardless of space and time. This is a good opportunity to use sound as a research material, and there is extensive potential to grow as a new way to understand social phenomena as we do with Twitter.

According to Smith, smartphone ownership reached a tipping point in 2012; “Nearly half (46%) of American adults are smartphone owners as of February 2012, an increase of 11 percentage points over the 35% of Americans who owned a smartphone last May” (“PewResearchCenter”). As the Internet of Things (IoT) becomes more popular, a lot of small, personal devices such as watches, bracelets, and shoes function as computers. Thoughtful use of sound can greatly replace the need for visual feedback in these small tools, as well as provide a safer feedback mechanism in larger, data intensive applications.

It is very common to see cars with a central computing system to control and inform the driver of the vehicle's status, however actively receiving visual information can distract drivers. Navigation systems providing information audibly is a prime example of the implementation of sound to reduce user distraction.

Although the IoT is a relatively new phenomenon, sound is already being incorporated in IoT devices. *Point,* a kickstarter project, is an audio smart home security device which was developed to detect audio information (see Figure 10.). This small device provides some functions security cameras alone cannot, alerting owners to unusual activities such as a window breaking or a loud party, via their smartphone.

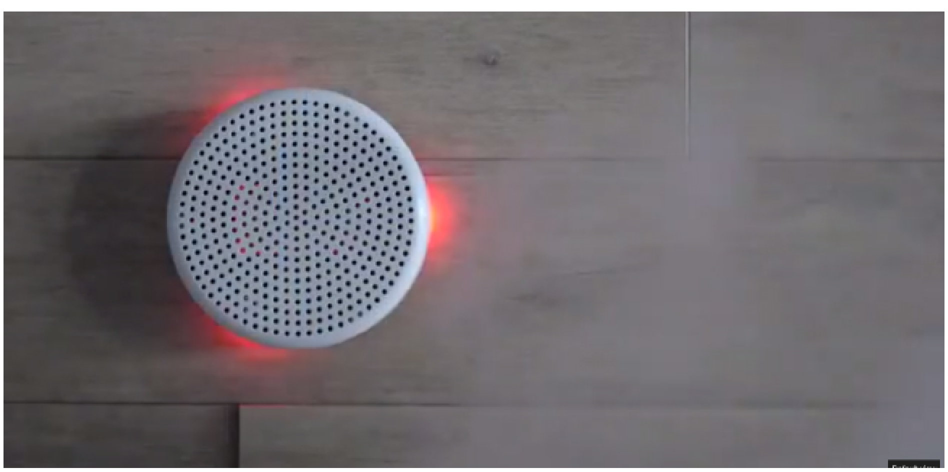

Figure 10. Audio Smart Home Security: Point

This kickstarter project demonstrates the future potential of the unique features of sound. “Sound provides opportunities that do not require visual focus in product usability; that ‘our ears are continuously active’ is a widely recognized truism” (Tahiroğlu et al. 59-60). We find this feature used in product design such as fire alarms and ovens, and it can play a role in the computing interfaces designed in DH as well.

Figure 11 is an interactive sonification created in Pure Data, which is an open source visual programming language. Young designed a sonifier which analyzes the data of NASDAQ. [4] This example highlights a benefit of the “always active” nature of hearing. Stock market data fluctuates rapidly, and it is very hard to follow the information we want unless we stare at the screen all the time. This sonification allows us to hear rather than to see the data. It provides users an opportunity to do other tasks, offering a huge advantage in usability, and suggesting a potential use of sound in a DH context. When exploring a large, automatically collected data set, researchers can set audible cues to notify them of a single event in a potential occurrence of millions of events, even if their eyes or screen are busy with other tasks.

[4] https://youtu.be/iSmMaPT9VI8

Figure 11. Interactive Sonification Using Pure Data (cc) -NASDAQ

As mentioned, sound can provide a spatial sense. Since sound helps us perceive space, it can play a significant role in locative media, that which is defined as “mobile media with geographical positioning and context sensitivity” (Santaella 294). According to Sutko and de Souza Silva, “Most locative media applications, and the discourses surrounding them, are heavily biased towards visual, textual, and often map-based interactions” (Sutko and de Souza Silva 2011). Locative media needs to be balanced by various perspectives in order to overcome its limits. Sound for instance, can help a user perceive temporal, situated and contained aspects of locative media. In “*The sound of locative media,”* Behrendt suggests an auditory approach to how we experience locative media.

The National Mall, a locative sound application released in 2011 by *Bluebrain,* shows how auditory components and spatial perceptions can be engaging (see Figure 12.). While users walk around the park area in Washington DC, they hear a variety of sounds and music, with the user's movements acting as a form of remixing. The rhythms, shifts, and melodies change depending on each user's path. When users approach the lake for example, their auditory experience is changed to a harp sound, demonstrating how sound can be immersed in physical and media contexts, and allow us to experience our environment in a new way, as interactive art. [5]

Figure 12. *The Nationa Mall*

As can be seen from Figure 12, *The National Mall* suggests a completely new way to feel the space using smartphones. While other historical walking

[5] https://youtu.be/fluxcyxEwUw

tours focus on passive ways of delivering information to users, such as telling stories, *The National Mall* allows users to explore the environment actively by increasing user engagement and making it more intuitive. Many projects in DH could benefit from embracing sound's power to increase user interactivity, and thereby possibly user engagement.

In this section, I have argued that sound has the potential for widespread application as a uniquely powerful means of spatial perception in today's world of mobile, digital media. Exploring the utility of sound to both inform and engage will invariably lead to the conclusion that vision is not the only sense worth exploiting for its impact on user experience. In the next section I will examine how sound, alone or paired with visual information, can play a major role in improving usability.

2.2 Usability

"Product sounds can give useful information about the state a product is in."
- Jordan -

When we talk about design, we often mention three aspects: aesthetics, functionality, and usability. What we consider a good design will have good balance among the three aspects. In the past, functionality was the most important consideration in people's choice of products. The performance of computers has traditionally been the main factor considered during their purchase: CPU (processor), RAM (memory), HDD (storage). However, as technology has developed, usability has become a major factor in product choice. People are often interested in how convenient something is rather than how fast it is. iPad commercials, for instance, focus more on ease of use rather than explaining hardware specifications, showing people of all walks of life enjoying their product.

Usability in computing is no different from the usability of other products. Improvements in technology allow graphic designers to worry less about hardware limitations when making usability decisions. Graphic designers can freely use a variety of effects such as sliding images, fixed/unfixed navigation bars, and collapsible menus to enhance usability; modern animation effects, for instance, work even on mobile devices. Furthermore, contemporary data processing is much faster than in the past. One can explore a very large database almost in a real time, however our ability to receive information remains the same. Vision is limited to providing us only what the eye can discern, and our eye cannot effectively differentiate a great number of simultaneous stimuli. Using an additional sensory system offers the potential to overcome this limitation. The use of a touch screen, for instance, increases usability tremendously; the combination of touching and seeing provide a very intuitive environment that can assist anyone, including older adults and younger children to become confident computer users.

Although the use of touchscreen proves that usability can be improved using sensory systems besides vision, current efforts surrounding usability are mostly focused on elements experienced visually. More effectively using sound in computing will bring substantial benefits to usability since hearing has a very different nature than vision; it provides spatial information and can powerfully evoke emotions. While hearing cannot replace the function of vision, it can certainly supplement it. The implementation of sound can be a benefit for a variety of fields in computing; among them is AR.

AR, primarily using GPS and a camera, has been used successfully for many purposes such as education, advertising, training, and design. However, it is limited as a representation of reality since it does not cover all of our sensory function. By incorporating sound, AR can provide users a more realistic experience. Figure 13 is an example which demonstrates the effectiveness of using sound in AR, using sound not only to deliver information audibly but also to help users engage with the information. [6] Because this application uses audio to deliver information, data loading is split, and users' eyes can pay more attention to the illustrations.

[6] https://youtu.be/7zYBz7FbhFY

Figure 13. Augmented Coaster

Sound artist Tanaka created *Malleable Mobile Music* which shows how our environment can be sonically designed in locative media (see Figure 14.). The bass of music, for example, becomes louder when mutual friends of the listener get closer in physical distance (Tanaka 2004, 2005). This example shows us how sound can be used as an alternative way of developing spatial awareness instead of using visual methods. *Malleable Mobile Music* takes social dynamics and mobility as inputs to a streaming music re-mix engine. The work extends on simple peer-to-peer file sharing systems towards ad-hoc mobility and social computing. It extends music listening from a passive act to a proactive, participative activity. The system consists of a network based interactive music engine and a mobile rendering player. It serves as a platform for experiments on studying the sense of agency in collaborative creative process, and requirements for fostering musical satisfaction in remote collaboration; urban mobility of communities of users create a "social re-mix" (2004, 2005).

Figure 14. *Malleable Mobile Music*

In designing graphic notifications, designers are challenged to effectively communicate temporally significant information to users without interfering with current tasks. Sound notifications present similar difficulties. We all have experienced notification sounds that interrupt us while we are using audio functions. A notification sound might overlap with music, for instance, causing a distraction. *Malleable Mobile Music* suggests a creative solution technique. Modifying the velocity of particular instrument sounds, for example making the bass sound louder whenever a target word appears in a search, can effectively notify users, minimize disruptions, and permit ongoing engagement with current tasks.

The study of big data has become more and more significant as the speed at which data is produced increases. If sound can be used to increase engagement, and thereby usability in mobile computing, it follows that *usage* will also increase, leading to more data, more research possibilities, and likely more discovery.

Sound has huge potential benefits to outdoor computing since sound can provide spatial information, which is not to suggest the benefit of using sound is necessarily limited to mobile computing. It offers equally huge potential benefits to general computing as well. GUIs (Graphical User Interfaces) are more widely used than text-based interfaces because of their increased usability. GUIs, however have limitations on multi-processing. Brewster and Crease experimented with correcting menu usability problems with sound. According to Brewster et al., users cannot look at the menu and their main task at the same time since the visual system has a narrow focus (Brewster et al. 5). Furthermore, the experiment showed that user attention when using a menu system is too short to receive additional visual feedback. Extra graphical feedback works only when users are looking at it; if users have to interrupt their task in order to check additional graphics, usability decreases. The combination of sound and graphical interfaces can improve usability significantly.

Gaver developed the use of non-speech sounds such as Auditory Icons in computing environments (qtd. 7). Gaver's SonicFinder uses Auditory Icons which produce sounds for selecting, dragging, and copying items. He designed different bass sounds for different types of objects; a metallic sound for applications, a paper sound for folders, and a wooden sound for files. He also differentiated the pitch of sound to inform users whether an application was small or big (7). His experiments were not fully tested to prove the effect on usability, however they suggest how various sounds might be implemented in computing.

Improving website usability is even more crucial than general computing since the exact number of websites is virtually uncountable, competition is fierce, and users have high expectations. According to DOMO, 571 websites are created every minute (“DOMO”). As well, many research projects are web based, so increasing website usability is an important and growing consideration for research and knowledge advancement. Nielsen explains the importance of usability on websites:

> On the Web, usability is a necessary condition for survival. If a website is difficult to use, people leave. If the homepage fails to clearly state what a company offers and what users can do on the site, people leave. If users get lost on a website, they leave. If a website's information is hard to read or doesn't answer users' key questions, they leave. Note a pattern here? There's no such thing as a user reading a website manual or otherwise spending much time trying to figure out an interface. There are plenty of other websites available; leaving is the first line of defense when users encounter a difficulty (Nielsen 2012).

The appropriate use of sound on websites can significantly increase usability, but also can be a double-edged sword; it also has the possibility to simply add audio clutter and cause confusion. Thus, incorporating sound with appropriate graphics is very important to enhance usability. Figure 15 demonstrates how we can use sound effectively to increase usability. This website relies not only on sound to communicate to users but also uses attractive graphics to grab users' attention. Users can track the source of sound by examining the illustration, and control the existence of music on the website depending on their preference. By successfully incorporating sound with graphics this website will encourage users to stay longer and explore.

Figure 15. Using sound for usability

As previously mentioned, a lot of research projects in DH are web-based, however the use of sound in web-based DH research projects is rare relative to the use of graphics. Sound can not only work as an informative tool to demonstrate data but also to increase the chance users explore the details of projects on the website.

Good usability is a necessary, salient aspect of web design, and efforts to improve usability in computing are ongoing. An ever greater number of sites are being created by designers who can effectively control the use of different colors, fonts, shapes, and layouts in order to enhance usability. As well, more and more websites are utilizing usability testing to determine usability issues. Eye tracking, for instance, is an effective way to measure our gazing points. Figure 16 displays a heat-map showing where users eyes most often rest on a website. This method has been used to improve usability in computing for a long time, however eye tracking also suggests a limitation to our visual perception; it can primarilly process only a single visual item at once.

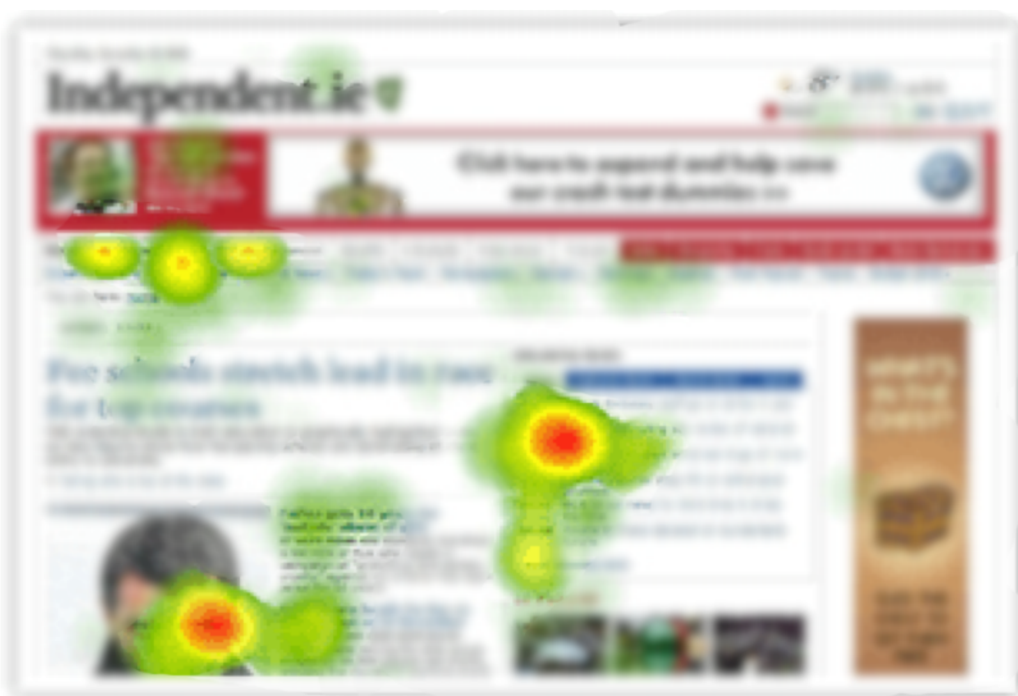

Figure 16. The use of Eye Tracking Tool

As graphics have potential limitations to usability, so too does sound. Sound for instance, has the potential to be ignored more easily than graphics. Incorporating multiple sensory systems in our computing environment has the potential for them to supplement each other's weaknesses. For example, motion detecting devices cannot effectively replace keyboards to type texts, but they can provide a more interactive and engaging experience than a keyboard alone. Hearing is one of our major sensory systems, and it has huge potential to be used in computing. The appropriate use of sound can augment the communication possibilities offered by our other senses, increasing engagement and usability.

In this section, I have asserted that sound can improve usability in computing by filling a gap which vision cannot, however using only sound as an interface also has limitations. Incorporating sound and visual elements together will allow users an opportunity to enjoy better usability in computing. Just as the use of touch screens changed our perception of normal computer interaction, addressing sound as an aspect of usability can further revolutionize that perception.

2.3 Interactivity

"Technology should bring more to our lives than the improved performance of tasks: it should add richness and enjoyment. A very good way to bring fun and enjoyment to our lives is to trust in the skill of artists. Fortunately, there are many around."
- Norman -

Interactivity is defined as “a measure of a media’s potential ability to let the user exert an influence on the content and/or form of the mediated communication” (Jensen 201). In computing, interactivity is different from a batch that runs programs without user involvement. “Batch applications are processed on the mainframe without user interaction. A batch job is submitted on the computer; the job reads and processes data in bulk— perhaps terabytes of data— and produces output, such as customer billing statements” (“IBM Kknowledge Center”).

Interactivity is an active form of user activity, and it is effective to increase user engagement. Interaction between users and products is quite important in terms of working efficiency even though it is invisible. Good interactivity provides users not only an understanding of the process but also fun, to motivate users. Barnum points out the relationship between effort and reward, and how users do not mind learning a few things when the rewards are bigger than the effort (Barnum 1). One of the goals of interactivity is minimizing the effort that users expend learning by providing an engaging environment. For example, video games have rules and goals to achieve. Depending on the interactivity in a game, users may or may not feel learning it is difficult. Some games implement a few interactive mechanisms which provide users an intuitive, step by step method to learn the game. Users will naturally learn things developers want to deliver by interacting with elements of the game, provided the environment is engaging.

Unlike the not-too-distant past, the number of existing applications and websites is uncountable. Today user expectations are focused not only on the functionality of applications but also on the intuitively enjoyable experience of interacting with them. Hence, without good interactivity, it is hard to get chosen by users. Contemporary interactivity represents a significant change from the traditional computing environment, especially on the web. Engaging interaction between computers and users increases user motivation, and can lengthen the amount of time they will dedicate to an application. When the users stay longer, providers have a chance to deliver more information to them.

Interactivity also helps to improve usability. Animation effects on a website, for instance, are used not only to catch users' attention but also to help users understand the process of what they are doing by providing instant feedback. Visualizations for example, have become much more effective since dynamic, online interaction became a reality. As we process more and more data, the importance of interactivity in visualizations increases as it becomes necessary to effectively display a huge range of data.

Building Hamiltonian Graphs from LCF Notation, for instance, provides a dynamic visualization environment. Users can change the settings of the visualization, and the changes are applied on the screen instantaneously (see Figure 17.). If users had a given analysis of data in the past, interactive visualization allows users to understand data based on any new settings they want to investigate. Furthermore, when the users drag the circle of visualization, it "moves". This "fun" feature also makes this visualization more playable.

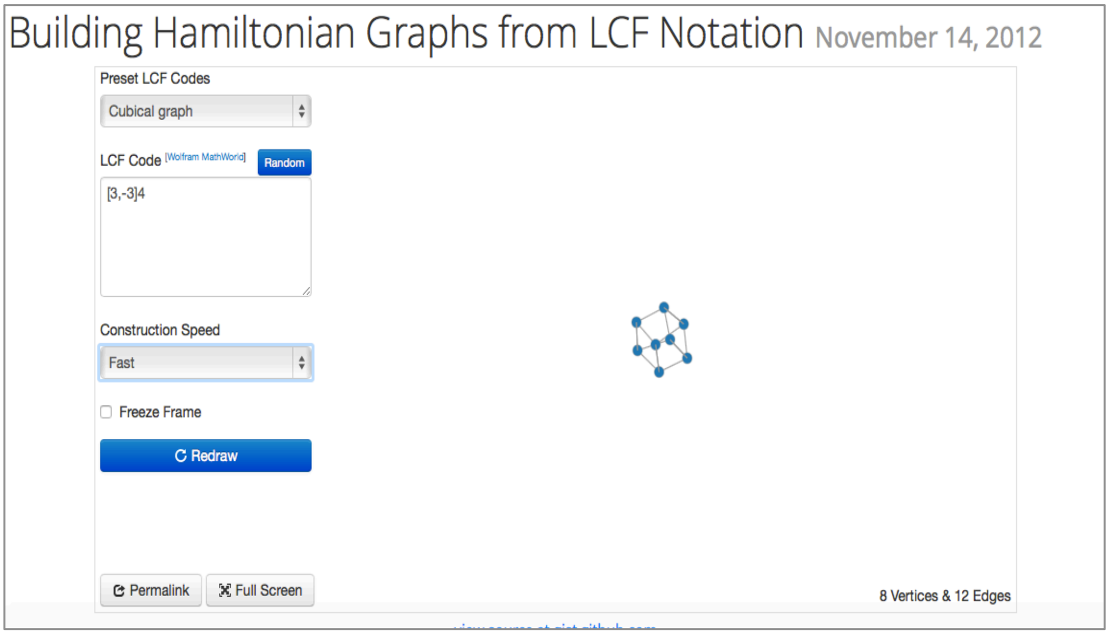

Figure 17. Interactive Visualization

In traditional computing, input and output devices were limited in variety; most input was by mouse and keyboard, and most output was by computer monitor. Improving interactivity via traditional input/output gadgets has limited possibility, however with the advent of today's mobile technology, computing is no longer limited only to the desk. Smartphones, tablets, even small wearable devices are computers that support more than simply the traditional input and output devices, providing interactivity in a new way. iBook on tablets, for instance, allows us both a familiar and a new experience as we navigate the digital pages with an analogue swipe of our finger.

Shoogle, a mobile phone application, is designed to inform users, using a variable pebble sound, of the presence of unread SMS when they shake their phone. *Myo Gesture Control Armband* demonstrates for us not only the potential amusement of interactivity but also the potential impact on our lives. As we can see from the Figure 18, users can play or stop the video by gestures.


Figure 18. Myo gesture Control Armband

Interactivity in gaming is on the rise. *Wii Fit*, from Nintendo is a videogame that provides interactive 'training' for sports such as yoga, aerobics, swimming, and soccer (see Figure 19.). The key to the success of *Wii Fit* is interactivity. Unlike other video tutorials, users can get instant feedback on their posture, and getting points motivates users. Furthermore, the interactivity of Wii Fit provides users a lot of fun, making it widely used for non-traditional purposes; it has been used, for instance, as a rehabilitation tool for physically impaired patients or the elderly.

Figure 19. Nintendo Wii Fit

As shown, the power of interactivity lies in user engagement. When interactivity is good, users are easily immersed, and sound is an effective immersion enhancer. In Bull's Walkman study and iPod study, Bull explains how listening to music allows users to manage their moods and experience (Bull 2000, 2007). People, for instance, might listen to music in a café to prepare themselves mentally before getting down to work. This feature of sound has the potential to greatly increase the amount of interactivity on websites.

Google is the most used web search tool in the world. The main interface of Google.com is relatively clean and simple; the only part we often see changes to is the logo at the centre of the website. Google presents a different logo look when they have a message they want to deliver. Figure 20 shows the logo designed by Google to celebrate the 96th birthday of guitar legend Les Paul. Google introduced this interactive doodle guitar with a message, “I hope you have as much fun playing with and sharing the doodle as we did making it.” This clean, simple illustration is both intuitive and engaging. Users can play the virtual guitar by hovering their mouse cursor over the strings. According to Google.com, 40 million songs were recorded with this virtual guitar in just 48 hours in the U.S. This illustrates sound’s possible impact on website interactivity (“Google.com”). Even relatively simple, interactive tools encourage users to explore websites.

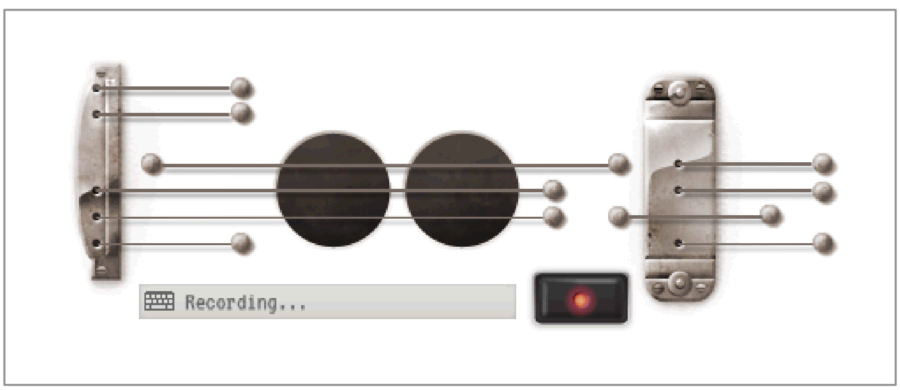

Figure 20. Interactivity on the website

As Schnapp et al. argue, the second wave of Digital Humanities need to be more qualitative, as opposed to the first wave’s focus on quantitative work (Schnapp et al. 2), which was often functional but not necessarily engaging; today’s computer user expects to be engaged. Since sound can affect mood, sensible use of sound can help improve a computer user’s interactivity experience, more effectively delivering information by engaging the user and maintaining their attention.

In this section, I have argued the importance of interactivity in helping users engage with tasks, and examined the potential benefits of sound in interactivity. Most Digital Humanities projects rely on visual elements such as animation to improve interactivity. However, as the example shows, engaging multiple sensory systems can be more effective at improving interactivity than engaging only a single sense. Since most computers already have speakers, incorporating sound is an easy, natural way to increase the benefits of interactivity.

2.4 Accessibility

"Accessible design is a design process in which the needs of people with disabilities are specifically considered. Accessibility sometimes refers to the characteristic that products, services, and facilities can be independently used by people with a variety of disabilities."
- Disabilities, Opportunities, Internetworking, and Technology (DO-IT), centre -

Disabled people should enjoy everything the abled enjoy, however in practice, this is rarely the case. We often merge the terms "Accessible Design" and "Universal Design", and while both terms include an aspect of helping the disabled, they are not entirely synonymous. In this section, I examine what is accessible design, and how current accessibility in computing affects people who are disabled. I also present an example which shows the benefit of combining coexisting visualization and sonification.

Accessible design aims at specific people while universal design pursues to include broader groups of people. With computers now such a large part of our lives, accessibility in computing should be regarded as an important component of hardware and sofware design. Currently, however, awareness of accessibility in the digital world is limited, and this creates a significant digital barrier for those with accessibility issues: the disabled, the elderly, children.

Sound alone is not likely to solve every accessibility issue, however in combination with our other major sensory systems, sound in digital applications can play a role in overcoming this barrier for many people. In the early 90s, Karshmer et al. experimented with using sound within navigation menus to help visually impaired users (qtd. Brewster et al. 7). The visually impaired cannot see the screen, so sound offers them a way to understand the navigation process. Different timbres were implemented in the menu; the pitch of sounds increased or decreased depending on the user's navigating, with the computer speaking the name of the menu when it is clicked. This is an example not only of the accesibility enhancing potential of sound in a digital application, but also of how tonal variety in sound might be used substantially in places where the use of tonal variety in color is for some reason ineffective. Our ability to perceive a range of sonic tones is similar to our ability to percieve a range of visual colors. By differentiating sound, users can be provided color information without having them need to see the screen. In Chapter 3.1 Sonification, I will discuss this feature more specifically with my prototype "Sonifyer of Visual Data."

Another example of accessible design was released in 2005; the HCIL (Human-Computer Interaction Lab) at the University of Maryland released *iSonic* (see Figure 21.), an interactive data sonification which, according to Zhao, H, et al., is designed to assist visually impaired users to explore georeferenced data. [7]

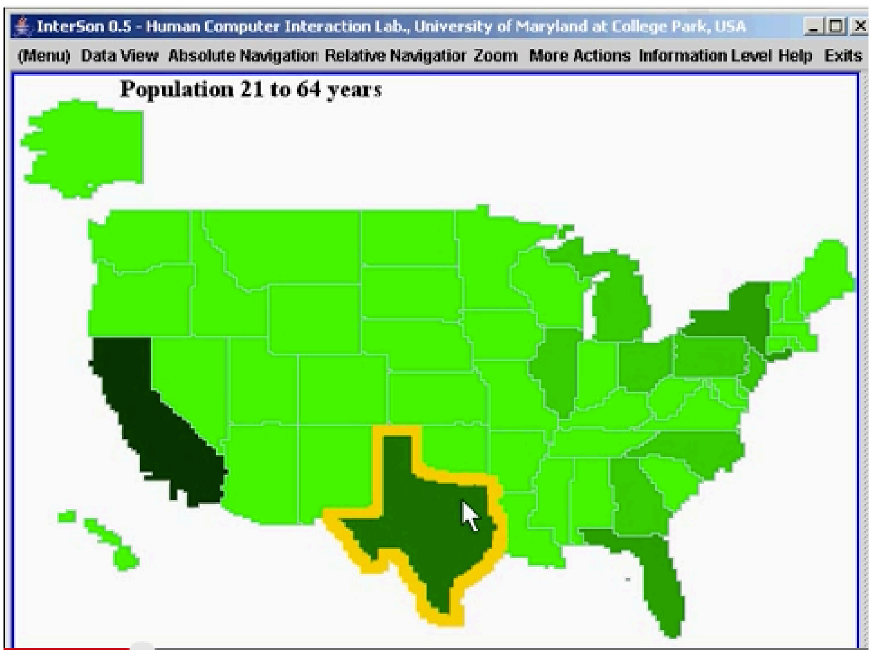

Figure 21. iSonic

> Sounds of various timbres and pitches are tied to map regions and other interface widgets to create a virtual auditory data display. The integrated use of musical sounds and speech allows users to grasp the overall data trends and to explore for more details.

---

[7] https://youtu.be/8hUIAnXtlc4

> Users use a standard computer keyboard, or a smooth surface touchpad when available, to interact with data. Examples of already implemented interactions include: (1) Automatically sweep to scan the map or the table to hear the data patterns; (2) Recursively partition the map into 3 by 3 ranges and use the keyboard number pad to explore each range, or use arrow keys to move among individual regions; (3) Glide a finger or press individual spots on a smooth surface touchpad to examine individual regions; The touchpad can be remapped to a partial map through zooming; (4) Dynamically adjust the auditory feedback information detail level. Our goal is to explore the design space by conducting user studies to identify effective sonification of choropleth maps and geo-referenced data, and examine the effectiveness of our tool in helping vision-impaired users. We also want to investigate the sonification of maps as a complement to visual maps for sighted users (e.g. to make "visible" the District of Columbia) (Zhao, H, et al. 1).

The use of sonification and audible data allows visually impaired users to experience the map *visualization*, and demonstrates how the use of audio elements do not lower the quality of existing visual elements, but instead help users understand data even more effectively as they are exposed to multiple, coordinated stimuli.

Technology develops quickly, and while ten year old *iSonic* would likely not satisfy today's users' expectations, it remains an example of the potential use of sound in improving accessibility in digital works, particularly in digital mapping. Digital mapping is a widely used technique in DH to display a variety of research topics on geographical maps. While embracing accessibility remains an elusive goal for many DH projects, improving accessibility would provide DH the opportunity to share research outcomes with a wider, more diverse audience. We need to ensure "our current digital resources continue to be not only useful but usable" (Williams 10).

Current vision based interfaces provide a potentially serious accessibility barrier for the web. According to W3C, "The Web is fundamentally designed to work for all people, whatever their hardware, software, language, culture, location, or physical or mental ability. When the Web meets this goal, it is accessible to people with a diverse range of hearing, movement, sight, and cognitive ability" ("W3C"). For this reason, websites should include alternative ways to provide information, like text tags and image descriptions. Most websites and web designers however, continue to focus their efforts almost solely on splendid graphics to catch the users' eye.

According to Williams, although scholars have been developing standards to preserve digital information for the future, there are a lack of efforts to accommodate the needs of disabled people. Hence, "many of the otherwise most valuable digital resources are useless for people who are blind, have low vision, or have difficulty distinguishing particular colors" (1). Inserting alternative text for images and keyboard input does not affect user's current visual experience, but tremendously helps people who are visually impaired.

It is true that more effective use of sound in digital applications will benefit almost everyone a little, but it will be hugely beneficial for only a limited number of people. However, incorporating digital sound more effectively will not only have an impact on improving current digital accessibility, but also help create a greater general awareness of the importance of accessibility. A more effective utilization of sound might act as a catalyst leading to more effective integration of all of our sensory systems in to our digital world, with a corresponding increase in overall accessibility.

Although DH provides users tools to analyze and understand data, the utilization of sound in those tools, whether for the purpose of improving accessibility or otherwise, is limited. As DH moves forward, sound can help improve the quality and utility of tools produced, among other ways, by helping assure accessibility for the widest audience possible. The long-term impact of improving accessibility, while perhaps not immediately visible, can help to share DH outcomes with, "as wide and diverse an audience as possible" (Williams 6).

One of the factors contributing to the lack of more widespread investment in accessibility is the high development cost relative to the perceived few beneficiaries. In the next section I will examine universal design, an ideology that could have a significant impact on current barriers in the digital world. Universal design champions the notion of "design for all" as a way to reduce perceived cost while greatly increasing accessibility. I will discuss the effectiveness of universal design by exploring examples in our lives, and by examining the potential of sound as a component of universal design.

2.5 Universality

Universal design is a broader concept that is defined by The Center for Universal Design at North Carolina State University as 'the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.'
- Disabilities, Opportunities, Internetworking, and Technology (DO-IT), centre -

While there have been many attempts to use sound in digital works for the specific benefit of the disabled, sound can and should be effectively implemented as an interactivity aid not only for *specific* users, but for *most* users. This is a key component of universal design which is greatly absent almost everywhere, including many projects in DH.

An often cited representative example of universal design is the "sidewalk curb cut." This design is universally beneficial whether one has an accessibility need or not. Visualization, text mining, and data analysis tools have developed significantly since the birth of DH, however we cannot say our developed tools include *universal design*.

First wave Digital Humanities developed innovative, powerful user tools, but was relatively unconcerned with accessibility. As the second wave of Digital

Humanities progresses, universal accessibility is an obstacle humanists must endeavor to overcome. Digital Humanities insists on the importance of openness in order to share knowledge with more people, and trying to include “more” people means designing for “all” people.

Not all accessibility enhanced designs can be called universal; some quality, perhaps cost or style related, might render the design undesirable by many potential users. William states, “Something created to assist a person with a disability - to make their environment more accessible in some way - might not be affordable or aesthetically pleasing even if it is usable and helpful” (Williams 3). He further explains that we design and produce tools to improve accessibility, but at the same time we also create other barriers to access. Universal design has the potential to improve this situation.

In 2013, a kickstarter project called *The Bradley,* inspired by paralympic swimming medalist Bradley Snyder, offers a successful universal-design centered solution to the problem solved by a traditional watch (see Figure 22.). Using two ball bearings instead of watch hands, people can read time using their fingers. Alone this is an interesting innovation, but what makes this watch really special is that it is designed for everyone’s use and enjoyment, not only the visually impaired. Every material and style choice was made to ensure the possibility of appeal to and, use by, the broadest group possible, disabled or otherwise.

Figure 22. *The Bradley*

Many cell phones have a function that speaks the time to users, but this is less effective in a noisy environment, and users feel they interfere with privacy. In their video "*The Current Market*", Jeffrey Drucker says "Blind people want to know the time without having the whole world know we are checking the time."

This point is worth noting. We frequently create tools, facilities, and signs for people with specific accessibility requirements, while disregarding those same people's experiences outside their accessibility requirement. In other words, we sometimes try to limit one form of discrimination, only to create another. The significance of universal design lies both in potential economic benefit, and in providing everyone equal access and experience without physical or emotional obstruction. *The Bradley* demonstrates how incorporating more of our sensory systems into our digital tools can make them more universal, that is, equally desirable and usable by the greatest number of people.

Xylophone Cup is a great example demonstrating how incorporating sound into design can help even analogue products to be universal. Pouring water in a cup might be a simple task, but what if one cannot see? Visually impaired people usually put one of their fingers in a cup to know when to stop filling it. This is a fine solution unless the water is hot. As we can see from Figure 23, the handle of the cup rotates and creates a “ding” sound when the cup is filled. This sound notification provides not only useful information to the visually impaired, it also adds a layer of “fun” and “interactivity” to the user’s experience.

Figure 23. *Xylophone Cup*

The importance and potential impact of widespread implementation of universal design in the digital world grows each year as computers become an ever more integrated and important facet of our lives. *Siri* is an example of contemporary digital design that strives for maximum universality. *Siri* provides users a human voice controlled digital interface that is helpful to not only visually impaired users but also general users by increasing the interactivity and intuitiveness of input and output methods (see Figure 24.).

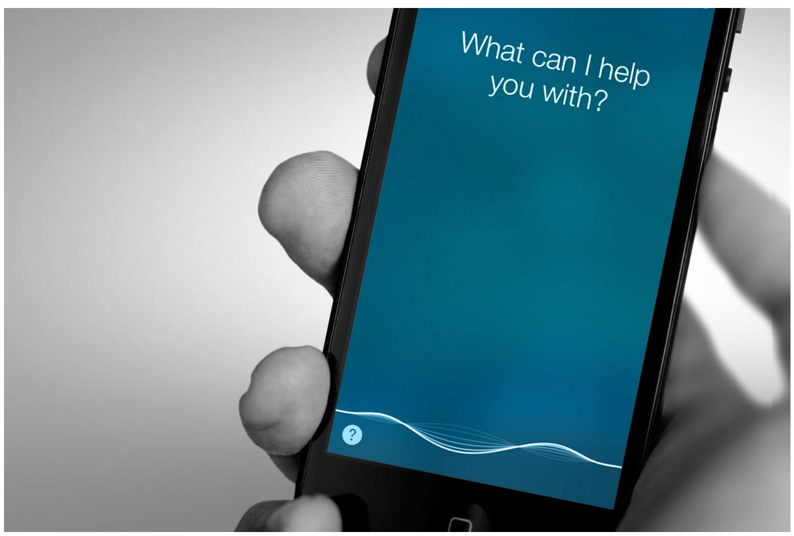

Figure 24. *Siri*

While no design will likely ever be truly "universal," the power of universal design thinking to increase awareness of often overlooked social inequities should not be underestimated. Awareness is a necessary component of not all change, but certainly of purposeful change. The development of smartphones, for example, can be explained as the result of technology, but it is also a reflection of identified needs.

In DH, openness and sharing are considered needs as important as knowledge development itself. Borgman argues, "openness matters for the digital humanities for reasons of interoperability, discovery, usability, and reusability" (qtd. Spiro 9). For this reason, we often see openness in DH; open-source software, free digital collections, and open-access journals to name a few examples. This open-source data helps us share knowledge. As Williams points out however, "inaccessible design choices remain a significant barrier to information for disabled people" (Williams 6). In order to realize true "openness," digital humanists must include universal design principles in their work.

In this section, I have argued the potential of sound to improve accessibility as a component of universal design, though in no way does this imply that sound in computing is limited only to helping the disabled. Some digital functionality is certainly designed for specific users, however as universal design insists, we need to develop functions which can benefit everyone. In the next chapter, I will discuss the features and the potential uses of sonification. I will also explore eight sonification techniques suggested by Grond and Hermann (2012), in order to demonstrate the application of sonification in DH.

Chapter 3. Applying Sound in computing

In this chapter, I examine the use of sonification in a number of fields in the arts and sciences, and demonstrate how collaboration can fill the gap between functional success and aesthetic success in the application of sonification. I then discuss existing forms of digital sonification including auditory icons, earcons, and audification in order to provide readers context for understanding the potential of sonification in general computing, and provide an original experiment as an example of both the potential of sonification in DH, and a reminder of the limitations of working alone. I explore the prototype I created, "Sonifyer of Visual Data," to discuss the potential use of sound as well as demonstrate the significance of collaboration. Finally, I present aesthetic strategies of sonification in order to suggest appropriate uses of sound in digital media.

3.1 Sonification

"Sound design is the art of getting the right sound in the right place at the right time."
- Tomlinson Holman -

Kramer defines sonification as an interdisciplinary method "ranging from scientific applications to sound art and composition" (qtd. Grond and Hermann 1). Sonification has been used for 20 years in many fields: data analysis, monitoring systems, and navigation systems. Although sonification has been used widely for a long time, the effort to collaborate with other fields has been weak which can make a great impact.

Weinberg and Thatcher state, “Sonification of data has been found effective, utilizing the auditory system’s unique strengths, such as wide spatial cover and aptitude for pattern recognition” (Weinberg and Thatcher 9). Interactive sonification systems have been developed to help users with things like dataset queries, but not to support dynamic interactions that satisfy both functional and aesthetic requirements.

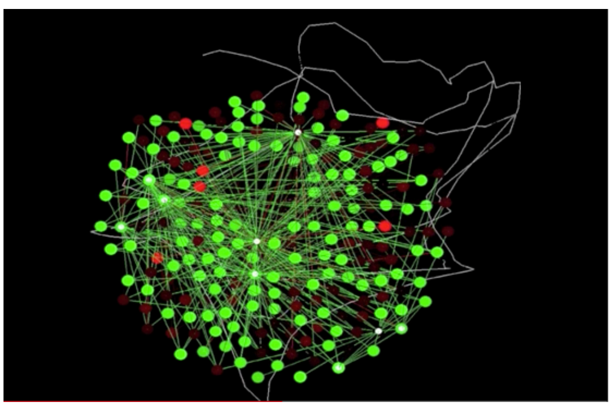

Figure 25. Musical Sonification of brain activity

Figure 25 is an example of sonification use in science, where a musical melody is generated depending on brain activity. The changing speed and melody allows people to see and hear how a brain signal moves in real time. Both visual and audible interactions allow the user to perceive the invisible data in different and powerful ways; both sight and sound are capable of representing spatial information, yet we experience them differently.

Although a term now widely used in many fields, sonification was originally defined as the acoustic representation of data. Sinclair states, “Over recent years, the use of data sonification has become increasingly widespread” (Sinclair 1). We are learning to use things like clicks, beeps, varying pitches or chords as carriers of important information, in the same way we know to pull over when we hear a siren while driving.

Gresham-Lancaster and Sinclair suggest expanded terminologies of sonification to help us understand it:

- *Auditory Icons*, mentioned earlier in Chapter 2.2*,* have a symbolic relationship to a represented action; and example is the icon for the Trash on a PC, which, when activated, produces the sound of crumpled paper falling in a wastepaper bin.
- *Earcons* are usually short tones, combinations of tones or simple melodies (e.g. the jingle preceding and announcement on the PA of a train station).
- *Mapping-Based Sonification* refers to data that directly modifies parameters of a sound such as pitch or amplitude. An example found in the medical domain is the pulse-oximeter, which monitors the patient’s blood oxygen saturation as pitch, and pulse rate as tempo.
- *ReMapping* refers to information encoded as a perturbation of parameters in an audio source. The output of a given and possibly familiar sound

source is modified by the time series data flow, giving the listener information through this channel, which is made as a layer of a familiar acoustic and/or musical environment.

- *Audification* is the direct transposition or transduction of a signal into the audio domain-think of audio-biofeedback, where sensors connected to a subject's muscles or skull capture electrical impulses, which are then directly amplified and played through a loudspeaker as an audio signal (usually crackly or noisy) (Gresham-Lancaster and Sinclair 68).

The above examples suggest the importance of using sound in a manner appropriate to its purpose. Put another way, it is important that the application of sound in digital works follow the design principle that form ought to follow function.

In visualization, avoiding unintentional bias is very important. Visual designers can affect meaning by manipulating colors, shapes, and size, and sonification is no different. How a sound is designed and applied can change our perception of data. We seek the perception of sound based on our experience in natural or cultural contexts (Grond and Hermann 1). Negotiating between limitations of the data and how a sound is used in sonification is a necessary balancing act, as poor sound design risks leaving users dissatisfied and confused.

Good sound design for data sonification often involves consideration of not only the aesthetics of sound, but also unbiased interpretation of data. *Two Trains* is a sonification of income inequality in New York (see Appendix A.).

Using an interactive map of the New York City subway, the user travels the city, with the sound changing to reflect the income level of the current neighbourhood. In order to avoid causing offense, Foo explains that he focused on making differences of volume and dynamics from given data rather than finding a sound which represents the rich or the poor.

> At any given time, the quantity and dynamics of the song's instruments correspond to the median household income of that area. For example, as you pass through a wealthier area such as the Financial District, the instruments you hear in the song will increase in quantity, volume, and force (Foo).

Figure 26. Two Trains

Two Trains is a good example of how data can be presented audibly. It also serves to demonstrate the great potential of sonification to mutually benefit visualization since they both offer unique features. Effectively creating a harmony between sonification and visualization can significantly impact usability. If some amount of data can be communicated audibly, it stands to reason that less information remains to be displayed on screen, leading to less distraction and more efficient information communication (see Figure 26.).

Social media is a relatively frequent research subject and source of research data in DH. Twitter for example, is widely used as a research tool to understand social phenomena. Figure 27 is an example of how a text corpus can be used to generate sounds. This sonification plays sounds algorithmically based on the appearance of target words in tweets. [8]The example sonification plays sounds when the word “Osama” appears in tweets. The corpus is comprised of tweets collected May 10, 2011, shortly after Osama bin Laden’s death, and the tempo of the sounds, when played back, provides a unique, and immediate understanding of the explosion of this topic over a very brief time.

Figure 27. Sonification of Twitter

[8] https://youtu.be/MUsBeJoBRxw

This example illustrates that text data can be demonstrated in different ways, including audibly, with sometimes serendipitous effects. According to Lindroth, this sonification does not “express the subject matter of the tweets. Rather, it represents the communities that grow around particular twitter messages” (Lindroth).

Prototype: Sonifyer of Visual Data

In the previous chapter, I have argued that sound can improve usability, interactivity, accessibility, and universality of DH projects. The potential use of sound in DH is great, because DH is so broadly interdisciplinary. In the prototype my focus is on creating a connection between colors and sounds to provide users an engaging environment while on task.

Motivation

As a graphic designer, I have worked on many illustrations and websites. In order to create good design, I need to consider many things such as typeface, color, layout, dimensions, and empty space. All elements are important, however color is the most important factor I consider in visual communication. Color is a powerful tool that affects people’s mood. Hospitals for instance, do not use a lot of purple since purple tends to decrease patients’ spirits.

People do not absorb all the details on a screen at a glance; they see the whole screen first, and get into details later. Color is the first thing most people notice, and it affects their first impression of any task. People associate colors with particular feelings, or concepts, what visual communicators refer to as warm and cold. Figure 28 illustrates how these colors exist in relation to one another on the color wheel. People expect to be presented with colors that are appropriate to their emotional experience, and they find it disconcerting or confusing when their visual experience does not match their expectation. Sound works similarly to color in this respect. Major chords influence the audience to feel bright, happy, and joyful while minor chords change people's mood to sad, depressed, and melancholy.

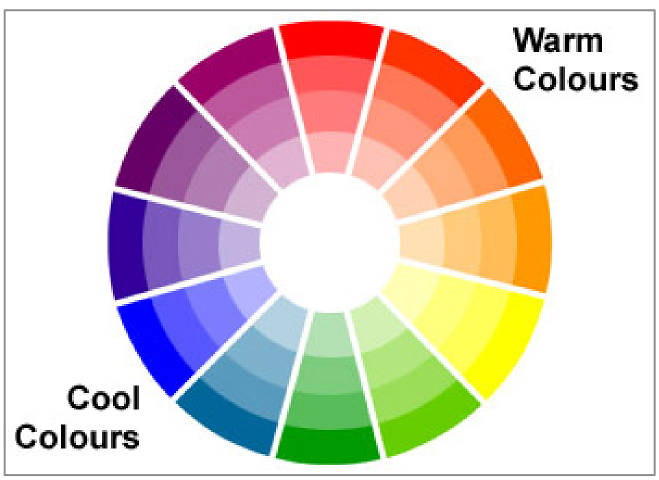

Figure 28. Warm and Cool colors

Goal of the prototype

I hypothesize that these similarities between color and sound can be combined in a sonification which will help users engage with their task. The goal of this prototype is creating a sonification that converts the colors of visual inputs to sounds, increasing engagement and offering an alternative form of perception.

Related work

Synesthesia is a psychological phenomenon which demonstrates the relationship between colors and sounds. Palmeri et al. define synesthesia as, "an anomalous blending of the senses in which the stimulation of one modality simultaneously produces sensation in a different modality" (qtd. "Scientific American"). Synesthetes hear colors, feel sounds and taste shapes. There have been some research outcomes which study synesthetes, however outcomes are subjective; different people interpret colors as different sounds. I decided to create my own pattern interpretation tool, using my experience as a graphic designer.

Method

The prototype was created in Max, "a visual programming language for media" produced by Cycling 74 (see Figure 29.). Users can use a webcam or image files to generate sounds using the following steps: (1) Pixelate the visual inputs (e.g. 80 by 60) in order to decide the length of sonification process; (2) Analyze the color of each pixel to obtain RGB (Red, Green, Blue) numbers; (3)

Change the scale of these numbers in order to avoid generating extremely high or low pitches; (4) Create a chord based on the dominant color of each pixel; (5) Generate three different sounds, and allow users to enable or disable each; (6) Generate a noise when the RGB numbers have one dominant number; (7) Allow users to designate the point in the image where the sonification begins (see Appendix B.).

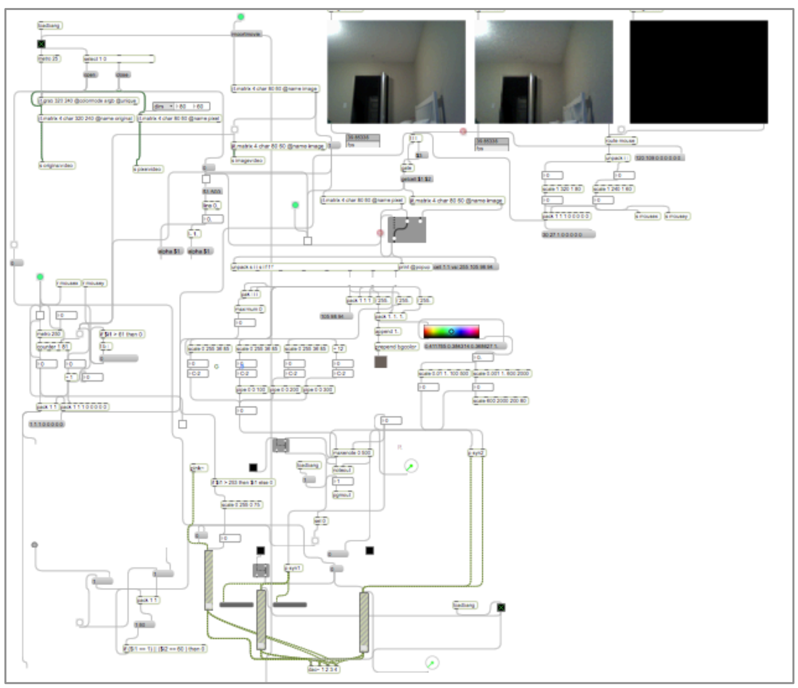

Figure 29. The patch of Sonifyer of Visual Data

Results

My initial goal of "Sonifyer of Visual Data" was to create a sonification application which could interpret an entire image, and generate a melody representing the image overall, rather than playing sound pixel by pixel (see Figure 30.). Creating the necessary algorithms required quite advanced programming skills however, and matching those algorithms to musical chords required an additional understanding of music and sound composition theory. For these reasons I had to find an alternate way which required less programming and musical skills.

In December 2014, this prototype was introduced to the public for the first and only time at a concert in a music studio, at the University of Alberta. Around thirty people participated, and their response suggested the importance of finding the right connection between data and sound feedback, and by extension, visual feedback as well. Many people were very interested in hearing colors, and some even tried to hear their outfit through the camera input, but most ultimately expressed feeling a disconnect between the sound they were presented with, and their expectations. Furthermore, they provided a few suggestions regarding what they hoped to see on the next version. The initial version, for example, provides only three different types of sounds, while people expressed a desire for many more sound options. As well, participants suggested my initial goal, the interpretation and representation of the image as a whole, would have been much better received.

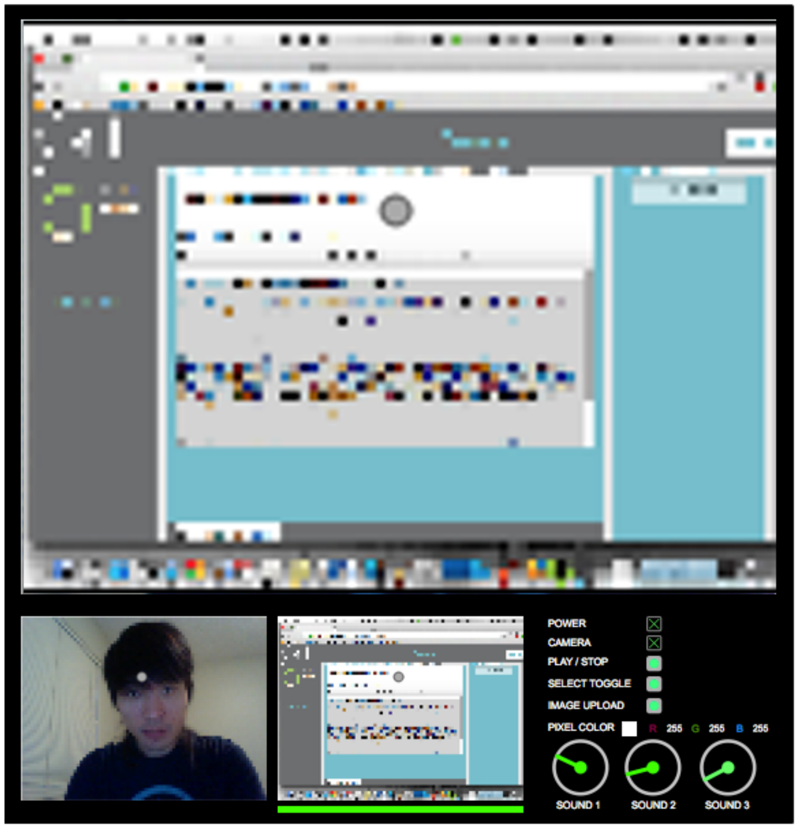

Figure 30. The interface of Sonifyer of Visual Data

Conclusion

This prototype was used only once in public, so it is hard to generalize test results, however it certainly demonstrates that people are interested in sound, and proves sonification has the potential to attract users and help them engage with their tasks. Furthermore, as we incorporate more visual data into a variety of DH research, analyzing visual data becomes more and more important. Providing appropriate, engaging sound design can offer users an effective way to not only see, but also hear and feel data as well.

This prototype was designed and made by me from beginning to end. As a graphic designer, I have participated in many visualization projects in DH; however my experience with sound was new. I was able to provide a clear, effective interface, but as an expert in only one field of this interdisciplinary project, writing code to strike a balance between visual form and audio function proved challenging. In order to make a connection between colors and sounds, I had to acquire programming skills in order to analyze numbers to create functional and smooth algorithms. While showing potential, the prototype highlighted the importance of collaboration with subject matter experts, in this case sound designers, by exposing the potential of inadequate sound design to create dissatisfaction in the user.

In this section, I have explained sonification and how it can have a significant impact when combined with visual elements in computing. This approach to interactivity in sonification can provide artistic, scientific, and educational benefits. One big challenge is how we balance our objective scientific goal with subjective aesthetic desire (Weinber and Thatcher 11). In order to make sonification more applicable and widely useful, Grond and Hermann suggest eight aspects of sonification that help listeners engage in different ways. In the following section, I will examine aesthetic strategies of sonification in order to show how we can utilize sound in computing.

3.2 Aesthetic strategies

Sound in computing can help primary users understand process but can also be an annoyance to secondary users. Well designed sound can inform users, but is likely to confuse users when it is poorly designed. Hence, when we design sonification, applying a technique that is suitable given a project's needs is very important. Grond and Hermann suggest eight strategies of sonification that help listeners engage in different ways. I define and discuss each below with examples (Grond and Hermann 2012).

(1) Elicited sounds

Interactive sonification is frequently utilized in the area of new musical interfaces. Due to the intimate connection between the nature of sound and the action which elicited it, listeners will try to deduce a sound's cause. Shoogle, a mobile phone application, is an example of interactive sonification. Shaking your phone produces the sound of pebbles which represent unread SMS. Appropriately designed elicited sounds can be an effective method of increasing user interaction. A developer for instance, might implement an interesting sound on a portion of a web-based project they want to emphasize, in order to capture user attention.

(2) Repeated sounds

Repetition, which generates similarity and difference, is an important characteristic of sonification. Auscultation for example, is a popular way to diagnose our body using the repetitive sounds from your heart and lungs. Whether or not we have the musical skills to recognize pitch, chords, or intervals, the similarities and differences in sound repetition can be widely and easily used for analysis. As demonstrated by Tweet scraping example in Figure 27, this technique can be applied to the analysis of big data; expressing data via sound interval and repetition, allows users to experience the frequency of the target word in a data set.

(3) Conceptual sounds

In 1965, Alvin Lucier designed "*Music for Solo Performer*", an installation sound-art piece. In it, brain waves were amplified and turned into acoustic signals, activating a loudspeaker, which then caused percussion instruments to emit sound. In this performance, no specific data were used to make the brain signals, only the random thoughts and mental processes of the performer. Lucier argues that "the conceptual aspect of sound as a metaphor or medium is reinforced by the fact that we do not hear the sound directly from the speaker but only its reinterpretation through the percussion instrument" (Grond and Hermann 216). Conceptual sounds demonstrate the potential of experiencing "data-inspired" sound rather than systematical sound.

(4) Technologically mediated sounds

When we listen to natural sound through technological gadgets such as walkman, disk-man, or *iPod*, we perceive not only natural sounds but also sounds both genrated and mediated by technology. “It is not the sound itself that catches our attention,” say Grond and Hermann, “ but the technological apparatus that produces or projects it” (Grond and Hermann 216). Technology is an enabling factor in sonification. A lot of people are concerned that mobile devices ability to deliver clear audio is too limited to be used for research, however as the example demonstrates, audiences perceived sounds include noise from “technological apparatus.” Technologically mediated sounds can work as contextual sign posts.

(5) Melodic sounds, cultural aspects

Melody and music are more related to aesthetics than other aspects of sonification. Melodic sounds can help users to understand the process of their actions. *Auditory icons* and *earcons,* discussed earlier in Chapter 2.2 and 3.1*,* show how melodic arrangements can fill an understanding gap between the user’s actions and the process of non-existing objects. Auditory icons are defined “as sounds that naturally occur with a certain action or are readily associated with it” (217). For example, the sound a computer makes when a user deletes a file; paper thrown into the trash. Earcons are defined “as sonic proxies for actions that have no natural sounding reference” (217). For example, the musical sound of an OS booting up, a warning beep, or the negative honk indicating an error. This sonification technique can be widely used in DH to improve interactivity. For example, a relevant melodic sound experienced while exploring a visualization can improve usability and increase user efficiency.

(6) Familiar sounds

The notion of familiarity in sonification refers to sounds we have heard before. The familiarity of a sound can be unclear because our perception of familiarity can change over time. Audification is "the most direct conversion of measurements into sound" (Grond and Hermann 218). This technique can be used to convert inaudible data into something interpretable by the human ear. Figure 6 offers an example of how earthquakes can be perceived by human ears using auditication techniques. A lot of sound data in nature is ignored since it is not audible to humans. As I mentioned in Chapter 2.1, audification techniques not only allow us to hear data but also provide an opportunity to demonstrate scientific data in an artistic way.

(7) Multimodal sounds

Sonification is often presented with visualizations. According to Guttman et al., ears overrule what eyes can see when stimuli are rhythmical. Audiences always try to find a visual source for what they hear from multiple stimuli (qtd. 219). The installation *Intermittent* (2006), developed by Florian Grond and Claudia Robles, shows people viewing simultaneous audio and video from independent sources;

the sounds are not related to the video. The people in the video try to find the visual cause of the sound after noticing both audio and video sources share the same rhythm. This installation demonstrates how audio overrides the visual with rhythmical stimuli. Multimodal sounds further demonstrate the potential of sound as an engaging interactivity enhancer when used in conjunction with graphic elements.

(8) Vocal sounds

The human voice still has an important role in sonification even though sonification is defined as non-speech sound for delivering information (Grond and Hermann 220). *Spearcons*, for instance, are designed for connecting auditory icons and earcons. Spearcons, designed to aid the visually impaired, speak menu items at a very fast speed. Not only does this sonification technique makes it easy to identify similar items on a list, such as “save” and “save as,” the sound of a human voice is particularly meaningful to people, and a vocal sonification is not regarded as simply a technological artifact. As I argued in Chapter 2.4, accessibility is an important goal which DH needs to pursue in order to fully embrace a true diversity of users, and the use of vocal sounds in sonifications could be a means of improving accessibility for many projects in DH.

Sound can be disruptive

We all have probably experienced studying in a quiet space like a library, and noticing the sound of someone else's booting computer, even if we do not see them. If you are more sensitive, you can even guess if they are using Mac or Windows. In the past, computers were mostly used in a private space. Using computers, including smartphones and tablets, in a public space is common today, however, the practice of utilizing sound in a public space is less well developed. Using sound in a public space, for instance, can be an annoyance. Inappropriate uses of sound can disturb primary users as well as secondary users even if the sound is informative. Berglund et al., define the annoyance of sound as "a feeling of displeasure associated with any agent or condition known or believed by an individual or a group to be adversely affecting them" (qtd. Brewster et al. 8). Berglund et al. describe the appropriate level of sound as the level of noise of a hard disk, however the introduction of the Solid State Drive (SSD) will force us to reevaluate this standard.

Edworthy et al. suggest a hardware technique to avoid sound annoyance. Much as a computer screen detects the brightness of the room in order to find the proper brightness for the display, so can the volume of sound be modified in a similar way. If the room gets noisy, for example, the volume of sound can be adjusted to accommodate the increased noise (qtd. 11). Furthermore, Buxton et al. (1991) report sound designers often make a loud sound to grab user attention, however, this method is not always desirable since loud sounds can annoy secondary users. Manipulating sound parameters can be a solution to grab user attention. Changing a rhythm or pitch, for example, can notify users sufficiently since the human auditory system is good at recognizing changes in dynamic stimuli (qtd. Brewster et al. 11).

The history of portable computing is short relative to that of desktop computing, and relatively little research has yet been performed surrounding effective utilization of sound. However, because sound offers a huge potential benefit to computing, we need to think about how we can maximize benefits, and minimize side effects.

The goal of sonification is providing users a new way to perceive information. Just as well-designed graphics help us engage with visual information, aesthetics in sonification are equally important. Furthermore, as with visual elements, the use of sound can be a double-edged sword; implementing sound in a right place can greatly improve usability, while implementing sound in the wrong place can lead to unnecessary distraction and confusion.

In this chapter, I have examined some current uses of sonification and argued for its use in DH. I have explored aesthetic strategies of sonification, and discussed "Sonifyer of Visual Data" which demonstrates how visual data can be converted to sounds, and illustrates the importance of collaboration in interdisciplinary DH projects.

Conclusion

"If you don't imagine, nothing ever happens at all."
- John Green -

In the "Where good ideas come from" of Ted talk, Johnson shares the history of GPS. In 1957, Sputnik 1 was launched, and around twenty researchers gathered in a coffeehouse to talk about this great scientific achievement. One of them suggested listening to the sound of the satellite because he thought it would be interesting. Fortunately, another knew how to set up an antenna and amplifier, so they started to listen and began to record the time of the bleep sound. By analyzing the pattern of the sound, they calculated the orbital speed and location of the satellite, and the idea for GPS was born.

Johnson describes the coffeehouse as "a space where people would get together from different backgrounds, different fields of expertise, and share" (Johnson 2010). If we think about our current level of technology, the invention of GPS is not special. Even if the scholars did not drink coffee and talk about the satellite at that time, someone would invent it eventually. What the coffeehouse story tells us is the huge benefit of sharing knowledge among people with different areas of expertise. Johnson states, " [It is] a great lesson in the power, the marvelous, kind of unplanned emergent, unpredictable power of open innovative systems. When you build them right, they will be led to completely new directions that the creator never even dreamed of" (Johnson 2010).

Researchers in Digital Humanities have proven the power of collaboration, with innovative and powerful solutions to visualization, text mining, and digital mapping problems. While researchers are aware of the significance of diversified knowledge, and the potential of collaborating with experts in different fields is tremendous, hurdles such as conflicting academic credit and criteria remain. Spiro mentions, "Many humanities departments favor solo work in their tenure and promotion Pollicies and may find it difficult to determine how to assign credit for collaborative work" (Sprio 16). However, the world is changing, we have no doubt this change will continue as technology keeps developing, and interdisciplinary studies has become an important to key to getting past the current limitations.

Sonification has been used in general computing for a long time (Gresham-Lancaster and Sinclair 67). A good use of sonification can provide us a new perspective to understand data, and though its effects may be significant, the effort to apply sonification to research has been deficient. Sound can offer us a new perspective on a variety of areas in computing. Integrating sound studies with interdisciplinary studies might be slow in the beginning, however just as a collaborative group of researchers came up with the idea for GPS, a new perspective on sound may provide Digital Humanists with inspiration to address a variety of issues.

Current tools in DH can be improved in many ways. Visualization, for example, can deliver information in a more effective way when combined with sound rather than when using only graphical elements such as color, size, and shape. Augmented reality fields can provide users with more informative and engaging environments, helping users perceive a virtual space not only visually but also audibly. While sound can be utilized to enhance current tools, its real power lies in the possibilities provided by combining sound technologies in new interdisciplinary projects. Breaking the wall to sound will help DH embrace more diversified work, and applying various specialized areas of knowledge to problems both old and new, will help discover completely different solutions.

When the touch screen was introduced, no one expected the impact it would have on our digital experience. Even if we have a good idea, sometimes our technology is not up to realizing it, and when it was introduced, touch-screen technology was nowhere near as smooth as it is today. As Green says, imagining is the first step to making things happen (Green 346). While the use of sound might initially be rudimentary, and there are limitations to the quality of sound recorded and produced by our computers, tablets and smartphones, our interest and ability will drive industry to meet our needs, providing us with tools that will inspire our interest and ability even more.

Works Cited

"Auăleu." Auăleu. Auăleu Theatre, n.d. Web.

Azuma, Ronald, et al. "Recent Advances In Augmented Reality." *IEEE Computer Graphics And Applications* 6 (2001): 34. *General OneFile*. Print.

Barnum, Carol M. Usability Testing Essentials: Ready, Set-- Test / Carol Barnum. n.p.: Burlington, MA : Morgan Kaufmann Publishers, 2010. Print.

Behrendt, Frauke. "The Sound Of Locative Media." *Convergence: The Journal Of Research Into New Media Technologies* 18.3 (2012): 283-295. *Communication & Mass Media Complete*. Print.

BERGLUND, Birgitta [b1 b2] (analytic), Kathleen [b1 b2] (analytic) HARDER, and Anna [b3 b4] (analytic) PREIS. "Annoyance Perception Of Sound And Information Extraction (English)." *The Journal Of The Acoustical Society Of America* 95.3 (0001): 1501-1509. *FRANCIS*. Print.

Bluebrain. "BLUEBRAIN: THE NATIONAL MALL." *BLUEBRAIN: THE NATIONAL MALL*. Bluebrain, 2011. Web. 23 Apr. 2015.

Borgman, Christine L. "The Digital Future Is Now: A Call to Action for the Humanities." *Digital Humanities Quarterly* 3.4, 2009. Print.

Brewster, Stephen A., and Murray G. Crease. "Correcting Menu Usability Problems With Sound." *Behaviour & Information Technology* 18.3 (1999): 165-177. *Business Source Complete*. Print.

Brewster, S. A., P. C. Wright, and A. D. N. Edwards. "The Design And Evaluation Of An Auditory-Enhanced Scrollbar." *Chi -Conference-* (1994): 173. *British Library Document Supply Centre Inside Serials & Conference Proceedings*. Print.

Bull, Michael. *Sound Moves : Ipod Culture And Urban Experience*. n.p.: New York : Routledge, 2007. Print.

Bull, Michael. *Sounding Out The City : Personal Stereos And The Management Of Everyday Life*. n.p.: Oxford ; New York : Berg, 2000. Print.

Burnham, Ted. "Audio Smart Home Security: Point- Postscapes." Postscapes. Postscapes, n.d. Web. 23 Apr. 2015.

Buxton et al. "The use of non-speech audio at the interface." *Proceedings of ACM CHI'91 (ACM Press, Addison-Wesley)*, 1991. Print.

"Colour." Aberdeen Quest. N.p., n.d. Web. 23 Apr. 2015.

"Cycling '74 Max 7." Cycling '74: Makers of Max. N.p., n.d. Web. 23 Apr. 2015.

Davidson, Cathy N., and David Theo Goldberg. *The Future Of Thinking.: Learning Institutions In A Digital Age*. n.p.: Cambridge, Mass. : MIT Press, c2010. Print.

de la Motte-Haber, Helga " Sound-spaces-fields-objects." In: Leitner B (ed.) Sound, Space. Ostfildern: Hatje Cantz Verlag, 1998. Print.

"Disabilities, Opportunities, Internetworking, and Technology." *DO-IT*. University of Washington, 2013. Web. 23 Apr. 2015.

Dombois, F.: "Using Audification in Planetary Seismology", in *Proceedings of the 2001 International Conference on Auditory Display*, Espoo, Finnland, 29/07/2001–01/08/2001, pp. 227–230. Print.

Dumas, Roger. "Musical Sonification of Brain Activity." *YouTube*. YouTube, 22 Oct. 2013. Web. 23 Apr. 2015.

Edworthy et al. "Improving Auditory Warning Design : Relationship Between Warning Sound Parameters And Perceived Urgency (English)." *Human Factors* 33.2 (0001): 205-231. *FRANCIS*. Print.

"EONE - Design for Everyone." *EONE - Design for Everyone*. Eone Timepieces, 2013. Web. 23 Apr. 2015.

Foo, Brian. "Data-Driven DJ | Two Trains." *Data-Driven DJ*. Brian Foo, 2 Feb. 2015. Web. 23 Apr. 2015.

Gaver, William W. "Auditory Icons: Using Sound In Computer Interfaces." *Human-Computer Interaction* 2.2 (1986): 167. *Business Source Complete*. Print.

Gaver, William W. "The Sonicfinder: An Interface That Uses Auditory Icons." *Human-Computer Interaction* 4.1 (1989): 67. *Business Source Complete*. Print.

Gaver, W. W. "Using And Creating Auditory Icons." *Santa Fe Institute Studies In The Sciences Of Complexity -Proceedings Volume-* 18.(1994): 417. *British Library Document Supply Centre Inside Serials & Conference Proceedings*. Print.

Gaver, William W. "Synthesizing Auditory Icons." *Proceedings Of The Interact '93 & Chi '93 Conference: Human Factors In Computing Systems* (1993): 228. *Publisher Provided Full Text Searching File*. Print.

Green, John. *Paper Towns*. n.p.: New York : Speak, 2012, c2008., 2012. Print.

"Where Good Ideas Come from." *Steven Johnson:*. TED, 2010. Web. 23 Apr. 2015.

Grond, Florian. "Intermittent." *FLORIAN GROND*. FLORIAN GROND, 2006. Web. 23 Apr. 2015.

Grond, Florian, and Thomas Hermann. "Aesthetic Strategies In Sonification." *AI & Society* 2 (2012): 213. *Academic OneFile*. Print.

Gresham-Lancaster, Scot, and Peter Sinclair. "Sonification And Acoustic Environments." *Leonardo Music Journal* 1 (2012): 67. *Project MUSE*. Print.

Guttman, Sharon E., Lee A. Gilroy, and Randolph Blake. "Hearing What The Eyes See." *Psychological Science (Wiley-Blackwell)* 16.3 (2005): 228-235. *SPORTDiscus with Full Text*. Print.

Hahn, Jason. "Everything You Say to Siri, Cortana and Samsung Phones May Be Heard by a Human Being." Digital Trends. N.p. N.d. Web. 23 Apr. 2015.

"History of the Graphical User Interface." Wikipedia. Wikimedia Foundation, n.d. Web. 23 Apr. 2015.

Holman, Tomlinson. *Sound For Film And Television.* n.p.: Burlington, MA : Focal Press, c2010. Print.

Homing in on the Human Element. David Flynn, 6 Apr. 2006. Print.

"IBM Knowledge Center." *IBM Knowledge Center*. International Business Machines Corporation, 2005. Web. 23 Apr. 2015.

James, Josh. "How Much Data Is Created Every Minute? | Domo Blog." Data Created Every Minute. DOMO, 8 June 2012. Web. 23 Apr. 2015.

Jensen, Jens F. "'Interactivity': Tracking A New Concept In Media And Communication Studies." *NORDICOM Review* 19.1 (1998): 185-204. *Communication & Mass Media Complete*. Print.

Johnson, Steven. *Where Good Ideas Come From : The Natural History Of Innovation*. n.p.: New York : Riverhead Books, c2010. Print.

Karshmer, A. I., P. Brawner, and G. Reiswig. "An Experimental Sound-Based Hierarchical Menu Navigation System For Visually Handicapped Use Of Graphical User Interfaces." *ACM SIGACCESS Conference On Computers & Accessibility* (1994): 123. *Publisher Provided Full Text Searching File*.

Keitlen, Tomi. *Farewell To Fear*. n.p.: [New York] B. Geis Associates; [1960], 1960. Print.

Klein, Julie Thompson and William H. Newell. "Advancing Interdisciplinary Studies," in William H. Newell, ed., *Interdisciplinarity: Essays From the Literature.* New York: College Entrance Examination Board. Print. 1998. Print.

Kramer, Gregory, (Ed.). *Auditory Display: Sonification, Audification, And Auditory Interfaces*. Reading: Addison-Wesley, 1994. *RILM Abstracts of Music Literature*. Print.

Lam, Margaret. "Beyond the Score: Music visualization and digital humanities." *Bulletin of the American Society for Information Science and Technology* 2012: 45. *General OneFile*. Print.

"Les Paul's 96th Birthday." Google.com. N.p., n.d. Web. 23 Apr. 2015.

Lindroth, Scott. "Sonification of Twitter - Scott Lindroth." *YouTube*. YouTube, 27 July 2012. Web. 23 Apr. 2015.

Manning, Christopher. "Building Hamiltonian Graphs from LCF Notation." *Christopher Manning*. Christopher Manning, 14 Nov. 2012. Web. 23 Apr. 2015.

Nielsen, Jakob. "Usability 101: Introduction to Usability." *Nielson Norman Group*. Nielson Norman Group, 4 Jan. 2012. Web. 23 Apr. 2015.

Norman, Donald A. *Emotional Design : Why We Love (Or Hate) Everyday Things*. n.p.: New York : Basic Books, 2005. Print.

Palmeri, Thomas J. "What Is Synesthesia?" Scientific American Global. N.p., 11 Sept. 2006. Web. 23 Apr. 2015.

Pinch, Trevor, and Karin Bijsterveld. "Sound Studies: New Technologies and Music." *Social Studies of Science* 2004: 635. *JSTOR Journals*. Print.

Plaisant, Catherine. "ISonic: Interactive Data Sonification for Blind Users." *YouTube*. YouTube, 11 Sept. 2013. Web. 23 Apr. 2015.

Plotkin, Robert. *The Genie In The Machine : How Computer-Automated Inventing Is Revolutionizing Law And Business*. n.p.: Stanford, Calif. : Stanford Law Books, c2009. Print.

Polli, Andrea. "Soundscape, Sonification, And Sound Activism." AI & Society 2 (2012): 257. Academic OneFile. Print.

Porsdam, Helle. “Too Much ‘digital’, Too Little ‘humanities’? An Attempt to Explain Why Many Humanities Scholars Are Reluctant Converts to Digital Humanities.” (2011): n. pag. Web. 2 Dec. 2013.

Ralph, P., and Y. Wand. "A Proposal For A Formal Definition Of The Design Concept." Lecture Notes In Business Information Processing 14 (2009): 103-136. British Library Document Supply Centre Inside Serials & Conference Proceedings. Print.

Santaella, Lucia. ‘Mobile and Locative Media : In between Thanatos and Eros’(2011), *International Journal*, pp. 294-296. Print.

Schafer, R. Murray. The Soundscape: Our Sonic Environment And The Tuning Of The World. Rochester: Destiny, 1993. RILM Abstracts of Music Literature. Print.

Schnapp, Jeffrey et al. “The Digital Humanities Manifesto 2.0.” 22 June 2009. Web. 9 Aug. 2012.

Shneiderman, Ben. "Designing For Fun." *Interactions: New Visions Of Human-Computer Interaction* 11.5 (2004): 48. *Publisher Provided Full Text Searching File*. Print.

Schreibman, Susan, John Unsworth, and Raymond George Siemens. *A Companion To Digital Humanities. [Electronic Resource]*. n.p.: Oxford : Blackwell, 2004. Print.

Sinclair, Peter. "Living With Alarms: The Audio Environment In An Intensive Care Unit." *AI & Society* 2 (2012): 269. *Academic OneFile*. Print.

SINTEF. "Big Data, for better or worse: 90% of world's data generated over last two years." ScienceDaily. ScienceDaily, Web. 22 May. 2013.

Smith, Aaron. *Nearly Half of American Adults Are Smartphone Owners*. Rep. N.p.: PewResearchCenter, 2012. *Nearly Half of American Adults Are Smartphone Owners*. PewResearchCenter, Web. 1 Mar. 2012.

Spiro, Lisa. "'This Is Why We Fight:' Defining the Values of the Digital Humanities." *Debates in the Digital Humanities*. Ed. Matthew K. Gold. U of Minnesota Press, 2012. Print.

Sterne, Jonathan, (Ed.). *The Sound Studies Reader*. New York: Routledge, 2012. *RILM Abstracts of Music Literature*. Print.

Subxaero. "Augmented Coaster / Augmented Reality Bierdeckel." YouTube. YouTube, Web. 6 Mar. 2012.

Sutko, DM, and ADS Silva. "Location-Aware Mobile Media And Urban Sociability." *New Media & Society* 13.5 (n.d.): 807-823. *Social Sciences Citation Index*. Print.

Tahiroğlu, Koray, Oğuzhan Özcan, and Antti Ikonen. "Sound In New Media And Design Studies." Design Issues 30.2 (2014): 56-66. World Textiles. Print.

Tanaka, Atau.“Malleable mobile music. In: Proceedings of the 1st Mobile Music Technology Workshop”(2004): n.pag. Web. 23 Feb. 2015.

Tanaka, Atau.“Malleable contents and future musical forms. receiver 13.” (2005): n. pag. Web. 23 Feb. 2015.

"TELEPATHICTRAFFIC | BLUEBRAIN / THE NATIONAL MALL." N.p., n.d. Web. 23 Apr. 2015.

"The Fun Theory." *The Fun Theory*. Volkswagen, n.d. Web. 23 Feb. 2015.

van den Doel et al. "Foleyautomatic." Proceedings Of The 28Th Annual Conference: Computer Graphics & Interactive Techniques (2001): 537. Publisher Provided Full Text Searching File. Print.

"W3C." *World Wide Web Consortium ()*. N.p., 2015. Web. 23 Apr. 2015.

Weinberg, Gil, and Travis Thatcher. "Interactive Sonification: Aesthetics, Functionality And Performance." Leonardo Music Journal 16.1 (2006): 9-12. Humanities International Complete. Print.

Williams, George H. "Disability, Universal Design, And The Digital Humanities." *Debates in the Digital Humanities*. 202-212. MinneaPollis, MN: U of Minnesota P, 2012. *MLA International Bibliography*. Print.

"Www.smh.com.au." *Homing in on the Human Element*. The Sidney Morning Herald, 6 Apr. 2006. Web. 23 Feb. 2015.

Xylophone Cup – Cup For The Visually Impaired by Soon-sik Choi » Yanko Design. N.p., n.d. Web. 23 Apr. 2015.

Young, Kat. "Interactive Sonification Using Pure Data (cc)." *YouTube*. YouTube, Web. 12 Jan. 2013.

Zhao, H, et al. "Data Sonification For Users With Visual Impairment: A Case Study With Georeferenced Data." *Acm Transactions On Computer-Human Interaction* 15.1 (n.d.): *Science Citation Index*. Print.

Appendix A.

Two Trains (2009)

Creator/Director:
Brian Foo

Description:
Brian Foo is a programmer as well as visual artist residing in New York City. According to Foo (2015), the goal of Two Trains is "to explore new experiences around data consumption beyond the written and visual forms by taking advantage of music's temporal nature and capacity to alter one's mood. Two Trains displays average income across New York City. This example is used to discuss how sonification has a wide range of uses.

Filename:
A-Two Trains.MP4

Appendix B.

Sonifiyer of Visual Data (2014)

Creator/Director:

Dongju In (author)

Description:

This application is developed to show the potential of sonification as a supplemental tool of visualization. It demonstrates how we can use similarity between colors and chords, and suggests the importance of collaboration by exposing the limitations of amateur sound design.

Filename:

B-Sonifyer of Visual Data.app