Exploring Internet CO₂ Emissions as an Auditory Display

Stuart James McFarlane B.Design (Distinction)
School of Architecture and Design
Design and Social Context Portfolio
RMIT University
DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in the whole or in part, to qualify for any academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

Sign:

Name: Stuart James McFarlane

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ABSTRACT

This research project explores the effectiveness of an auditory display prototype for the sonification of internet CO₂ emissions to a small user group within their office context. To date, methods do not exist for the reporting of this information to users of personal computing while they perform simple internet enquiries. Underpinning the theoretical development of this project is a focus on auditory displays guided by the concept and forms of auditory displays, together with the auditory perception elements to be considered in their design. Evaluation of the prototype takes place through two iterative field study’s in an office context. The following exegesis gives an account of the design and development of the auditory display prototype and its respective sonification, the design methodology employed and the research findings, and concludes with recommendations for further exploration within this context.
Chapter 1
Introduction
1.1 INTRODUCTION

This introductory chapter describes the motivation behind and the context for this research. It provides an overview to the theoretical foundations I have focused on for the research, together with the research design approaches I have taken. The focus of the inquiry and the research proposition are explained along with a summary of the findings. An outline of the exegesis concludes the chapter.

1.2 MOTIVATIONS AND DIRECTIONS FOR THE RESEARCH

This exegesis is concerned with the design of an auditory display prototype for the conversion of internet download data size into sound. This conversion of information into sound variation is commonly called sonification (Walker & Kramer, 2006). I make a correlation between this data and that of internet carbon (“CO₂”) emissions as a measure of carbon pollution for every internet search inquiry. The aesthetic challenge set, in the context of the design exploration, is how to design the sound to present this information in a calm and pleasing manner.

The motivation for this research is in questioning two fundamental challenges that have presented themselves as a result of the technological advancement of western civilisation in the last 150 years. The first is the rise in carbon-producing technologies that have arrived through the advancement of the combustion engine and their effects on our environment. The second is the ubiquity of information provided by the information “superhighway” (www.oxforddictionaries.com) now commonly known as the internet. I argue through this design research that the latter can create an awareness of the former, that information technology, in this case a designed sonification “engine”, that presents download data as change in tonal sound information, can create an awareness of the amount of carbon we use when searching the internet. I argue that, in designing and presenting sound, consideration needs to be given to how it is perceived, interpreted and valued. In other words, how is it recognised, and what interpretations and values does the listener bring to this recognition.

1.2.1 INTERNET CO₂ EMISSIONS

To define the context for data exploration in this research I have selected internet CO₂ emissions as the data to be mapped and sonified for interpretation. The issue of sustainability is at the forefront of social awareness, from government policy, to industry and to personal behaviours; it is a term familiar to most and increasing as a key element of our global, social and economic construct. Correspondingly, as our reliance on the internet increases there is a growing concern of its global environmental impact as carbon pollution. Research has shown that every unique Google search generates approximately 20 milligrams of CO₂ (Holtz, 2009) through the energy expended by the hardware and associated mechanisms employed to provide the service. Considering there are approximately one billion unique Google searches and two billion YouTube views every day globally (Gombiner, 2011, p119-124), this figure is compelling. One estimate suggests that the internet releases around 300 million tonnes of CO₂ per annum – as much as all the coal, oil and gas burned in Turkey or Poland in one year, or more than half of that burned in the UK (Clark & Berners-Lee, 2010). To date, methods do not exist for the reporting of internet CO₂ emissions to users of personal computing while performing simple internet enquiries, and considering predictions for growing internet CO₂ emissions of “6% per year” (Arnaud, 2007); this data exploration forms a valid point for investigation within this project’s context.

It must be noted here that this exists as a context to base the data gathering aspect of the design on and is not intended as a subject for ideological debate within the research itself. The intention of the designed outcome is the presentation of information to participants for interpretation. Any further enquiry into the justification and validity for internet CO₂ emissions should be left for another debate and is not the focus of this research.
1.2.2 CALM TECHNOLOGIES

To begin to understand the ways in which we perceive sound and to present a model to assist design I turn to the idea of calm technology as presented by Weiser (Weiser & Brown, 1996). Today, as in many fields of research, ubiquitous computing, calm technology and ambient display have evolved within HCI to encompass specific research fields that in many cases have become established disciplines in their own right. In recent decades there has been a great deal of research into the field of ubiquitous computing, a term defined by Weiser as a “new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background” (Weiser, 1991, p1). As an extension of this vision, the term calm technology was later coined to describe “technology that will move easily from the periphery of our attention, to the centre, and back” (Weiser & Brown, 1996, p9). Weiser & Brown’s early theories arose from their observations of the growing saturation in society of computing devices where most users are inundated with real-time information, which has the potential to lead to an overloading of sensory abilities (particularly screen-focused visual displays) to interpret such information. Weiser and Brown’s research approach incorporated a greater empathy towards humans in this experience.

It is not uncommon for a person to have a smart phone in their pocket, a tablet or laptop in their bag, and a desktop computer in their office. All of these demand primarily visual interaction by the simple virtue that we are required to by design, and more frequently as a symptom of modern life. To circumvent this phenomenon, researchers now look to other means of communication (modes) to complement and/or elevate the visual loading placed on us by current design. These modes (that may include light, sound, smell and movement) engage other senses for communication and are generally aimed at the periphery of attention so as not to overburden our already dense visual stimuli. That is, using “periphery to name what we are attuned to without attending to explicitly” (Weiser & Brown, 1996, p8). In essence, “the result of calm technology is to put us at home, in a familiar place. When our periphery is functioning well we are tuned into what is happening around us, and so also to what is going to happen, and what has just happened” (Weiser and Brown, 1996, p11).

This research continues the exploration of calm, peripheral and ambient information communication through the specific focus on non-visual modes – specifically non-speech audio. Sound has shown to provide a unique set of properties that are useful for dynamic information like the types encountered in the variation of download data packet sizes. I discuss this in the next section.

1.2.3 CALM APPROACHES WITH NON–SPEECH AUDIO

The modern human when born has “an interest in, and sensitivity to, the rhythms, tempos and melodies of speech long before we are able to understand the meanings of words”.

(Mithen, 2005, p69)

Historically humans have employed non-speech audio as an important mode of communication in situations where visual means of communication do not suffice, or are not feasible (eg, Everett, 2012; Gleick, 2011; Mithen, 2005; Schafer, 1977). Today an appreciation for sound as a form of communication has evolved to become a significant element of modern society. Mobile telephony, for example, increasingly promotes the integration of sound within interfaces to communicate a variety of information to the user. One specific sound may indicate a text message has been received, another sound may indicate the battery is running low and requires charging. At present – and more commonly – there is an acceptance of sound to assist in the domain of non-visual information transfer and interpretation.

The general terminology to describe these non-visual sound-focused communication systems is ‘auditory display’. This is a “generic term including all intentional audio that is designed to transmit information between a system and a user” (Walker & Kramer, 2006, p1022). Their objective is to present meaningful information in appropriate situations for tasks where common methods of information delivery (such as vision) are inappropriate, insufficient or simply unviable. Perhaps the most common example of an auditory display is the Geiger counter, where detected levels of radiation are relayed to the user by a clicking sound. For instance, if there are large quantities of radiation detected the sonification rapidly clicks. In contrast, if there is minimal radiation detected the sonification will click slowly or not at all.
There are a number of auditory displays by definition (Walker & Kramer, 2006; Walker & Nees, 2011). Sonification (a sub-type of auditory display) however is a focal point within this research as it is exclusively designed to employ “non-speech audio to represent information” (Walker & Nees, 2011, p9). These types of displays are “most common, and most effective, in situations where the change in data values and relationships between different values are more important than absolute quantities” (Walker & Kramer, 2006, p 1253). An example of this approach is Mauney & Walker’s sonification system that was designed to “dynamically render sonifications of real-time stock market data” (Mauney & Walker, 2004, p1). When activated the system deployed stock market data as a soundscape of complementary ecological sounds to the stock trader for interpretation.

This research employs approaches for sonification design that are conceptually inspired by work in the field of interaction design and calm technology for the purpose of communicating internet search CO₂ emissions to the participant through sound.

1.2.4 HUMAN AUDITORY PERCEPTION

“What is that sound?”

There are many valuable theories on human auditory perception that have inspired, informed and assisted in framing research efforts made within the discipline of interaction design (eg, Broadbent, 1958, cited in Pashler, 1988; Cherry, 1953; Gaver, 1993; Gibson, 1966; Shafer, 1977; Treisman, 1960, cited in Styles, 2006).

Broadbent (1958), Cherry (1953) and Triesman (1960) present related theories on human auditory perception that focus on selective attention. These insights explore a cognitive system within the brain that can attend to stimuli while rejecting others, and is often dependent on a range of factors including pitch, timbre and spatial location of the sound for effective selection.

Gaver (1993) formulates an ecological approach to how humans may perceive “hearing events in the world rather than sounds” (Gaver, 1993, p1). He presents an alternate model of auditory perception to that of Broadbent (1958), Cherry (1953) and Triesman (1960) which suggests the perception of sound can be defined through the actual combined elements and nuances of a sound event; these are described as “audible sound attributes” (Gaver, 1993, p1) and include events involving “vibrating solids, aerodynamics or liquids” (Gaver, 1993, p22). Gaver explores a hierarchical model for ecological listening based on sound events and the deconstruction of the fabric of what humans perceive to hear. In the context of this research, this perspective is more relevant to earcon design and not sonification, as it is explicit in its function, rather than presenting unobtrusive approximate values. See Chapter 2.

Gibson (1966) outlines a total system of perception that considers the physical and optical capabilities of the body in ecology of perception. Gibson’s focus is on explaining all factors in which we perceive through this system, however this research presents little reference to auditory perception that is considered useful for the framing of this research as it focuses on sedentary body listening.

Shafer’s (1977) qualitative observations of human auditory perception are focused on the soundscape more generally. Here he makes a connection between the auditory soundscape and visual paintings, suggesting that like an images foreground and background composition, so to the soundscape can consist of a similar composition, where more prominent sounds within a soundscape could be considered as foreground sounds, and less intrusive sounds may be considered as background sounds within the soundscape.

In this research I focus on a connection I have made between Broadbent (1958, cited in Pashler, 1988) and Shafer’s (1977) quantitative and qualitative observations and results in relation to the research objectives. This section outlines the foundations of the psychological approach to the sound design and concurrent prototypes produced with relation to human auditory perception.

Broadbent (1958, cited in Pashler, 1988) presents a theory that suggests “all stimuli reaching the sensory system are processed to a point at which certain attributes are analysed and explicitly represented”. This process is largely facilitated by what he termed as the selective filter. Auditory stimuli initially enter the system after which the filter is initialized. This filter then sorts between the stimuli after which the selected or attended stimuli proceed further to recognition, focusing our centre of attention. Furthermore, later studies
suggest that this process is shaped by three separate influences, namely conscious choice, salient and primed stimuli. Conscious choice refers to a human specifically attending to one stimulus by automatically filtering the remaining stimuli out. Salient stimuli override conscious choice, and priming theoretically overrides both conscious choice and salient stimuli.

Beyond these three stimuli exists sounds that form the background of the human listening experience. These sounds do not compete for attention, resembling salient or primed stimuli; however they do possess the capacity to inform a listener of certain information in a subtle manner within the listener’s periphery of attention. For example, a person working on their computer in their home office can hear another watering their garden outside. This sound informs the listener of this action, however does not distract them from their work, which is their centre of attention. This information could be described as peripheral information.

To broaden the conceptual scope beyond selective attention theory and the periphery of attention concept, Schafer’s (1977) theories of the soundscape presents two key observations with respect to human perception and attention and sound. Namely, keynote sounds and signals. Keynotes are sounds which reside in the background of the soundscape, and when united form the tonal ambience of that soundscape. Theoretically this sound type has the capacity to represent information in the periphery of attention. Signals, in contrast, are valued as sounds that are listened to consciously as foreground sounds within the soundscape that primarily demand attention; a train horn for example.

This research incorporates and adapts these theories of selective attention, the soundscape and the concept of the periphery of attention as key elements for exploration when designing an auditory display for the sonification of CO\textsubscript{2} internet emissions.

**1.3 FOCUS, METHODS AND SUMMARY OF FINDINGS FOR THIS INQUIRY**

This research project presents initial insights into the communication of internet CO\textsubscript{2} emissions to participants through an auditory display via its subset sonification. Central to this research is the evaluation of these sonifications as salient and ambient communication within the background of the soundscape in an effort to produce informative yet unobtrusive and pleasing information. Using a research through design process this inquiry results in two designed prototypes which explore salient and ambient sound types, as environmental and synthetic sound, that are observed in use, with a small group of professional architects within their office environment. The methods used to achieve the design of these prototypes and to observe them in use are a combination of Constructive Design Research (Koskinen et al, 2012) and iterative design, together with contemporary ethnographic observation following the principles of Contextual Inquiry (Beyer and Holtzblatt, 1998). Through this process this research responds to the following proposition:

*To examine the relationship formed between searching the internet and designed sound as a measure of internet CO\textsubscript{2} emissions.*

*That through easing the amount of salient feedback towards ambient feedback, the intended outcome is that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand.*

The findings gained in the context of this proposition are:

- A relationship can be constructed between participants and their internet searching as perceived CO\textsubscript{2} emissions through the auditory display and concurrent sonifications.
- Easing the salient properties of a sound towards ambient can produce an unobtrusive and pleasant experience and not divert the users centre of attention, however the communicative intention is more difficult to achieve.

Further insights include:

- Higher-order understandings can be achieved between sonifications and internet searching as CO\textsubscript{2} emissions.
• Metaphoric interpretations a sound promotes may be just as important a consideration in the design as the auditory details of the sound design itself; however further research in the fields of psychoacoustics, human auditory perception and semiotics would be required for clarification.

• Larger sample groups will produce stronger results.

1.4 OUTLINE OF THIS EXEGESIS

As the intention of this research is to explore the potential for an auditory display to successfully communicate quantities of perceived internet CO₂ emissions through sonification, this document presents the stages of the research as an unfolding design process and narrative through the following chapters.

Chapter 2 reviews the literature within the field of HCI, auditory display, and sonification together with the theoretical standpoints of soundscape theory as keynotes and signals, adapted as a model to achieve the shift from salient to ambient information.

Chapter 3 then discuss the methodological approaches of the study, including Constructive Design Research (Koskinen et al, 2012) and iterative design as methods for producing knowledge. I outline ethnographic approaches to observation and highlight design ethnography through the principles of Contextual Inquiry (Beyer and Holtzblatt, 1998). I then explain my research plan and ethical considerations in relation to the field studies and the research more generally.

With Chapter 4, I explore the concept of the first prototype together with the theoretical approaches that informs the sound design. This includes an explanation of the software used, the coding developed, its function and the intended output. The sound design is also explained, including the sourcing of the sound samples observed in the study and refined with the prototype in preparation for the first field test.

Chapter 5, reports on the objective and the design methodology employed, together with the participants observed, the physical test space and the equipment used of the first field study. The procedure and questionnaire design are explained, followed by the user study findings. From these findings, the discussion explores the most successful of the sound types as an auditory display, how the sound types are perceived, and the performance of the prototype with respect to the participant’s centre of attention. These findings then inform the design iteration of Prototype Two, and its observation in Study Two respectively.

Chapter 6 presents Prototype Two through the design of the system which was informed by the findings from the first study. This includes the intention to pursue the perspective that by easing the amount of salient feedback towards ambient feedback. With this design it is proposed that the communication of perceived internet CO₂ will progress from being intrusive to unobtrusive while remaining pleasant, informative and not distracting the listener’s centre of attention. The sonification mapping models developed from this concept are refined in response to the findings from the first field study. The sound design section then reports on the development of four individual designs outlining their conceptual and theoretical frameworks to address the before-mentioned proposal.

Chapter 7, reports on the second field study, its objective, the design methodology employed for the study, together with the participants observed, the physical test space and the equipment used. The procedure and questionnaire design are explained, followed by the user study findings analysed through identification and attribute ratings (Bonebright & Flowers, 2011). From these findings, the discussion and analysis section of this chapter explores the most successful of the sound types as an auditory display, how the sound types are perceived, and the performance of the prototype with respect to the participant’s centre of attention.

Chapter 8 concludes this exegesis. It reports on and discusses the findings from the inquiry in the context of this research and demonstrates that successful communication can be formed between ambient sonifications and users. By shifting from salient modulation approaches, to a more musical salience through subtle timing variations, easing salient feedback towards ambient feedback can be achieved. The chapter concludes with a discussion on the limitations and future directions of the research together with a reflection on the project.
Chapter 2
Review of Literature
2.1 INTRODUCTION

This research project explores the effectiveness of auditory display to communicate internet CO₂ emissions generated by internet searching. It provides a background for the design and evaluation of the auditory display prototype presented in Chapter 4, Chapter 5, Chapter 6 and Chapter 7 of this exegesis. The chapter begins with a discussion of conceptual approaches in HCI, the concept and forms of auditory displays, together with the auditory perception elements to be considered in their design. A definition of the subset of auditory displays known as sonification is then presented with consideration for how it informs the approach to the design of the research prototype. The chapter concludes with examples of related works within the field, highlighting specific research that informs the approach to the design of this display.

2.2 BEYOND THE SCREEN – TOWARDS CALM, PERIPHERAL & AMBIENT INFORMATION

Today, as in many fields of research, ubiquitous computing, calm technology and ambient display have evolved within HCI to encompass specific research fields that in many cases have become established disciplines in their own right.

In recent decades there has been a great deal of research into the field of ubiquitous computing, a term defined by Weiser as a “new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background” (Weiser, 1991, p1). As an extension of this vision, the term calm technology was later coined to describe “technology that will move easily from the periphery of our attention, to the centre, and back” (Weiser & Brown, 1996, p9). Weiser & Brown’s early theories arose from their observations of the growing saturation in society of computing devices where most users are inundated with real-time information, which has the potential to lead to an overloading of sensory abilities (particularly screen-focused visual displays) to interpret such information. Weiser and Brown’s research approach incorporated a greater empathy towards humans in this experience.

It is not uncommon for a person to have a smart phone in their pocket, a tablet or laptop in their bag, and a desktop computer in their office. All of these demand primarily visual interaction by the simple virtue that we are required to by design, and more frequently as a symptom of modern life. To circumvent this phenomenon, researchers now look to other means of communication (modes) to complement and/or elevate the visual loading placed on us by current design. These modes (that may include light, sound, smell and movement) engage other senses for communication and are generally aimed at the periphery of attention so as not to overburden our already dense visual stimuli. That is, using “periphery to name what we are attuned to without attending to explicitly” (Weiser & Brown, 1996, p8). In essence, “the result of calm technology is to put us at home, in a familiar place. When our periphery is functioning well we are tuned into what is happening around us, and so also to what is going to happen, and what has just happened” (Weiser and Brown, 1996, p11).

A contemporary extension of this philosophy is the study of what are titled ambient displays. These displays are directly influenced by ubiquitous computing, and the calm technology directive and aim to provide information in a peripheral, non-obtrusive way. More specifically, these displays aspire to “reduce a user’s cognitive load by alerting the user to an interesting development, rather than requiring the user to occasionally check the status of an information source” (Morgan, 2002, p2).

Ishii’s ambientROOM (1998) is an early example of how ubiquitous computing and calm technology informed the ambient display approach to implementation and testing. Designed as an “interface to information for processing in the background of awareness” (Ishii, 1998, p1), ambientROOM consisted of numerous displays with different tasks, which informed the user through “subtle displays of light, sound, and movement” (Ishii, 1998, p1).

The primary objective of ambient displays is to alleviate a user’s cognitive load by alerting the user to an interesting development, rather than requiring the user to occasionally check the status of an information source. This type of display does not compete for attention but instead provides information that may be “concurrently monitored in the background” (Ishii, 1998, p1) while information is also presented in the foreground.

Ambient displays call to action different modes of interaction that aim to broaden our bandwidth of information registration. This research project continues the exploration of calm, peripheral and ambient information communication through non-visual modes – specifically audio.
2.3 AUDITORY DISPLAY

I would now like to draw attention to the specific mode of communication that bears deeply on my own research; sound and audio. Whist inspired by the theories of ubiquitous computing, calm technology and ambient display, other more recent research will be explored and could be considered as a subset of ambient display which solely explores the role of audio as the mode of communication. These displays are titled auditory displays.

An auditory display is a “display that uses sound to communicate information” (Walker & Nees, 2011, p9). More specifically, “auditory display is a generic term including all intentional audio that is designed to transmit information between a system and a user” (Walker & Kramer, 2006, p1022). Originally defined by Kramer (Kramer, 1994), his proposal was to focus on the use of sound to present meaningful information in appropriate situations for tasks where common methods of information delivery (such as vision) are inappropriate, insufficient or simply unviable.

There is a long history to the concept and use of auditory display. Throughout documented history humans have employed sound to communicate different forms of information. Beyond verbal communication, early examples include bells, drums and horns that were utilized to communicate religious ceremony, danger and celebration. The work of Steven Mithen in The Singing Neanderthal: the origins of music, language, mind and body (2005) suggests that pre-verbal human ancestral communication was largely formed by a ‘musical’ form of communication within various cultures. Furthermore he alludes to the understanding that the modern human when born has “an interest in, and sensitivity to, the rhythms, tempos and melodies of speech long before we are able to understand the meanings of words” (Mithen, 2005, p69). This suggests that the use of sound for the purpose of communication has an intrinsic value within human biology.

Today communication through sound is a ubiquitous element of society and in the western world is experienced and interpreted by humans on a daily basis. Auditory displays are designed to facilitate this form of communication in a wide variety of contexts. For example, street intersections rely heavily on sound as a representation of traffic light changes – indicating whether a pedestrian should cross or not. Within the home, auditory displays may inform you to empty the washing machine or that it is off-centre. At present – and more commonly – there is an acceptance of auditory displays to assist in the domain of information transfer and interpretation.

2.3.1 FORMS OF AUDITORY DISPLAY

The most common form of auditory display is an alert. This display’s primary task is to inform us that an event, has, is or is going to take place. Alerts can convey a diverse amount of information. For example, a simple electronic door bell informs us that someone is at the front door; however a more complex alert may give us information on who is at the door.

Warnings are similar to alerts and may contain even the same sounds; however warnings rely on training and assimilation to elicit its communicative intent. Rail crossing warnings as an example are ubiquitous in most societies by virtue of the priming that takes place through experience, education and popular culture (film, TV, literature, etc). Once understood, these displays inform us not to cross because there is a train coming. As with alerts, simple warnings may fail to inform on a detailed level. They may neglect, for example, to communicate how far away the train is; how fast it is going, and how long we have to wait, or if it has been falsely triggered. We simply know not to cross.

Through the advance of research and technology – particularly in computer interface design – there is an increased capability to produce more content-rich auditory displays to assist in the communication of information within this digital spectrum. Auditory icons and earcons are two auditory display approaches that focus on this goal.

Auditory icons are displays tailored for the computer interface that are an audible representation of a graphic icon that may exist on a screen. Their purpose is to inform the user of a particular process, status or action that would have previously been portrayed as a graphical icon. For example, “a sound that is used to display the status of a file transfer procedure can sound like a bottle filling with water, with the perceived ‘size’ of the container and ‘composition’ of the liquid being determined by the size and type of file that is being transferred” (Walker & Kramer, 2006, p4). Auditory icons typically employ analogy as a basis for the sound design and can incorporate speech or non-speech audio.
Alternatively, earcons focus on a more musical approach to their sound design and often require assimilation by the user to gain an understanding of the intended message. Generally consisting of two to three notes played as a melodic pattern, earcons could be applied to a number of different tasks while consisting of the same notes. As opposed to auditory icons, earcons are initially devoid of any analogic relationship between their task, and in many cases are enlisted for uncommon tasks that have yet to establish a common well-defined analogy. In relation to a computer interface, “a rising pattern, like ‘bong-bing-bing’ might mean a file was opened, whereas a descending pattern like ‘bingbong-bong’ could mean the file was closed. Different timbres could represent different file types” (Walker and Kramer, 2006, p4). Earcons can also incorporate speech or non-speech audio in their design.

Sonification and audification are two other forms of auditory display. Sonification is solely concerned with communicating information via the use of non-speech audio. Audification (considered a subset of sonification) is the “direct translation of data samples into sound” (Walker and Kramer, 2006, p2). Sonification is a key area of enquiry in this research; a more detailed discussion of these forms of auditory display will be explored in the sonification section of this chapter.

### 2.3.2 THE RISE OF AUDITORY DISPLAY

Over the last two decades, the rise of the field of ambient display technology has largely been attributed to the rapid advancement of computer technology and accessibility of sound production software and hardware. The increased use of mobile phones in the 1990s is an example of the expansion of ambient display; options available to customize a sound for display increased alongside the uptake of the use of mobile phones. The number of tasks available with auditory display options increased with the complexity of personal communication devices. SMS notifications and personally assigned ringtones for contacts are some examples of earlier options; however these options have more recently expanded to include applications that inform the user of more complex information.

This rapid development of technology has made it feasible for researchers to explore auditory display design to a degree of detail previously unavailable. Microprocessors, sensors and ‘downloadable’ software such as Arduino, Max MSP and Pure Data (Pd) all enable prototype production of research. The affordability of these technologies (in some cases, they are cost-free) has enabled a broad uptake of their use in user-testing scenarios in the academic setting. This project is located within the above-described discourse within the field of auditory display through its use of integrated open source software for prototype production.

### 2.3.3 A CONTEXT FOR AUDITORY DISPLAY

There are several elements to consider when evaluating what may be the best approach of communication for an intended interface when designing an auditory display. Generally speaking, it is a culmination of factors that lead to the implementation of an auditory display that reside in the more general ‘design’ paradigm.

> “Considering the users, their work environment, and the tasks that they need to accomplish is just as critical here as it is in the design of any display. Thus, sound may be a potentially very effective display device in a large number of situations where information must be conveyed, so long as due care is taken in the total information display design, and each modality is used appropriately”.

(Walker & Kramer, 2006, p1022)

For instance, an auditory display on a noisy stock market trading floor would be an ill-advised approach to communicate, for example, stock market fluctuations to brokers. However this display could potentially perform well in the quieter confines of a stock trader’s office.

In practical terms, auditory displays are best-suited in situations where vision may be impaired through blindness, environmental effects, line of sight or saturation due to vision-focused tasks. Furthermore Walker & Nees (2011, p12) outline four broad categories in which auditory displays may perform:

- Alarms, alerts, and warnings
- Status, process, and monitoring messages
Data exploration
Art, entertainment, sports, and exercise

In the context of this research data exploration is the most appropriate function description. Data exploration frames auditory display types which “use sound to offer a more holistic portrait of the data in the system rather than condensing information to capture a momentary state such as with alerts” (Walker & Nees 2011, p14). Similar to Mauney & Walker’s sonification system which focused on “dynamically rendering sonifications of real-time stock market data” (Mauney & Walker, 2004, p1), the display that is the subject of this research renders sonifications of real-time internet CO₂ emissions data.

2.3.4 AUDITORY PERCEPTION CONSIDERATIONS FOR AUDITORY DISPLAYS

There are a number of considerations a designer of auditory displays must acknowledge when designing the sonic elements of a specific display, namely loudness, masking, pitch, tempo, rhythm and timbre.

Loudness is a most important element as it defines whether the sound design can be heard or not by the user. Although a simple and straightforward notion, loudness must be considered, as the intended function of an auditory display is to communicate via sound, and more directly, a sound that is heard and interpreted by the user.

Masking identifies that once the loudness of the display is considered the design must fulfil its task amongst other sounds, whether they are existing sounds of a soundscape or competing auditory displays. Masking denotes the consideration of the sound within the soundscape.

Pitch, tempo, rhythm and timbre are terms derived from the musical world to explain the musical characteristics of a sound.

Pitch is a familiar term that describes the audio frequency of a sound. Generally speaking pitch can be easily recognized and interpreted by users for the purpose of communication. The Geiger counter is one example where pitch is used to denote quantity or distance. For instance; when the radiation levels are high the pitch of the Geiger counter is high. In contrast when the radiation levels are low the pitch is also low.

Tempo and rhythm denote time-related qualities of sound. They are considered useful approaches to be considered when designing an auditory display. Coupled with the previous example, the Geiger counter can be used as an example where the frequency of an event (radiation reading) can be mapped to the tempo of that event and its corresponding rhythm. Furthermore when the device is in close proximity to the radiation the tempo and rhythm of the auditory display increases. If the radiation levels decrease so too does the display’s tempo and rhythm.

Timbre – or tone colour – is another musical term defined to describe sonic attributes other than loudness, pitch, tempo or rhythm that make a sound distinguishable, such as its harmonic content. Timbre is an important element in auditory display design through its ability to communicate information via nuanced ‘voices’. For instance one data set may be defined by a sound with the timbre of a piano. A secondary set of data may be reporting information within the same display through the timbre of a trumpet. Timbre of sound in auditory display affords the potential creation of families of sounds within these displays, which linked through their similar tone colours.

2.3.5 ATTENTION, PERCEPTION AND HEARING

Central to the design concept of this auditory display and building on the auditory perception considerations previously discussed is the psychology of attention, perception and hearing.

Broadbent’s selective attention theory suggests that “all stimuli reaching the sensory system are processed to a point at which certain attributes are analysed and explicitly represented” (1958, cited in Pashler, 1988). This process is largely facilitated by what Broadbent termed as the selective filter. Stimuli initially enter the system whereby a filter is initialized. This filter then sorts between the stimuli with the attended stimuli being the only one to proceed further to recognition, focusing our centre of attention. Furthermore later studies suggest that this process is shaped by three separate influences, namely conscious choice, salient and primed stimuli.
As the title implies, conscious choice refers to the process where a human specifically attends one stimulus by automatically filtering the remaining stimuli out. Salient stimuli are theorized as being able to override conscious choice, diverting the listener’s centre of attention away from their conscious choice. For example a loud sound with distinct physical properties is found to be automatically attended to over other stimuli and hence overrules conscious choice. Priming is a similar process whereby certain stimulus increases the chance of attention and theoretically overrides both conscious choice and salient stimuli. A person’s name is a familiar example of primed stimuli. For instance; a person may be consciously listening to the radio when their centre of attention is drawn to a loud banging sound. During the banging their friend calls their name which then focuses their attention to their friend.Treisman (1960, cited in Styles, 2006, p27)(561,657),(907,957) “proposed that the nervous system contained a set of dictionary units and those different words have different thresholds depending on their salience and probability”. When heard, these words have the probability of gaining attention in the unattended channel. Furthermore Christopher Wickens suggests that “a warning presented over the auditory channel stands a good chance at capturing the operator’s attention, even if the operator is otherwise engaged” (Wickens et al, 2013, p78). See Figure 1 for a visual representation of this theory.

**FIGURE 1: SELECTIVE ATTENTION THEORY.**

It is important to note here that beyond the three stimuli mentioned within the selective attention theory exists sounds that form the background of the human listening experience. These sounds do not compete for attention resembling salient or primed stimuli; however they do possess the capacity to inform a listener of
certain information in a subtle manner within the listener’s periphery of attention. For example, a person working on their computer in their home office can hear another watering their garden outside. This sound informs the listener of this action, however does not detract them from their work, which is their centre of attention. This information could be described as peripheral information. See Figure 2.

![Diagram of Centre of Attention and Periphery of Attention]

**FIGURE 2**: PERIPHERY AND THE CENTRE OF ATTENTION.

In this research, selective attention theory and the periphery of attention concept will form a basis for consideration in the development of the prototypes and the methods in which the sound design and mapping is tailored and portrayed via sonification.
2.3.6 THE SOUNDSCAPE & AUDITORY DISPLAY

To assist in the communicative intention of this prototype and to broaden the conceptual scope of the sound design beyond selective attention theory and the periphery of attention concept, I now turn to theories of the soundscape.

Through Murray Schafer’s (1977) observations of the soundscape, there are two key elements he has defined which I am taking into consideration when designing Prototype One’s sonification. Namely, keynote sounds and signals.

As Schafer (1977) outlines, “The keynote is the note that identifies the tonality of a particular composition.” These notes “do not have to be listened to consciously, but the fact that they are ubiquitously there suggests the possibility of a deep and pervasive influence on behaviour” (Schafer, 1977, p9 - 10). Keynotes could be considered as sounds which reside in the background of the soundscape, and when united form the tonal ambience of that soundscape. Theoretically this sound type has the capacity to represent information in the periphery of attention.

Signals, on the other hand, are valued as stimuli that are listened to consciously as foreground sounds within the soundscape that primarily demand attention; a train horn for example. These sound types could be considered as salient stimuli with respect to selective attention theory. Generally speaking, keynotes and signals differ through their musical attributes. These may include – but are not restricted to – the loudness, masking, pitch, tempo, rhythm and timbre of the sound’s composition.

Within this study, the term ‘keynote’ with respect to soundscape theory is interpreted as ‘ambient stimuli’ which reside in the periphery of human perception and attention with respect to Broadbent’s selective attention theory (1958, cited in Pashler, 1988). Signals can be denoted as ‘salient stimuli’ in this context also.

I have adapted Schafer’s musical theories of keynote sounds (ambient stimuli) and signals (salient stimuli) to further complement my understandings for the sound design of this auditory display’s sonifications.

2.3.7 ATTENTION, PERCEPTION AND HEARING & SOUNDSCAPE FEATURES

Through my exploration of Broadbent’s selective attention theory, and Schafer’s (1977) principles of the soundscape, I have established associations between these elements that can be referenced to assist the sound design component of Prototype One. The points below outline my observations of these relationships offering insight as to how a sound may be initially considered and treated with respect to the sound design of Prototype One.

- **Ambient stimuli** with relation to selective attention theory can include conscious choice by virtue of human free will, and can exist as a keynote sound in relation to soundscape theory.
- **Salient stimuli** with relation to selective attention theory can include conscious choice also, and can exist as a signal sound in relation to soundscape theory.

Figure 3 below illustrates this concept from a visual perspective where the intersection may include a mixture of both.

[Figure 3: ATTENTION, PERCEPTION AND HEARING & SOUNDSCAPE FEATURES.]
Further to the discussion on the relationships drawn between selective attention theory, peripheral information and soundscape theory, I now explore these in the context of the built environment. I consider this an important evaluation consideration due to the fact that the prototype will be tested and observed with participants within an office environment.

As previously described, the soundscape features have been referred to as foreground or background sounds within the soundscape. With this knowledge, and in reference to Figure 3 and associated discussion above, it is now possible to explore how these relationships may reside within a built environment context with respect to human perception and attention.

Figure 4 below presents a visual representation of these observations, illustrating how the ambient and salient stimuli may reside within the soundscape. The auditory foreground is defined by salient stimuli through signal approaches that demand human attention. In contrast, the auditory background is defined by the ambient stimuli where keynotes have the ability to provide information in the periphery of attention.

To refine this concept further I now explore how sound can be considered as salient or ambient within the background of the soundscape. I propose that the keynotes that define this soundscape component can contain salient and ambient qualities, which renders each different within this soundscape as salient or ambient keynotes. For example, two sounds may be designed as keynotes that reside in the background of the soundscape; however one is more noticeable through its specific musical composition. This sound could be described as a salient counterpart to the other keynote within the background of that soundscape.

Furthermore to attain an informative yet unobtrusive form of communication within the periphery of attention, this concept defines avenues for consideration when designing the sound types for Prototype One. See Figure 5 below.
2.3.9 DISCUSSION

This exploration and observation underlines the complex nature of sound design with respect to human perception and attention while at the same time draws attention to the fact that many variables exist that can alter the perception of a sound type within this environment. Factors such as the loudness, masking, pitch, tempo, rhythm and timbre may all contribute to how a sound is perceived as a foreground or background sound, and as a salient or ambient keynote.

To assist the reader, the following points below outline the sound stimulus ‘type’ and soundscape terminology that I will be utilizing as descriptions of their perceived functional and perceptual characteristics.

Soundscape terminology:

- **BACKGROUND**: The background of the soundscape.

Sound stimulus terminology:

- **AMBIENT**: An ambient sound stimulus that resides within the backdrop of the soundscape background. These sound types aim at providing information in the periphery of attention without obstructing the listener’s centre of attention. Furthermore, when relayed to a listener to display information, they may be described as ambient feedback.

- **SALIENT**: A sound stimulus type that resides within the foreground of the soundscape background. These sound types also provide information in the periphery of attention without obstructing the listener’s centre of attention; however they contain musical characteristics that produce salient qualities when compared to other sound stimuli within that spectrum. These sounds can also be described as salient feedback when displaying information.

Informed by the above, this project will investigate easing the amount of salient feedback towards ambient feedback, with the intended outcome that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand.

2.4 SONIFICATION

Sonification is considered a subtype of auditory display that uses “non-speech audio to represent information” (Walker & Nees, 2011, p9). Auditory displays output speech or non-speech audio, sonification is differentiated by specifically focusing on non-speech audio to provide information to the user. Walker & Kramer (2006) stipulate that “Sonification is most common, and most effective, in situations where the change in data values and relationships between different values are more important than absolute quantities” (Walker & Kramer &, 2006, p 1253).

2.4.1 SONIFICATION REFINED

Sonification and its definition is continually being refined and updated as the field of research progresses. Building on Walker & Kramer’s (2006) definition, Thomas Hermann contends that:

“A technique that uses data as input, and generates sound signals may be called sonification, if and only if:

- The sound reflects objective properties or relations in the input data.
- The transformation is systematic. This means that there is a precise definition provided of how the data (and optional interactions) cause the sound the change.
- The sonification is reproducible: given the same data and identical interactions (or triggers) the resulting sound has to be structurally identical.
- The system can intentionally be used with different data, and also be used in repetition with the same data”

(Herman, 2008, p2).
This research project satisfied both Kramer’s definition and Hermann’s prerequisites for sonification. Firstly, broadly speaking, this auditory display does include sonifications of non-speech audio to communicate information. As outlined further in the Prototype chapters, in this research the objective properties or relations in the input data exist as an extension of the design. Specifically, the input data has been mapped to sounds which reflect the fluctuations of perceived internet CO₂ emissions while searching the internet. These mappings can also be precisely defined by virtue of the specific design of the system (Chapter 4 & 6). The sonifications explored are also reproducible in repetition and can be used with other data sets (see Chapters 4, 5, 6, & 7 for further explanation).

In summation, this research employs sonification as defined by Kramer and expanded by Hermann to communicate fluctuations of perceived internet CO₂ emissions to users while searching the internet.

2.4.2 APPROACHES TO SONIFICATION

Today there are three commonly accepted approaches to sonification:

- Parameter mapping sonification
- Model-based sonification
- Audification

Parameter mapping sonification “involves the association of information with auditory parameters for the purpose of data display” (Grond & Berger, 2011, p1) and can be described as the mapping of data parameters to sound parameters. An example of this type of sonification is an audible thermometer where the sonification presents relative information of the current temperature, or the increase or decrease in the relative temperature of that environment depending on the mapping design. Parameter mapping sonification exposes the complexities of sonification mapping when there is an arbitrary relationship between the data and sound. A key consideration for sonification is that of which qualities of sound (such as pitch, volume, and timbre) represent data in the correct context of its application. In the instance of the audible thermometer, what sound best represents colder for its intended listeners?

Model-based mapping sonifications differ from parameter mapping sonification in that they are designed to present information in response to a user’s interaction with a system (model) and the data (as a sonification) that this interaction produces. “Model-based approaches rely upon the active manipulation of the sonification by the user” (Walker & Nees, 2011, p17). Furthermore;

“The listener’s task may involve identification of the overall structure of the data and complex relationships among multiple variables. Through interactions with the virtual object, the listener hopes to extract information about the relationships within, and structure of, the data represented”

(Walker & Nees, 2011, p17)

Audification is “the direct translation of data samples into sound” (Walker & Kramer, 2006, p1). Considered the simplest form of sonification; audification “traces the exact physical wave in an analogue manner” (Dubois & Ickle, 2011, p301) to present information through sound. They define four sets of data that are applicable for audification.

These are:

- Sound recording data
- General acoustical data
- Physical data
- Abstract data

(Dubois & Ickle, 2011, p302)
Generally speaking, data that portrays graphical relations to sound waves are the most appropriate for audification. The metal detector is an example of audification where proximity data of metals is scaled to a resonant sound wave or tone indicating the distance from the device (and operator) to the metal object.

This research project incorporates a combination of parameter mapping sonification and model-based sonification as the approaches employed. Parameter mapping sonification is employed in this system through the scaling, mapping and data discrimination that produces the sonifications. Further, there is potential for the system to be included into the model-based sonification approach depending on how users react to the system. Although the system has been designed to passively display perceived quantities of internet CO$_2$ to the user, there is potential for the user to take an interactive approach to the system and alter their actions to modify the sonification. This phenomenon will be explored further in the conclusion sections in Chapter 8.

2.4.3 INTERACTION & SONIFICATION

There are two common types of interaction between the user and a display. The first is concert mode (Walker & Kramer, 1996) which describes a display where the user does not have the option to dynamically alter the display. Conversation mode (Walker & Kramer, 1996) displays give the user the opportunity to manipulate the parameters of the sonification.

Parameter mapping and audification can be considered as concert mode interactions because they do not permit interaction by the user. Whereas model-based sonifications entail conversation mode interactions by virtue of their user based manipulation.

A concert mode display has been developed as a first stage investigation for this research project to gain initial insights as to how the participants interpret their internet searching as CO$_2$ emissions. This approach was deemed the most appropriate for the task of ‘reading’ the sonification rather than manipulating the contents of the sonification. Future work may include the development of a conversation mode display depending on the conclusions drawn from this research.

2.4.4 MAPPING DATA & SONIFICATION

Mapping data in sonification is the process of translating data into audio representations of that data. What is important here for the designer is developing the most appropriate sound to represent the data in relationship to the task undertaken. This process may employ symbolic sounds, environmental sounds and the use of analogy or metaphor depending of the design intention. Walker & Kramer (2006, p1022) outlines a useful guide to help frame where symbolic (symbolic representation of the data) or analogic (representation of data through analogy) approaches of a sonification should reside in context with the information being displayed. See Figure 6.

![Figure 6: Symbolic and Analogic Relations, Walker & Kramer (2006, p1022)](image-url)
At the extreme left of the above diagram lies the symbolic region and at the far right the analogic region. The reference data at the symbolic end of the scale may have a subjective relationship with the sound employed by the display. For example a display that informs a driver of the amount of petrol left in their car could be a sharp beeping sound that is emitted when the tank is getting empty.

Conversely, the reference data at the extreme analogic end of the spectrum has the most essential relationship to the sound displayed. With this approach the driver may be informed of their car’s petrol status by actual audio samples of the petrol tank. An analogic correlation can be drawn between how the petrol tank sounds when it is full compared to how it sounds when it is empty.

It can be seen that sonification lies between the two extremes implying a mixture of symbolic and analogic relations to display the data. Here the sonification of petrol quantity may be a fusion of the two examples above where at a specified threshold the display blends from the analogic audio to the symbolic audio as the tank nears empty.

Beyond analogic and symbolic relations between the mapped data, Walker & Kramer (2006) present the notion of metaphor for the use in sonification also; where “changes in an auditory variable such as loudness are intuitively understood by the user to represent changes in, say, quantity” (Walker & Kramer, 2006, p1254). This approach is referred to as trend estimation. Trend estimation has become intrinsic in the sound design development of this research project through the mapping of data to sound with volume metaphorically indicating a rise in ‘quantity’ of internet CO2 emissions.

2.5 RELATED WORK

With respect to auditory displays and their corresponding sonifications, several projects are relevant to this study in their mapping of data to sound in an attempt to convey information to users.

2.5.1 DESIGNING AUDIO AURA

Designing Audio Aura (Back, Mynatt & Want, 1998) is a project that aimed to provide “serendipitous information (useful but not required), via background auditory cues, that is tied to people’s physical actions in the workplace” (Back, Mynatt & Want, 1998, p1). Produced as a prototype and evaluated among nine volunteers, the authors investigated the use of sound effects, music, and voice “to connect a person’s activities in the physical world with information culled from the virtual world” (Back, Mynatt & Want, 1998, p1).

This project was framed by three key factors:

- The use of audio to communicate
- Communicating serendipitous information
- Informing of physical actions within the workplace

To address the above constraints Back, Mynatt and Want (1998) developed three scenarios where Audio Aura may be effective. These are ‘email’ quantities, ‘footprints’ (individuals activity within the office), and ‘group pulse’, an auditory cue informing the participant of the group activity within the office. For the purpose of this research I will focus on one in particular: ‘Email’. The authors explain:

“When you enter the bistro, you will hear a cue that conveys approximately how many new email messages you have and indicates messages from particular people and groups”.

(Back, Mynatt & Want, 1998, p4)

Four sound design themes were developed for this scenario that included Sound effects, Music, Voice and Rich. Sound effects and Music employ non-speech audio where Voice and Rich make use of speech in their displays. Sound effects map the amount of emails to seagull calls and individual email senders are mapped to an assortment of animal calls such as birds and seals. In comparison to the Sound effects, Music enlists a tuneful approach to conveying information rather than nature sounds. Here, the amount of email is conveyed by altering “melodies, pitches, and rhythms of a set of related short phrases” (Back, Mynatt & Want, 1998, p4).
Voice and Rich are of less concern within this review of literature as I am solely concentrating my research on sonification approaches.

The authors chose Sound effects as the sound design to be tested. Fundamentally framed by an ethnographic methodology, their evaluation of Audio Aura included nine volunteers that undertook a series of basic tasks. Firstly they participated in a short training session to familiarize themselves with the system and the sounds. Secondly, the participants performed a short evaluation session whereby they were asked to go to the bistro. The observation concluded with a questionnaire. Due to the qualitative nature of this research the authors preferred to concentrate on “user feedback than performance numbers” (Back, Mynatt & Want, 1998, p8).

Analysis of the test’s observations and questionnaires revealed that the participants were generally encouraging towards the system, citing that the sounds presented were of good quality and peripheral, however a portion of the participants where challenged when trying to recall their intention.

2.5.2 EXPLORING INTERACTIVE SYSTEMS USING PERIPHERAL SOUNDS

Similar to Audio Aura, Bakker, Hoven and Eggen (2010) strived to exploit synthetic and nature sounds to “leverage auditory perception skills in interactive systems” by testing three working prototypes that “subtly convey information to users in an open office” (Bakker, Hoven & Eggen, 2010, p1). These prototypes titled AudioResponce, EntranceSounds and RainForecasts are designed to communicate in the periphery also, where the participants have the opportunity to attend to the information or easily disregard it.

Their testing methodology was framed by an ethnographic approach that was focused on gathering qualitative data including direct observations, field notes and interviews. Nine participants were enlisted for the study which took place in an open plan office environment for a period of three weeks for each prototype.

AudioResponce is designed to communicate to the participants their contribution to the “loudness of sounds they and their surroundings produce” (Bakker, Hoven & Eggen, 2010, p3). They prototype reads the level of noise in the office through a microphone that is positioned in the centre of the office and displays this data to the participants by playing piano tones consisting of “semi-randomized pitches” (Bakker, Hoven & Eggen, 2010, p3). For example; the louder the office noise, the louder the prototype plays the piano tones.

EntranceSounds is a device that indicates to the occupants of the office the frequency of people entering and exiting the office in hourly intervals. To achieve these researchers monitored people moving through the office door with a sensor. This data was then mapped to a piano chord, which was then relayed to the participants. For instance; if many people entered the office in one particular hour, the pitch of the display is high. In contrast, the pitch displayed is low if there were few people that entered the office in an hour interval.

RainForecasts presents information to the office participants communicating transitory rain forecasts in their geographic vicinity. By monitoring precipitation levels at half-hour intervals, the researchers then used this data to map a series of sounds too. Working with an “8 point scale” (Bakker, Hoven & Eggen, 2010, p5) where 0 indicates no precipitation and 7 indicates a heavy thunderstorm, the increments between the two extreme readings were presented as audio representations of the perceived level of precipitation the participants may associate with metaphorically. The table below illustrates the author’s sound design approach.

<table>
<thead>
<tr>
<th>Level of precipitation</th>
<th>Precipitation in mm per hour</th>
<th>Sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>BIRD SOUNDS</td>
</tr>
<tr>
<td>1</td>
<td>&lt;1</td>
<td>THREE RAIN DROPS</td>
</tr>
<tr>
<td>2</td>
<td>&lt;2</td>
<td>FOUR RAIN DROPS</td>
</tr>
<tr>
<td>3</td>
<td>&lt;5</td>
<td>SIX RAIN DROPS</td>
</tr>
<tr>
<td>4</td>
<td>&lt;10</td>
<td>EIGHT RAIN DROPS</td>
</tr>
<tr>
<td>5</td>
<td>&lt;50</td>
<td>MILD THUNDER SOUND</td>
</tr>
<tr>
<td>6</td>
<td>&lt;100</td>
<td>MEDIUM THUNDER SOUND</td>
</tr>
<tr>
<td>7</td>
<td>&gt;100</td>
<td>HEAVY THUNDER SOUND</td>
</tr>
</tbody>
</table>

**TABLE 1**: (BAKKER, HOVEN & EGGEN, 2010, P6) SOUND DESIGN APPROACH
In summation, from the analysis of the three sets of data obtained from the tests, the authors concluded that the Rainforecasts prototype was the most successful, with EntranceSounds the second most successful, and the AudioResponses the least. The authors attributed these findings to the acknowledgement by the participants that the Rainforecasts prototype displayed, for the most part, appropriate information. AudioResponses, in comparison, did not provide any valuable information to the participants for its perceived context. When analysing why this is the case the author’s cited a number of potential reasons. Firstly, they raised ‘disturbing’ as an expression used by the participants as a point for exploration. Rainforecasts and EntranceSounds were considered by the participants as non-disturbing yet a portion of the AudioResponses responses deemed them to be disturbing. Bakker, Hoven & Eggen hypothesized that this may “signify that the relevance of the information is related to the extent to which the sound representing it is experienced as disturbing” (Bakker, Hoven & Eggen, 2010, p7). For example, if two displays communicate different information yet utilize the same sonification and sounds, with one considered disturbing and the other not, relevance of the information in relation to the sonification and sounds may indicate that relevance of information should be aligned with the sonification and sounds. The authors also “acknowledge that when and what information is relevant highly depends on the context as well as on the interests, state of mind and knowledge of the user” (Bakker, Hoven & Eggen, 2010, p7).

2.5.3 STOCK MARKET
Mauney & Walker’s sonification system focused on “dynamically rendering sonifications of real-time stock market data” (Mauney & Walker, 2004, p1). This included a predefined sound mapping that deployed stock market data as a ‘soundscape’ of complementary ecological sounds to the stock trader for interpretation (Mauney & Walker, 2004).

2.5.4 WISP
Kilander & Lonnqvist’s (2001) ongoing development of WISP (Weakly Intrusive Ambient Soundscape) “conveys information to a recipient by means of subtle sound cues” (Kilander & Lonnqvist, 2001, p1). WISP’s main intention is to communicate in a non-intrusive manner, yet remain informative, allowing the user to remain focused on their task at hand.

This research builds on these studies in that it aims to present perceived internet CO₂ emissions as an auditory display through sonification in an unobtrusive and pleasing manner. Drawing on Schafer’s (1977) theory of the soundscape and Broadbent’s filter theory in (Pashler, 1988) as a reference for the sound design, the resulting sonifications endeavour to remain informative yet not be interruptive.

2.6 CONCLUSION
In this chapter I discussed the concept and various forms of auditory displays together with the auditory perception elements to be considered in their design. I then defined the terminology that describes the ambient and salient considerations for the sound design of sonifications within the background spectrum of the soundscape.

I then acknowledged sonification (a subset of auditory display) with consideration for how it informs my approach to the design of the research prototype. I then discussed examples of related works within my field, highlighting areas in which acknowledged research informs the approach to the design of this display. Furthermore, this chapter extracted elements of knowledge that assist in producing further knowledge within and for this study to evolve.

As outlined in Chapter 1, this research and its associated tests, intends to supply computer users with information on the amount of CO₂ emissions arising from their internet searching.

Based on the above considerations, the proposal of this exegesis is:

To examine the relationship formed between searching the internet and designed sound as a measure of internet CO₂ emissions. Through easing the amount of salient feedback towards ambient feedback, the intended outcome is that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand.
This proposition will be approached through an ethnographic exploration of salient and ambient sound types, environmental and synthetic sound approaches and their compositional detail (for example, loudness, pitch, timbre, rhythm and melody). The methodology for this approach is outlined in the next chapter.
Chapter 3
Methodology and Research Plan
3.1 INTRODUCTION

In this chapter I discuss the design methodology employed to explore the central themes of my inquiry. Focused by ‘Constructive Design Research’ as described by Ilpo Koskinen (2012) I explore the elements of this methodology that draw bearing on my own investigation. Constructive Design Research is discussed alongside its antecedents to give an overview of designing as research. Prototyping is then explored, as to its influence on the practice of design as a tool for producing knowledge. The ‘Field’ section of this chapter (a term derived from Koskinen et al (2012)) outlines the ethnographic approaches to observation and how this relates to my inquiry. My research plan is then explained as an iterative cycle of designing and evaluation to explore the central proposition which is how amounts of internet CO₂ emissions can be effectively conveyed to a collective office through sound, considering ethical engagement with these field evaluations.

3.2 DESIGN PRACTICE AS RESEARCH

There are many theories on design research, an area of focus within design discourse and practice that continues to evolve with the main objective being to establish what research is: where it stands within the discipline of design as a means of knowledge creation, and how this knowledge is reported as research. Archer stipulated a scientific approach which states that to contend as research the contribution “must be knowledge directed, systematically conducted, unambiguously expressed. Its data and methods must be transparent and its knowledge outcome transmissible” (Archer, 1995, p13). Downton’s overarching proposition in his publication Design Research proposes a different understanding where “design is a way of inquiring, a way of producing knowing and knowledge” and this “means it is a way of researching” (Downton, 2003, p1). Similarly Cross (2001) describes that design knowledge “is of and about the artificial world and how to contribute to the creation and maintenance of that world” (Cross, 2001, p5). Furthermore he states that “knowledge is inherent in the act of designing, gained through engaging in and reflecting on that activity” (Cross, 2001, p5). A precursor to both Downton and Cross among others, Schön (1983) offered a constructivist paradigm where he proposed an epistemology of practice. He envisaged a “process of reflective research where practitioner’s gain and use insight derived from it as they participate in it” (Schön, 1983, p324). He termed this ‘reflection-in-action’ Schön (1983). Adding new perspectives to this territory is ‘Constructive Design Research’ as defined by Koskinen et al (2012). Referring to “design research in which the construction – be it product, system, space, or media – takes centre place and becomes the key means in constructing knowledge” (Koskinen et al, 2012), constructive design research more importantly, outlines an approach to research and design that strives to “integrate design and research” (Koskinen et al, 2012, p6). This approach makes the compelling assertion that design research does not have to exist as either art or science to produce knowledge, but can function as a synergy of the two. Given this, I assert that, with respect to my inquiry, design practice as a framework for knowledge-building can be a successful form of design research, particularly through the construction of concepts and prototypes that are developed through an iterative process, evaluated through user testing, and with the knowledge gained, constructing further knowledge.

3.3 CONSTRUCTIVE DESIGN RESEARCH

‘Constructive Design Research’ Koskinen et al (2012) is a relatively new term for contemporary design research. At its centre is the process of construction, as in physically building something, as a method for evaluation of a question, idea or concept to construct further knowledge pertaining to the question, idea or concept. Through three research approaches: namely the ‘Lab’, ‘Field’ and ‘Showroom’, Constructive Design Research demonstrates that this methodology can consist of many approaches to ‘achieve integration and still be successful’ (Koskinen et al, 2012). Key to this design research and apparent in the title is the process of construction: that is where “something is built and put to use. Not only concepts, but materials” (Koskinen et al, 2012, p7). As Koskinen et al (2012) further points out:

“When working with new technologies that have little origin in current practices, the best way to follow these technologies and practices is to build them, hand them to people, and then study what happens”

(Koskinen et al, 2012, p137)
The Lab is described by Koskinen et al (2012) as primarily a space for controlled testing of variables in the tradition of experimental psychology. This does not imply that design can be studied in its entirety within this space; however it does afford rigorous evaluation of relevant design questions, and hence it is the task of a discerning designer to apply the Lab thoughtfully. The Field is rendered different from the Lab and is more common among design practitioners for its ethnographic approaches derived from the disciplines of anthropology and social sciences through research approaches designed to explore and evaluate cultural events. These approaches often include observation (as a data gathering technique) of the subject matter in its natural context that is then analysed and evaluated to produce knowledge for the research. In the design context, an interpretative ethnographic approach is often employed to observe and analyse a design or part thereof in its intended setting, where the results of the findings aim to produce knowledge for the design research. Common research tools for this approach included video documentation (which collects verbal and physical responses), field notes (which may produce findings beyond the video footage), and more commonly in the field of HCI, data logging which can produce various types of data depending on the context of the research. The Showroom differs from both the Lab and Field. This form of research places art and design within an exhibition context and is commonly practiced in “shop windows, galleries and public installations” (Koskinen et al, 2012, p89). In this methodology the “Showroom encourages debate and questions the way in which people see and experience the material world through debate” (Koskinen et al, 2012, p89). With little reference to scientific or ethnographic approaches that unpack knowledge for research in the Lab and Field, the Showroom presents a different perspective of design research where “exhibiting objects such as prototypes, photographs, and video are as important as writing books and articles” (Koskinen et al, 2012, p95).

In my inquiry I will be primarily focusing on the Field as the primary aspect of Constructive Design Research as this is the first exploratory investigation of the design which is intended to be used by people in their natural work environment, and as such, greater knowledge for this research should be obtained when observed in its intended context.

3.4 CONSTRUCTION FOR KNOWLEDGE

Today prototyping is common within design research and, depending on the context; these prototypes can take on many forms utilizing many different media and technology. According to Rogers, Preece and Sharp (2011): “a prototype can be anything from a paper-based storyboard to a complex piece of software, and from a cardboard mock-up to a molded or pressed piece of metal” (Rogers, Preece and Sharp, 2011, p530). Though how these prototypes are employed within design research and practice needs some grounding. Koskinen believes that prototypes “may be ingenious and well made, but they remain researchers guesses about a possible product unless they are somehow studied” (Koskinen et al, 2012, p137). I point to Eric Zimmerman who sheds some light on a process within the practice of design through the methodology of Iterative Design:

“In an iterative process design decisions are based on the experience of the prototype in progress. The prototype is tested, revisions are made, and the project is tested once more. In this way, the project develops through an ongoing dialogue”

(Zimmerman, 2003, p176)

It is evident here that the process of construction is implicated within the iterative design process as well as the gaining of knowledge through the construction. Downton (2003) also points to iterative development by suggesting that the process of inquiry is iterative and like Zimmerman highlights the conversation-like character in that “aspects of knowledge produced by searching will suggest a design proposition” (Zimmerman, 2003, p176).

To portray an understanding of how prototyping and iterative approaches are utilized within research for the production of knowledge, I now present example works from the disciplines of Architecture, Industrial Design, Auditory Display and Sonification. These examples have been chosen for their relationship within the boarder context of design research, together with their sharing of this valuable research approach in different contexts.

For the development of the interactive installation series titled Lotus (an interactive dome that responds to human proximity), artist, architect and engineer Dan Roosegaarde of Studio Roosegaarde describes their process where the team undertook “a lot of material research and development in their studio in the
Netherlands, and out of an intensive process of trial and error they created the Lotus Foil” (McFarlane, 2013, p50). Lotus 7.0 as described by Roosegaarde is a “living wall composed of smart foils that fold open in response to human behaviour. Walking by Lotus, hundreds of aluminium foils unfold themselves in an organic way; generating transparent voids between private and public” (McFarlane, 2013, p50). Currently there have been two iterations of the prototype that have been deployed within the public domain, namely; Lotus 7.0 and Lotus Dome. What is important here is the reliance by the designers and engineers on the use of trial and error as a tool for knowledge building, and the refinement and development of matter to produce a physical manifestation of the original idea. See Figure 7.

FIGURE 7: LOTUS DOME (ROOSEGAARDE, 2013).
With respect to the discipline of Industrial Design, an industry with a long history of iterative design processes and continually increasing its “overlap” (Koskinen et al, 2012, p9) with HCI and interaction design through the growing technological product sector, I turn now to the German Industrial Designer Konstantin Gricic who actively employs an iterative process of design through prototyping when developing products for market.

"Design is not a mystery, yet there’s no rule to it either. I like to think of it as a journey. With every new project, we’re setting off for a destination without being sure how we’ll ever get there. Obstacles and sudden hitches often serve to stimulate our creativity and spur us on to more daring solutions". Figure 8 "shows a sequence of working models leading up to the final result'.

(Gricic, 2005, p182)

FIGURE 8: ESPRESSO MACHINE (GRICIC, 2005, P182).
In Auditory Display and Sonification design, the process of construction for knowledge and iterative design has been exemplified as an intrinsic element within the design and evaluation stages of various studies.

Audio Aura (Mynatt, Back, Want, 1998) alludes to the iterative process of design. In this research, they describe using “scenarios to explore issues in serendipitous information such as privacy and work practice” (Mynatt, Back, Want, 1998, p1). Here, the process of scenario development in itself could be considered a process of iteration within the practice of design by virtue of their ‘conversation like’ nature to produce a number of narratives. These are then evaluated and refined in an effort to unpack the best possible story to be told or imagined. In this respect, the deployment of a prototype for testing is a developing narrative of this inquiry. The authors describe that the “lessons learned at each phase of the process influenced our evolving design” (Mynatt, Back, Want, 1998, p7).

Iterative approaches to design research can be found within the Field also where the prototype is deployed and tested with real users. Allison Druin, Ben Bederson and Ann Weeks developed The International Children’s Digital Library, an online library for children, through an iterative approach that traversed three rounds of observation. “The findings from each round of evaluation enabled the researchers to learn more about the children’s needs” (Rogers, Preece and Sharp, 2011, p675). This then enabled them to “extend the functionality of the prototype and refine its usability” (Rogers, Preece and Sharp, 2011, p675).

Furthermore, studies such as ‘Creating Functional and Liveable Soundscapes for Peripheral Monitoring of Dynamic Data’ Mauney & Walker (2004), ‘Wisp’ Kilander & Lonqvist (2001) and ‘Exploring Interactive Systems Using Peripheral Sounds’ Bakker, Hoven & Eggen (2010) all include Field studies utilizing prototypes in an effort to garner knowledge of their context for further investigation which in totality can be interpreted as an iterative approach within design practice.

A thread begins to emerge with the role a prototype can play within design research. The prototype may be considered as a means to clarify understandings and produce knowledge within the practice of designing, and also within the testing, observation and analysis of the prototype within the Field. Implemented correctly, the value of the prototype as a tool for knowledge building and research contributions seems plausible in an iterative process. Prototypes have the ability to allow actual experiences between a user and the design within the Field that cannot truly be accounted for by the researchers in a conceptual framework. Furthermore, prototypes enable (through observation in use) the systematic recording and analysis of data from these observations that can determine areas of improvement for the design and research.

3.5 THE FIELD

This project seeks to evaluate the designed prototypes in the ‘field’, a term derived from ‘fieldwork’ or ‘field studies’ used in the social sciences (Denzin & Lincoln, 2003, p1). Originally developed “to study the customs and habits of another society and culture” (Denzin & Lincoln, 2003, p1), field studies have become common practice in many disciplines including “education, history, political science, business, medicine, nursing, social work, communications” (Denzin & Lincoln, 2003, p1) and now design. In design, the field refers to the actual social situations of practice and adoption of technologies by users in their intended environment.

Field studies are now common practice within design research as a means to investigate a particular aspect of a design in context. Field studies differ from Lab investigations in as much as they are taken away from a controlled environment and placed “where some part of a design is supposed to be used” (Koskinen et al, 2012, p69). Borrowing techniques largely from “interpretative social science” (Koskinen et al, 2012, p69), Field researchers are “interested in how people and communities understand things around designs, make sense of them, talk about them, and live with them” (Koskinen et al, 2012, p69). For example, to test the validity of their project ‘Exploring Interactive Systems Using Peripheral Sounds’ rather than hypothesize about the predicted effect, S. Bakker, E. van den Hoven, and B. Eggen (2010) tested it in a real office environment and observed what happened. As they explain:

“To evaluate the use of sound in these demonstrators, we were mainly interested in the experiences of the participants. Therefore, we gathered qualitative data to inform a discussion on this topic. All comments made by either participants or by visitors were carefully noted during the experiments. Furthermore, after each period of three weeks, a group interview was conducted with 4 to 5 participants”.

(Bakker, Hoven, and Eggen, 2010, p58)
3.5.1 THE FIELD AND ETHNOGRAPHY

'The Field' is the term describing the locality or situation to be observed in an inquiry and 'ethnography' is the qualitative research approach to the inquiry of the field. Ethnography as a title has relations within different disciplines and frequently includes empirical work, particularly observation in order to study people. 'Exploring Interactive Systems Using Peripheral Sounds' (Bakker, Hoven & Eggen, 2010), is an example of an inquiry with an ethnographic research design through the observations of the prototype in the field and the gathering of qualitative data to analyse and gain meaning for the field study.

3.5.2 CONCEPTUAL INQUIRY IN DESIGN RESEARCH

There have been a number of ethnographic approaches developed over the years to assist the designer in undertaking field study research. Design ethnography stems from the process of ethnography and it is similar in many ways though it "is probably the focus on products and things and the use of mock-ups and prototypes" (Koskinen et al, 2012, p75) that marks the difference between the two. Another more prescriptive methodology is Contextual Inquiry (CI) as defined by Beyer and Holtzblatt (1998). Again, following an ethnological approach, CI outlines a flexible methodology that allows the researcher to call upon and adapt where necessary to suit their own inquiry. A typical CI is guided by four main principles as defined by Beyer and Holtzblatt (1998):

- **Context** - Interviews are conducted in the user’s actual workplace. The researcher watches users do their own work tasks and discusses any artefacts they generate or use with them. In addition, the researcher gathers detailed re-tellings of specific past events when they are relevant to the project focus.
- **Partnership** - User and researcher collaborate to understand the user’s work. The interview alternates between observing the user as they work and discussing what the user did and why.
- **Interpretation** - The researcher shares their interpretations and insights with the user during the interview. The user may expand or correct the researcher’s understanding.
- **Focus** - The researcher steers the interaction towards topics which are relevant to the team’s scope.

In relation to this inquiry, CI is referenced as a guide to formulate my understandings of how the inquiry will be conducted in the field. Furthermore the use of adapted affinity diagrams as defined by Beyer and Holtzblatt (1998) focused on a set of themes adopted from Bonebright & Flowers (2011) will be a key reference when analysing the qualitative data obtained from the inquiry.

Observation is a key feature in field studies however they can be more effective when used in combination with other data gathering instruments. This data can then be compared and contrasted with other data collected from an inquiry that may include: "interviews, questionnaires, and studying artefacts used in the activities" (Rogers, Preece and Sharp, 2011, p330). The following is an adapted list which details what might be obtained during a design ethnographic study. See below.

- Activity or job descriptions.
- Rules and procedures.
- Descriptions of activities observed.
- Recordings of the talk taking place between parties involved in observed activities.
- Informal interviews with participants explaining the detail of observed activities.
- Diagrams of the physical layout, including the position of the artefact.
- Photographs of the artefacts used in the course of the observed activity.
- Videos of artefacts as used in the course of observed activities.
- Workflow diagrams showing the sequential order of tasks involved in observed activities.
- Process maps showing connections between activities.

(Rogers, Preece and Sharp, 2011, p333)
The analysis of field study data largely depends on the context of the study, how it has been designed, what is under inquiry within the study and what data is obtained. The data I will be collecting is the participant’s demographic information, interview responses, video footage and field notes. Analysis methods I will be using in this research include coded affinity tables of the video footage (if applicable) and interviews, together with the field notes obtained and any relevant demographic information. With respect to my research, the field is significant. It is here the prototypes are observed in context, with the intention of attaining a greater understanding of how they are perceived and interacted with by participants when in use, and more specifically, to evaluate how successfully CO₂ emissions are conveyed to the participant through sonification. By easing the amount of salient feedback towards ambient feedback, it is proposed that the communication of perceived internet CO₂ will progress from being intrusive to unobtrusive while remaining informative and not distracting the listener’s centre of attention.

3.6 METHODS AND INSTRUMENTS FOR THE INQUIRY

The observation program and data collection of this inquiry will be framed by a qualitative method with an ethnographic and interpretative focus. An adapted Contextual Inquiry (Beyer & Holtzblatt, 1998) has been employed focusing on the experience a small user group has when interacting with the ambient information display prototype. The method will include the design and development of functioning interaction prototypes, which are tested via their observation and evaluation in use. In this section I will explore this approach and the instruments concerned.

3.6.1 TRIANGULATION

To frame the data collection of this enquiry I turn to Rogers, Preece and Sharp’s (2010) strategy of triangulation. Described as a “strategy that entails using more than one data gathering technique to tackle a goal, or more than one analysis approach on the same set of data” (Rogers, Preece and Sharp’s, 2010, p293), triangulation has been instrumental in determining the data gathering and analysis methods in this inquiry.

3.6.2 DATA GATHERING DIAGRAM

The data gathering diagram outlines the three major data gathering techniques implemented in the contextual enquiry. This diagram paints a visual representation of the triangulated treatment of the data gathering approach and how these techniques can be used to clarify and compare understandings within other techniques in the analysis process. Refer to figure 9.

![Data Gathering Diagram](image)
3.6.3 VIDEO

Video will be used to observe the participant’s interactions with the prototypes when in use. As this inquiry is part observation, I have chosen this method for its visual and audio documentation capabilities. The observed data to be analysed is the user’s physical and verbal responses to the prototypes. The meaningful data is coded and transcribed. The transcription is undertaken post-inquiry as not to interrupt the observation being performed.

3.6.4 INTERVIEWS

To reinforce the data obtained through the video observation, an interview will be carried out with each participant after their interaction with the prototype in use. Again, I turn to Rogers, Preece and Sharp (2010) who outline three interview methods for data gathering, namely: unstructured, structured and semi-structured. Unstructured interviews are “exploratory, and more like conversations around a particular topic” (Rogers, Preece and Sharp, 2010, p298). These interviews are particularly useful if the researcher is interested in “generating rich data” (Rogers, Preece and Sharp, 2010, p298). Structured interviews are by comparison are employed “when the goals are clearly understood and specific questions can be identified” (Rogers, Preece and Sharp, 2010, p299). A semi-structured interview as the name suggests combines “features of structured and unstructured interviews” (Rogers, Preece and Sharp, 2010, p299). In both observations, I utilize this interview type searching for qualitative data. This interview type allows me to gain a greater understanding of the user’s experience when interacting with the prototypes, and as this inquiry is predominantly exploratory, was deemed most appropriate on consultation with my supervisor.

3.6.5 FIELD NOTES

Field notes are taken during the observations. The data recorded is the formal information of the observation as well as initial notes for the installations refinement, and the initial notes of participant’s actions. This data will be employed to compare and contrast with the video and interview data. Moreover this data is used to audit the performance of the prototype within the environment. See Figure 10.

<table>
<thead>
<tr>
<th>Field Study 1. Field Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location and time:</td>
</tr>
<tr>
<td>Researches:</td>
</tr>
<tr>
<td>Participants:</td>
</tr>
<tr>
<td>Date:</td>
</tr>
<tr>
<td>Weather:</td>
</tr>
<tr>
<td>Natural Auditory Environment:</td>
</tr>
<tr>
<td>Sound Description and Treatment</td>
</tr>
<tr>
<td>Title:</td>
</tr>
<tr>
<td>Treatment:</td>
</tr>
<tr>
<td>Volume:</td>
</tr>
<tr>
<td>Technical issues:</td>
</tr>
</tbody>
</table>

Initial notes for installation refinement through observation:
Initial notes of participants actions through observation:

FIGURE 10. FIELD NOTES EXAMPLE.
3.6.6 DEMOGRAPHIC INFORMATION

Demographic information is recorded for each participant involved in the study. This data is the initial insight into the ethnography of the participants. The data obtained outlines the participant’s reliance and frequency of use of the internet, their understanding of carbon emissions and their perceived appreciation of sound. As with the other types of data collected the demographic data will be called upon to clarify any thoughts if applicable within the other data sets. See Figure 11.

<table>
<thead>
<tr>
<th>Field Study 1. Demographic Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions</td>
</tr>
<tr>
<td>Name:</td>
</tr>
<tr>
<td>Age:</td>
</tr>
<tr>
<td>Gender:</td>
</tr>
<tr>
<td>Occupation:</td>
</tr>
<tr>
<td>Do you rely on the internet for the purpose of business and research?</td>
</tr>
<tr>
<td>How long each working day would you spend on the internet?</td>
</tr>
<tr>
<td>Briefly describe your understanding of carbon emissions:</td>
</tr>
<tr>
<td>Do you have an affinity with music and or sound?</td>
</tr>
</tbody>
</table>

FIGURE 11. DEMOGRAPHIC QUESTIONNAIRE.

3.7 ANALYSIS METHODS IN THE INQUIRY EXPLORED

Analysis of the qualitative data will be through video and interview responses that will be firstly coded and transcribed. Here observed patterns and themes will be established through the use of adapted affinity diagrams. The critical incidents (if they arise) within the observations will be defined within the data. The quantitative data will be analysed through the use of numbers and graphic aids. These findings are compared and contrasted alongside the field notes taken and the demographic information, if applicable. A first analysis is drawn from these findings followed by a, second higher, level analysis.

3.8 RESEARCH PLAN

My research plan structure is designed to follow an iterative process of designing, testing and observation in the field. The following section outlines the specific stages of the research plan, their objectives, the methods involved in the inquiry, and the instruments required for the inquiry.

3.8.1 THE STAGES OF THE RESEARCH PLAN EXPLAINED

STAGE ONE – LITERATURE REVIEW

The literature review assisted in establishing the intellectual background and proposition for this inquiry. Through this literature which includes conceptual approaches in HCI, the concept and forms of auditory displays, together with the auditory perception elements to be considered in their design, I could then define the subset of auditory displays known as sonification with consideration for how it informs my approach to the design of the research prototypes.
Examples of related works within my field highlighted areas in which acknowledged research informs the approach to the design of this display and, in turn, assisted in developing my research propositions – which is to:

*Evaluate how successfully CO\textsubscript{2} emissions are conveyed to the participant through sonification.*

And that;

*By easing the amount of salient feedback towards ambient feedback, it is proposed that the communication of internet CO\textsubscript{2} will progress from being intrusive to unobtrusive while remaining informative and not distracting the listener's centre of attention.*

**STAGE TWO – PROTOTYPE ONE DESIGN AND DEVELOPMENT**

The design, development and construction of the first prototype is an iterative process within itself, guided by the literature review and the corresponding focus of the enquiry. Firstly, it involves conceptualization of what design is required to perform the inquiry, followed by research on the technologies required for the concept. Resulting from this process was a prototype that represented an initial search to sound interaction that enabled informal lab tests conducted between my supervisors and I to refine our understanding of the quality of the prototype, its functionality and suitability for the first inquiry (Stage Three). Furthermore, the prototype was also discussed in seminars with other postgraduate students and academics to gain critical feedback on the prototype and its use.

**STAGE THREE – 1ST ENQUIRY DESIGN | FIELD STUDY 1.**

This stage involves the procurement of the test environment and participants to be observed. It also includes the development and refinement of the methodology to be employed, the observation program and documentation instruments, and the development of all relevant documentation required to formally undertake the inquiry within RMIT's policies. These include an ethics consent form and ethics participation form to be signed by each participant.

Field Study One is the first inquiry observing the experience a small user group has when interacting with the prototype within an office environment. Each participant is encouraged to perform internet searching as they would in a normal working day for a specified period of time, during which they will be video recorded. Following each participant's searching, they are required to respond verbally to a semi-structured interview that is documented on a digital audio recorder. The data gathered is video footage, questionnaires, interview responses and field notes. The field notes are recorded at the time of the inquiry.

**STAGE FOUR – ANALYSIS OF RESULTS | CONCLUSIONS**

Selected video and interview data is then transcribed, coded and analysed. The initial analysis takes the raw data from the video and interview to establish categories of converging and divergent themes. Higher analysis of these themes is then further analysed, pointing towards the refinement of the 2nd prototype and the methods involved for the inquiry.

**STAGE FIVE – PROTOTYPE TWO DESIGN AND DEVELOPMENT**

Stage five is informed by the results and conclusions drawn from the first inquiry. This may entail a complete redesign of the prototype or parts thereof. The design process is similar to that of Stage two; however it is centred on the refinement of the design with relation to the findings from Stage three. Continual reflection takes place between Stage four and five while continually referencing Stage one (the literature review), to maintain the focus of the inquiry.

**STAGE SIX – 2ND ENQUIRY DESIGN | FIELD STUDY 2.**

This stage will re-evaluate the observation program and documentation instruments employed in Stage three informed by the observations from the first field inquiry. As with the refinement of the prototype to yield finer grained results, this stage aims to refine the observation program and instruments in parallel with the revised prototype.
Field Study Two is the second inquiry observing the experience the same user group has when interacting with the revised prototype - Prototype Two. As with the first inquiry, each participant will be encouraged to perform internet searching as they would in a normal working day for a specified period of time, during which they will be video recorded. Following each participant’s searching, they will each respond verbally to a semi-structured interview that will be documented on a digital audio recorder. The data gathered is video footage, questionnaires, interview responses, field notes and any subsequent documentation dictated by the revised 2nd enquiry design.

STAGE SEVEN – ANALYSIS OF RESULTS | CONCLUSIONS

Analysis of the results follows the methodology employed in Stage five whereby the selected video and interview data is transcribed, coded and analysed. Initial analysis again takes the raw data to establish categories of converging and divergent themes. Higher analysis of these themes is then further discussed. Moreover, these findings will then be compared and contrasted against the themes to gain a greater understanding of the success of the inquiry as a whole. Conclusions will be then drawn and discussed through the writing of the exegesis.

3.9 ETHICS

Ethics approval is a precondition for this research as it relies on the involvement and responses of participants. As RMIT stipulates: “No research by RMIT staff or students involving humans as subjects will be allowed to be conducted unless that experimentation has the prior written approval of the Human Research Ethics Subcommittee in the college or, where appropriate, the RMIT Human Research Ethics Committee” (http://www.rmit.edu.au/dsc/chean). Furthermore without the ethics approval all observations, conclusions and coded data in this inquiry would barred from being presented to the public in any form. This in turn would devalue the research and my efforts made to define, produce and report valuable research. The ethics obtained was classified as low risk and was obtained during 2012 prior to the observations. See appendix.

3.10 CONCLUSION

In this chapter, I have discussed the overarching design methodology employed in my research to establish a framework to explore the central themes of this inquiry. Constructive Design Research was firstly introduced followed by theories of iterative prototyping as a means for knowledge production. The field outlines the ethnographic approaches to observation and highlights design ethnography and CI references to the field study. My research plan was then explained along with the methods and instruments for the inquiry. Ethical considerations were then discussed with relation to the field studies and the research more generally. This chapter outlined the methodology employed to ensure a thorough inquiry focused on producing knowledge to be considered for the design and refinement of the second prototype and further work to be explored in general.
Chapter 4

Designing Prototype One
4.1 INTRODUCTION

In this chapter, I explain the design process and generation of concept of Prototype One, including an overview of both its software and hardware elements. The soundscape features that inform the mapping model of the prototype’s audio renderings are then explored. The system development of Prototype One includes an explanation of the software used, the coding developed, its function and the intended output, including internet data collection and numeric operators for midi note generation. Sound design is then discussed including the sourcing of sound samples and the development of a sound library of these samples that gives a timbral spectrum of the sample set. These samples are observed and refined with the prototype in preparation for the first field study. The chapter concludes with a short discussion on the initial observations of Prototype One.

4.2 PROTOTYPE ONE DESIGN OVERVIEW

The primary objective of Prototype One is to convey to the user their internet CO₂ emissions through sonification when performing simple internet enquiries. This system can be conceptually described as an auditory display that utilizes data exploration which is a form of parameter mapping sonification that “involves the association of information with auditory parameters for the purpose of data display” (Grond & Berger, 2011, p1). The intended interaction with Prototype One is based on a concert mode design where the user is not encouraged to manipulate the sonification when active.

Technically speaking, Prototype One is software that, when connected to a network, ‘sniffs’ the internet traffic on that network in real-time. This data is then mapped to the designed software that produces audio feedback in relation to the internet traffic data obtained. The hardware for the prototype consists of a PC laptop running the software that is connected to the office network, two tweeter monitors and a bass woofer, including the relevant accessories. The prototype is currently using a laptop PC running the Windows Vista operating system; however the same prototype could be developed on other Windows operating systems. See Figure 12 for a visual diagram of the Prototype One system concept.

FIGURE 12. DESIGN CONCEPT VISUALIZATION.
4.3 SONIFICATION MAPPING MODELS

To conceptualize how the display and sonification may be designed we revisit the proposition. That is to:

*Examine the relationship formed between searching the internet and designed sound as a measure of internet CO₂ emissions. Through easing the amount of salient feedback towards ambient feedback the intended outcome is that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand.*

Initially two sonification mapping models were developed. Both models are inspired by Walker and Kramer’s definition of trend estimation in sonification where “changes in an auditory variable such as loudness are intuitively understood by the user to represent changes in, say, quantity” (Walker & Kramer, 2006, p1253). My approach is intended to metaphorically indicating a rise or fall in ‘quantity’ of internet CO₂ emissions to the user.

The first outlines that when data usage increases, a salient sound is produced with its intensity mapped to the volume of data used. Likewise as data decreases when mapped to a determined volume an ambient sound is produced. The preliminary assumption here is that when the salient sound is produced the user will interpret this as high CO₂ emissions and when the ambient sound is produced their CO₂ emissions are low. From a listening perspective the user would expect to hear the ambient sound idling in the background of the soundscape when the CO₂ emissions are low, and as the CO₂ emissions increase this ambient sound will increase in volume and smoothly transition to the salient sound as the perceived CO₂ emissions peak. These sounds would ebb and flow accordingly with the volume of data received by the system. See Figure 13 below for a visualization of sonification mapping model 1.

![Figure 13. Sonification Mapping Model 1.](image-url)
The second model excludes the transition between the salient feedback and ambient feedback. As the data increases a salient sound type or ambient sound type could be triggered to inform the user of their increasing or decreasing internet CO\textsubscript{2} emissions. That is; the salient or ambient sound type will idle in the background spectrum of the soundscape when the CO\textsubscript{2} emissions are low, and increase in volume and pitch towards the foreground of the background as the perceived CO\textsubscript{2} emissions increase. This model explores a combination of salience and ambience not only through sound type but also through volume, pitch and sound treatment. Therefore model 2 affords the exploration of saliency within the background spectrum where by the users CO\textsubscript{2} emissions may be successfully communicated in the periphery of attention. See Figure 14.

![Diagram of CO\textsubscript{2} emissions and sound type change](image)

**FIGURE 14. SONIFICATION MAPPING MODEL 2.**

### 4.3.1 DISCUSSION

Through discussion and evaluation of the two sonification mapping models with the supervision team, it was agreed upon to follow and expand on the second model due to its potential to enable saliency within the background spectrum of the soundscape.

Further refinement of this model was conducted by expanding its focus into salient and ambient sound streams responding to real-time data flow as CO\textsubscript{2}. For instance, minimal CO\textsubscript{2} produces a feedback representative of its quantity; likewise large amounts will be represented by another. The differentiating factor between the two streams is the nature of the feedback and interaction. Salient considers the effectiveness of more abrupt tonal renderings in the background, where the ambient feedback considers effective interaction within the user’s periphery through the use of subtle tonal renderings deployed in the background also. It must be noted that in theory both the salient and ambient renderings can consist of the same sounds; however the intersection can be defined through the manipulation of the sounds with relation volume, pitch and velocity to alter how they are perceived.
4.4 SYSTEM DEVELOPMENT

In this section I discuss the technical design decisions and software utilized to explore the data collection and sonification mapping of the designed model.

4.4.1 GATHERING THE DATA

There are a number of software packages available that have the ability to read (or sniff data packets within) internet traffic. These programs are essentially “a wire-tap device that plug into computer networks and eavesdrops on the network traffic. Just as a telephone wiretap allows the FBI to listen in on other people’s conversations, a ‘sniffing’ program lets someone listen in on computer conversations” (Sniffing (network wiretap, sniffer) FAQ. http://cs.baylor.edu/~donahoo/tools/sniffer/sniffingFAQ.htm). In this design one software program and two programming library’s for that software are enlisted to provide the foundations for the programs ‘sniffing’ functionality and data output; these are; Processing (www.processing.org), Carnivore (http://r-s-g.org/carnivore/installation.html) and Open Sound Control (OSC) (www.opensoundcontrol.org) respectively.

Processing was chosen as the preferred platform to facilitate the gathering of internet data as it is open source freeware, versatile, well supported and relatively easy to use. A Java-based platform created by Ben Fry and Casey Reas, “Processing was initially developed to serve as a software sketchbook and to teach fundamentals of computer programming within a visual context” (www.processing.org). Processing is the software that enables the ability to program the fundamental procedure of reading internet traffic and provide this data for output.

Carnivore is a Processing library that allows the designer to perform surveillance on data networks. Originally developed by the FBI, Carnivore listens to all Internet traffic on a specific local network. When utilised within the Processing code, it is possible to interpret network traffic in detail depending on the design and intention of the programmed code. In this case the ‘sniffed’ data is output as a string of bytes.

In ‘1997 Matt Wright and Adrian Freed’ (www.opensoundcontrol.org) developed the OSC protocol. OSC enables communication between computers and other media devices, and conveniently allows communication between programs running on the same machine. OSC is the key library which enables Processing to communicate and send data to the sound generation software chosen to be Pure Data (Pd).

In essence the code is produced in Processing which utilizes the Carnivore library to read the internet traffic as packets in bytes when they occur. This data is then forwarded to Pd as a string of bytes through the use of the OSC library for interpretation and manipulation.

See Appendix for the full Processing code.

4.4.2 RECEIVING THE DATA FROM PROCESSING WITH PURE DATA

Once the information has been sent from Processing it is then received by a custom-designed Pure Data (Pd) patch via what are known as objects. Pd is an open source, ‘object’ based programming language for producing synthesized music that was developed by Miller Puckette in the 1990’s. The objects utilized in Pd can have many different functions depending on the object type specified. For example one object may contain an algorithm to be executed when called, another may send a message. See the following for an explanation of the four major functions within the patch. Namely; receiving the data from Processing, unpacking the string, converting the payload into midi notes, and sending the midi notes to the sound processing software. See Appendix for the full Pd patch.
4.4.3 REceiving the Data From Processing

1. 
[import mrpeach] imports the objects necessary to read OSC into the Pd library. This enables other objects within the library to be called on within the patch.

2. 
From here the [udpreceive 9001] object listens to the computer's internal port which was specified as 9001 in the Processing code.

3. 
[send packet] then sends the information as a string of bytes to the [receive packet] object for unpacking.

4.4.4 Unpacking the String

1. 
[unpack 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0] literally breaks the string data down into its individual components until the 'payload' data is received as integers. The payload data is the amount of data being sent and received over the network as bytes. This integer can be viewed via the number atom (an object that displays numbers as they enter the object).

2. 
Once the payload data is received it is then sent [send payload] to the next section of the Pd patch (converting the payload into midi notes), shown in Figure 16.
FIGURE 1.6. UNPACKING THE STRING.
4.4.5 CALIBRATING THE DATA AS MIDI NOTES / VELOCITY AND DURATION

The payload data is received by the [receive payload] object. This data is then viewed within the number atom. At this juncture, the data is rendered between three different variable controllers: midi note (plays a note), velocity (determines the volume of the note being played) and duration (dictates the sustain of the note being played in m/seconds). Effectively, these three parameters render the sound output in relation to the volume of data received. For instance, if the payload value is low then the note played is low, at low volume and with minimal sustain. If the payload value is high the note output is high, at a greater volume and with increased sustain. This approach has been chosen in line with the sonification mapping model 2 outlined previously in this chapter (Figure 14). See Figure 17.

4.4.6 MIDI NOTE

The midi note is determined by scaling the payload data within the 1-127 note range. Through observation the minimum and maximum payload data values have been determined to lie between 0 and 300 bytes approximately and on average. From the number atom the data is passed to a mathematical object that multiplies the maximum data value of 300 bytes by 0.42333 to produce a maximum value of 126.999. This data is then sent in real-time to the midi note v-slider that has been calibrated to a maximum value of 127 and a minimum of 0. The midi note v-slider in essence now plays a midi note over the entire range in relation to the data received.

4.4.7 VELOCITY

The velocity v-slider receives the same scaled data as the midi note v-slider. This is due to the fact that velocity works on the same midi note scale (1-127). In the same manner, the duration v-slider is scaled between a range of values, however unlike the midi note and velocity v-sliders it is scaled in relation to time as m/seconds, rather than the 1-127 midi note scale. Having a minimum duration of 500 m/s and a maximum of 2000m/s the note being played fluctuates its sustain according to the data being received.
4.4.8 SENDING THE MIDI INFORMATION TO FL

![Image of makenote 1 500 and noteout 1 objects]

FIGURE 18. SENDING THE MIDI INFORMATION TO FL.

Now that the midi note, velocity and duration have been calibrated this information is then sent to Fruity Loops (FL), a sound production software package, via the [makenote 1 500] and [noteout 1] objects.

1. [makenote 1 500] makes MIDI-style note-on/note-off pairs, which can be used for MIDI output or to drive note-like processes within Pd. The 1 integer sets the initial velocity to be sent while the 500 integer stipulates that the lowest note duration is 500 m/s.

2. The [noteout 1] object writes a note-on MIDI message to the output port. Therefore the information being sent through [noteout 1] is the midi note, its velocity and the duration of sustain dictated by the duration v-slider over channel 1.

4.4.9 FL (FRUITYLOOPS)

![Image of FL sample loading interface]

FIGURE 19. FL SAMPLE LOADING INTERFACE.
4.5 SOUND DESIGN

In this section I discuss the development of a sound sample library that facilitates the categorization and refinement of the salient and ambient sound samples to be used by the prototype in the first field study. I report on defining the sounds for the library and how they are acquired. Furthermore these sounds are observed over two iterations with the prototype to define which are best suited for the first field study. This section concludes with a discussion on the performance of the sounds as ambient and salient representations of internet CO\textsubscript{2} emissions in the soundscape background.

4.5.1 DEFINING THE SOUNDS

Two sound themes have been developed to complement the sound design of Prototype One, namely salient and ambient. The salient approach represents a more abrupt tonal rendering that is aimed at gaining attention. The ambient approach represents a sound type that resides in the periphery of the user’s attention whilst still remaining informative.

Motivated by Schafer’s (1977) observations of organic, nature, and environmental sounds, as essential elements to the fabric of the soundscape, I have primarily focused the sound sample set for this inquiry as organic sounds. Furthermore, the deployment of these sounds in ambient display research is substantial within the HCI community, and these studies may further help to legitimize my inquiry’s findings when compared and contrasted.

A catalogue was developed containing two categories to assist in the sourcing of the sounds to be tested with the prototype. These sounds are categorized by their potential salient and ambient attributes with respect to selective attention theory, soundscape theory and concepts of peripheral information. See Table 2.

<table>
<thead>
<tr>
<th>Salient</th>
<th>Ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>THUNDER</td>
<td>RUNNING WATER</td>
</tr>
<tr>
<td>STRONG WINDS</td>
<td>CHIRPING BIRDS</td>
</tr>
<tr>
<td>GONGS</td>
<td>CALMING SEA</td>
</tr>
<tr>
<td>CYMBAL CRASHES</td>
<td>WARM CLEAR SUNNY DAY</td>
</tr>
<tr>
<td>TRAFFIC</td>
<td>CHURCH BELLS</td>
</tr>
<tr>
<td>BUILDING SIGHTS</td>
<td>WHALE NOISES</td>
</tr>
<tr>
<td>CITY SCAPES</td>
<td>CHIMES</td>
</tr>
<tr>
<td>SIRENS</td>
<td>FARM ANIMALS</td>
</tr>
</tbody>
</table>

TABLE 2. SOUND SAMPLE LIBRARY 1.
4.5.2 AQUIRING THE SOUNDS

In sourcing these sound types as samples, pre-existing sound samples were used. This approach was employed primarily to save time in the prototyping and testing phase of the research by avoiding finer grained, and time consuming field recording and audio engineering normally associated with sample construction. For example: locating the desired sound within the field, recording it in a satisfactory manner, exporting it to a sound editing program, compressing and normalizing it, and then trimming the desired section to be used. The sound samples obtained are from FL’s internal library as well as open source samples gathered from Soundbible (http://www.soundbible.com), a website database offering free samples for download to the public. All of the samples gathered are in the wav file format.

<table>
<thead>
<tr>
<th>Sound Sample</th>
<th>Source</th>
<th>Sound: Salient / Ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIRD IN RAIN</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT</td>
</tr>
<tr>
<td>FARM</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT / SALIENT</td>
</tr>
<tr>
<td>OCEAN WAVES</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT / SALIENT</td>
</tr>
<tr>
<td>SUNDAY CHURCH AMBIENCE</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT</td>
</tr>
<tr>
<td>SUNNY DAY</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT</td>
</tr>
<tr>
<td>WIND</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>SALIENT</td>
</tr>
<tr>
<td>WIND CHIMES</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>AMBIENT / SALIENT</td>
</tr>
<tr>
<td>BOTTLE HIT SLOW DOWN</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>SALIENT</td>
</tr>
<tr>
<td>RAIN STICK</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>SALIENT</td>
</tr>
<tr>
<td>NATURE</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>AMBIENT</td>
</tr>
</tbody>
</table>

TABLE 3. SOUND SAMPLE LIBRARY 2.

4.5.3 OBSERVING THE SOUND SAMPLES WITHIN PROTOTYPE ONE – FIRST OBSERVATION

As each sample was gathered an iterative process of trial and reflection took place when playing each individually in Prototype One. Firstly performed as a qualitative Wizard of Oz evaluation which involved playing the samples at different volumes and pitches, each sample was monitored for its sound quality, how it performed when triggered at specific pitches and what the overall sensation was derived from the sample for its context as salient or ambient. This information was relayed back and forth between the sample and the prototype while performing incremental changes in the prototype to achieve a desired result. Parameters such as pitch range, velocity, delay and db where all adjusted iteratively between each sample to define a balance so that all of the samples could be loaded and played with one global setting. This first analysis as an iterative process of design, however time consuming, and with many false leads did assist in defining a range of samples deemed appropriate to be further tested and potentially observed within the field. The refined sample set to be further observed is tabulated below including their perceived aural attributes as either salient, ambient or potentially both. See Table 4.

<table>
<thead>
<tr>
<th>Sound Sample</th>
<th>Source</th>
<th>Sound: Salient / Ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIRD IN RAIN</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT</td>
</tr>
<tr>
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<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT / SALIENT</td>
</tr>
<tr>
<td>SUNDAY CHURCH AMBIENCE</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>AMBIENT</td>
</tr>
<tr>
<td>WIND</td>
<td><a href="http://WWW.SOUNDBIBLE.COM">WWW.SOUNDBIBLE.COM</a></td>
<td>SALIENT</td>
</tr>
<tr>
<td>WIND CHIMES</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>AMBIENT / SALIENT</td>
</tr>
<tr>
<td>BOTTLE HIT SLOW DOWN</td>
<td><a href="http://WWW.FLSTUDIO.COM">WWW.FLSTUDIO.COM</a></td>
<td>SALIENT</td>
</tr>
</tbody>
</table>

TABLE 4. SOUND SAMPLE LIBRARY 3.
4.5.4 OBSERVING THE SAMPLES WITHIN PROTOTYPE ONE – SECOND OBSERVATION

Following the first trials of the salient and ambient sound samples, a second observation was performed with each sample using the hi-fidelity prototype. In this observation, the prototype was operating in its fully automated state, whereby data packets were ‘sniffed’ and interpreted as quantities of internet CO₂ emissions and output as sound. The most important difference between the two observations is that the second performs more randomly than the first and requires the internet to be searched by the designer to produce the feedback on demand to be referenced. These observations were carried out over a number of weeks generating informal discussion between my supervisor and I on the quality of each sound’s feedback and how this may be interpreted to the user. Within this observation continual refinement of the prototype took place while also referencing the feedback sounds. These refinements centred on producing the most consistent operation of the prototype over the spectrum of sound samples observed. Also, this was a perfect opportunity to rectify any anomalies within the prototype’s architecture and to minimize system failure. In some instances, the prototype was left running for hours to test its stability.

4.5.5 DISCUSSION

Through the second observation we were confident that the decisions made with regard to the sonification mapping model, the iterative prototype development, and the sound samples generated, that an auditory display prototype could convey internet usage as CO₂ emissions to a user in an unobtrusive manner. We conclude that this system is worthy of observing in the field for further analysis and refinement.

All of the samples did convey their intended elements with respect to salient and ambient information however some seemed to be more refined than others. Based on our own internal trials, for instance, the “Bird in rain” sample proved to be very ambient in nature when mixed correctly within the studio space yet conveyed enough salient elements to be able to be read consistently without being obtrusive.

“Bottle hit slow down” and the “Wind chimes”, by contrast, produced a more percussive feedback that wasn’t observed to be annoying to listen to, however, their salient attributes were stronger, as percussive sounds can be, and hence predominantly resided within the foreground of the soundscape background.

Another appealing observation is that the user does not have to consciously perform internet searching to produce feedback. Even if the computer seems idle it retains communication with the internet and hence produces feedback accordingly. This is a compelling element the prototype has exposed as it may indicate the beginnings of a keynote in its own right within the office environment if time permitted.

4.6 CONCLUSION

In this chapter, I have explained the design concept of Prototype One together with the soundscape features that inform the sonification mapping model of the prototypes audio renderings. This chapter included an explanation of the software used, the coding developed, its function and the intended output. The sound design was then discussed including the generation and sourcing of sound samples for the sound library. These sounds were then observed with the prototype over two iterations and refined in preparation for the first field test. A short discussion on the performance of the prototype and sound samples as salient and ambient through observation concludes the chapter, clarifying the suitability of Prototype One for further refinement and testing within the field.
Chapter 5
Study 1: Environmental Sounds in the Office
5.1 INTRODUCTION

In this chapter, I explain the design and implementation of the first study, including the participants observed, equipment used, the procedure and the questionnaire’s design. This is followed by the user study findings. From these findings, conclusions are drawn, pointing towards improvements of the prototype and highlighting issues to be addressed within the first study’s methodology in preparation for the next. Furthermore these conclusions aim to define the most successful of the audio renderings for this interaction in relation to the background spectrum of the soundscape.

5.2 THE DESIGN OF STUDY 1.

5.2.1 OBJECTIVE

The objective of the first user observation study is to investigate the issue of internet CO₂ emissions and how this information can be conveyed to a collective office through sonification. This study aims to examine the relationship between searching the internet and designed sound as a measure of perceived internet CO₂ emissions. Through easing the amount of salient feedback towards ambient feedback the intended outcome is that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand. The study is designed to extract preliminary understandings for this proposition through the interactions between the participants and the prototype while using the internet. Specifically, the study aims to highlight evidence of successful audio renderings for this interaction with respect to the proposition that will inform the second iteration of the prototype and second inquiry.

5.2.2 METHODOLOGY

The approach is to combine the design and development of a functioning prototype with observation and evaluation in the field. The study’s observations and evaluations are based on a qualitative method with an ethnographic and interpretative focus. An adapted Contextual Inquiry is conducted, focusing on the experience a small user group has when interacting with the prototype in their office space. The observations of the participants are recorded via video and analysed for gestures and movements in response to the prototype’s auditory feedback. A semi-structured interview was conducted with each participant after their internet searching to confirm understandings of the video footage. Selected video and interview data was transcribed, coded and analysed with conclusions drawn. The data gathered is video footage, questionnaires, interview responses and field notes that are compared to establish avenues for the additional refinement of Prototype One. See below.

- Ethics consent and participation forms – Essential documents required to undertake the field study.
- Demographic information – Information about the participants which includes their age, occupation, any prior experience with studies of this nature, and an indication of their musical listening experience.
- Video footage – Visual footage of the participants while performing the study.
- Semi-structured questionnaire - Participant’s verbal responses to the questionnaire to indicate how they perceived the sonifications.
- Field notes – Documentation of the study by the researcher which may include, weather conditions, how well the prototype is running and general notes of how the participants react while performing the test.

Please reference Study 1 in the appendix for all relevant documentation.
5.2.3 PARTICIPANTS IN THE STUDY

To evaluate the prototype, the system was presented to three participants who are architects in a commercial practice producing residential housing and renovations. These architects work within an open plan office arrangement and rely heavily on the internet for day to day business duties at their work station computers, of which are densely populated with visual feedback from their drafting and designing work. Dialogue passes fluidly between the architects within this arrangement without the need for eye-to-eye communication.

5.2.4 FIELD TEST OFFICE LAYOUT AND EQUIPMENT

The inquiry took place in the participant’s office space. A laptop containing the sonification engine was set up in the workspace, with the speakers positioned for audio clarity whilst being as inconspicuous as possible, reducing any visual attention being drawn to them. Likewise, the video camera’s location ensured the best possible view attainable to document the participants during the inquiry. Care was taken to ensure each sonification was within an acceptable dB range in the context of the pre-existing office soundscape. See Figure 20.

![](image.png)

FIGURE 20. FIELD TEST OFFICE LAYOUT.

The equipment necessary for the inquiry included all of the documentation hardware and system hardware to perform and observe the participants when they interact with the prototype. See below.

- 1 * JVC digital video camera
- 1 * Digital still camera
- 2 * Stereo audio tweeter monitors
- 1 * Sub woofer
- 1 * Laptop running the prototype software and samples
- 1 * Digital audio recorder for the documentation of the verbal interview
5.2.5 PROCEDURE

Study One is conducted over a three day period. The first day is a pre-study to liaise with the participants and to trial the prototype within the test environment. The second day tests the ambient audio feedback and the third day, salient. Both follow an identical observation program that focuses on the study of each participant for a period of 10 minutes while performing internet searching. Following each study, the participants then respond to a semi-structured questionnaire reflecting on their thoughts and experiences with each audio type.

**Pre-study – Day 1**

An initial meeting took place with the participants to introduce them to the project, its objectives and the field study. The participants were then informed of the documents they would be required to complete, the duration of the study and what will be expected of them during the study. A pre-connection trial was then undertaken to ensure the correct installation and operation of the prototype within the office space. The participants where then asked to read carefully and sign the Ethics consent form, along with the ethics participation form.

**Ambient feedback user study – Bird in rain sample - Day 2**

Firstly the participants were talked through the test procedure including the prototype system and what may be expected when activated. A simplified version of the procedure was given to each participant for their own reference. The participants were then required to complete a questionnaire that includes: demographic information, their understanding of carbon emissions, experience with music and any familiarity with similar studies. All participants were encouraged to work naturally performing tasks as they would in a normal day’s work. This includes internet research as a part of the participant’s professional obligations. It was then reinforced that each participant would be video recorded for a period of 10 minutes each as they perform internet activity. Lastly, any remaining questions from the participants would then be answered. The video camera and the prototype were then activated and the participant was requested to commence searching. Following each study, the participants answered a short semi-structured questionnaire to reflect on the study. These were documented with a digital audio recorder. To ensure a fluid testing procedure a comprehensive observation program guide was developed for the researcher to reference at any stage during the study.

**Salient feedback user study – Bottle hit slow down sample - Day 3**

The procedure as described above is repeated.

5.3 SEMI-STRUCTURED INTERVIEW QUESTIONS

5.3.1 OBJECTIVE

The objective of the semi-structured interview is to explore how the sonifications are perceived by the participants as amounts of internet CO\textsubscript{2} emissions. Furthermore it is aimed at producing initial insights as to how the sonifications perform as informative and unobtrusive information. The aim of the questionnaire is to establish clear grounds for the refinement of the prototype informed by the participant’s responses.

5.3.2 DESIGN

Predominantly a qualitative design, the questionnaire is focused on revealing initial insights into the participant’s sound aptitude and the way they may interoperate sound as a form of communication, with respect to internet CO\textsubscript{2} emissions.

The first question: **Could you describe the nature of the sound heard?** is included to gain an initial understanding of each participant’s aptitude with regard to hearing definition. The responses may draw a relationship between the participant’s experience and knowledge of sound and their perception of the sound during the study.

The participants where then asked **how they felt about the sound?** to establish any common themes between the participant’s feelings towards the sound. This question was also included to awaken any personal connection between the participants and the sounds represented…positive or negative.
The third question asked what **relationship they made between the sound and their internet searching?** as a means to gauge whether or not the participants made any relationship between the sounds and their internet searching regardless of the issue of internet CO\textsubscript{2} emissions.

The second last question: In the context of the office, **did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO\textsubscript{2} emissions?** is explicit and promoted a direct answer as to whether any relationship was formed. These responses could be used to hone sound types as feedback or to clearly define avenues for investigation.

The final question is quantitative in design. It was included to establish a rating between the two sound types as an overall experience and is as follows: **If you were able to rate your experience out of 10 in relationship to the sound, what would that be?**

### 5.4 RESULTS OF THE EVALUATION

In this section I present the results of the first field study. Field notes, video footage, and the questionnaire responses were analysed to draw initial insights as to how the sonifications are interpreted as amounts of internet CO\textsubscript{2} emissions, and how they performed as informative and unobtrusive information through ambient and salient sound types. Both sound types findings will be discussed then a comparative analysis is discussed to further define avenues for refinement of the sound types, the testing methodology and the prototype. This section ends with conclusions pointing towards improvement and highlighting issues within first study. The findings have been summarized based on verbal responses to the interview questions and qualitative evidence obtained from the video footage and field notes. The following results are discussed as themes derived (in bold) from the semi-structured interview. Please reference Study 1 in the appendix for a full coded transcription of the results.

#### 5.4.1 SUMMARY OF THE RESPONSES TO THE SEMI-STRUCTURED INTERVIEWS

The following results are discussed below in response to the themes derived (in bold) from the semi-structured interview.

**5.4.2 AMBIENT - BIRD IN RAIN SAMPLE**

**Initial hearing and interpretation of the sounds.**

All participants had an understanding of the nature of the sound. Participants A and C both described the sound as a “brook”. Participant B described the sound as “running water”. These responses indicate that all of the participants have the basic capacity to interpret sound and draw meaning from that sound. Furthermore these responses indicate that the participants could hear the sound within the soundscape of the office space clarifying that the audible listening level of the prototype is in an acceptable dB range.

**Participant’s feelings towards the sound.**

Participant B considered the sound to be “very calming” in nature and C found the sound to be “calm”. These responses indicate that a theme has been established between these two participants and the ambient sound type, which could be interpreted as calming. In contrast participant A considered the sound to be slightly “agitating”, and related it to the “un-nerving sound of the wind”. This response indicates that participant C may have had an experience with wind, which has instilled a negative perception in them towards the sound of wind. In summation the ambient sound was considered to have a positive effect on 2 of the 3 participants yet encouraged a negative reaction from 1 participant.

Based on a likert scale of 0 – 10 (0 equals negative, 10 equals positive), the overall experience was deemed below 50% where participant A graded it a 4, B a 2 and C a 7 stating that it was relaxing. Furthermore participant A expressed the notion of personal choice of the particular sound to be beneficial in the understanding and desirability of such feedback.
Relationship between the sounds and their internet searching?

No relationship was detected between the sound and the participant’s general internet searching even though the participants have demonstrated that they could hear, and draw an emotional relationship to the sound. Furthermore the participants (without prompting) expressed an expectation for the sound to have increased in volume to articulate the amount of traffic being used.

“Well I just wondered... and I became more aware of it so I was wondering if it was actually getting louder or not. And, I was looking at images at that stage so I don’t know if there was a relationship or not. I don’t think there was”. (A)

“I tried to make the sound go louder but it didn’t...seem too. It sort of seemed to a bit. I am wondering how you can get a lot of sound out of it”. (B)

This may indicate that the sonification mapping model is instinctively the correct approach, however the sound type chosen may be to ambient in design within this soundscape.

Internet usage in relation to internet CO₂ emissions?

Only participant B indicated an understanding of the audio feedback in relation to their internet CO₂ emissions.

“Probably yes. And by trying to get more sound out of it I was trying emit more CO₂. I wanted to find out which websites go higher and therefore involved more band width therefore involved more CO₂”. (B)

This is an interesting phenomenon as participant B previously stated they did not draw any relationship between their internet searching and the sound.

When considering the participants centre of attention, the video data and field notes indicated no gestural responses, signifying that the participants were not distracted, or that their centre of attention was interrupted when the system was running.

5.4.3 SALIENT - BOTTLE HIT SLOW DOWN SAMPLE

Initial hearing and interpretation of the sounds.

All participants had an understanding of the nature of the sound though their responses suggest a basic knowledge in the terminology of sound or instrumentation. Participants A and C both described the sound as percussive in nature where participant B likened it to “drums or bells”. As with the ambient sound these responses indicate that all of the participants have the basic capacity to draw meaning from sound, and that the audible listening level of the prototype is in an acceptable dB range. With regard to the participant’s centre of attention, the video footage does demonstrate that the prototype is functioning correctly and the sonification is audible.

Participant’s feelings towards the sound.

The consensus is that the salient sound wasn’t as pleasing to listen to as the ambient variation, citing it as “less good” (A) and “less relaxing” (C). However the participants displayed a greater awareness of its presence, which may confirm that it does have greater salient qualities by design, when compared to the ambient variation. The salient sounds overall experience was deemed below 50% where participant A graded it a 2, B a 3 and C a 5 explaining that it was less relaxing than the ambient version. Furthermore the experience was described as “obtrusive” and “irritating” by participant’s A and B respectively.

Relationship between the sounds and their internet searching.

No relationship was detected between the salient sound and internet usage by participants A and B. Participant C drew a relationship; “It sort of seemed to a bit. I am wondering how you can get a lot of sound out of it. ” The video footage does demonstrate that the prototype is functioning correctly and the sonification is audible.
Internet usage in relation to internet CO₂ emissions?

Participants B and C had some experience of understanding the audio feedback as an illustration of their internet CO₂ emissions. Participant B states that they could interpret the sound as amounts of perceived internet CO₂ emissions, however they did not draw any relationship between their internet searching and the sound. However B considered it less effective than the ambient version. Participant A didn’t draw any relationship whatsoever.

The following diagram visualises these results.
FIGURE 2. AMBIENT AND SALIENT SOUND ANALYSIS.

AMBIENT

BIRD IN RAIN SAMPLE

WAS THE SOUND HEARD?
ALL PARTICIPANTS COULD HEAR THE SOUND

"tricking break" (A)
"running water" (B)
"syringing breaking" (C)

FEELING TOWARDS THE SOUND

"neutral" (A)
"very quiet" (B)
"very calm" (C)

INTERPRETATIONS

"The sound was too quiet" (A)

METAPHORIC RELATIONS

"It was a bit close to dolphin sounds for my liking.
Maybe it's the new age deep sound that slightly annoyed me" (A)

"Maybe it's like sitting in wind...you kind of feel a bit...same" (A)

WAS THE SOUND HEARD?
ALL PARTICIPANTS COULD HEAR THE SOUND

"pops tones" (A)
"drums and bells" (B)
"percussion" (C)

FEELING TOWARDS THE SOUND

"lots and then the after louds" (A)
"drum" (B)
"slower and more intense than previous" (C)

INTERPRETATIONS

"It's a little more abrasive, the other noise made me a bit restless, this one didn't" (A)

RELATIONSHIP BETWEEN THE SOUND AND INTERNET SEARCHING

PARTICIPANT & ONLY
"It sort of seemed to a bit, I am wondering how you can get a lot of sound out of it"

RELATIONSHIP BETWEEN THE SOUND AND INTERNET SEARCHING

"CREW: A DIRECT RELATION
"The intensity of the sound would fade as the searching did and increased as the intensity increased"

RELATIONSHIP BETWEEN THE SOUND AND INTERNET CO. EMISSIONS

PARTICIPANT E AND C ONLY
"No" (C)

"It was a bit close to dolphin sounds for my liking.
Maybe it's the new age deep sound that slightly annoyed me" (A)

"Maybe it's like sitting in wind...you kind of feel a bit...same" (A)
5.5 DISCUSSION AND ANALYSIS – COMPARISON OF THE SOUNDS AGAINST THE THEMES

As an auditory display, the salient sonification was observed as the most successful in communicating perceived internet CO₂ emissions to the participants based on the data obtained. However from the data analysed both sound types could be deemed unsuccessful or not as successful as was originally intended with respect to the proposition. Many factors could be attributed to this outcome. The sound used and their level of auditory complexity in relation to the information being communicated could be a factor, as to the theme of environmental sounds.

Both sound types were clearly identified by the participants, where the ambient sound was described as a “trickling brook” (A), “running water” (B) and a “burbling brook” by participant C. The salient sound was described as; “tom toms” (A), “drums and bells” (B), and “percussion” (C).

From an aesthetic perspective the ambient sound was generally considered to be less obtrusive than the salient sound and was described as “very calming” by participant B, and “calm” by participant C. Participant A found the ambient sound to be “agitating”, however when describing their feelings towards the salient sound, they described it as ”less good” than they felt about the ambient sound in comparison. Participant C found the salient sound “less relaxing” than the ambient sound. In this aesthetic context, the responses obtained did indicate that the intention of the designed sounds being ‘salient’ and ‘ambient’ was correct. Contrasting the calming responses to the ambient sound, the salient sound was also described as “a little more obtrusive”, and as an “irritant” by participants A and B respectively, which could be interpreted as an effect of salience.

With respect to the concept of communicating internet CO₂ emissions, the salient sound was marginally more successful. Participant B had some understanding of the ambient feedback as CO₂ emissions, where both B and C interpreted the salient feedback as internet CO₂. From this and with relation to the intention of the ambient a salient sound design, it could be deduced that the ambient sound design may have been too subtle in nature to project any decipherable information where as the salient’s ‘irritating’ effect gained attention through its salient design. In the context of the soundscape background, the ambient sound did elicit responses that indicate it was in this vicinity, however the salient sound may have moved beyond the background to the foreground of the soundscape through its percussive nature, timbre and higher pitch.

Important to note is the interpretation and metaphoric relations that are found within the data obtained. Participant A describes a particular dislike to the ambient sound due to the metaphoric associations they derive from sound. For instance:

‘It was a bit close to dolphin sounds for my liking. Maybe it’s the new age shop sound that slightly annoyed me.’

and...

‘Maybe it’s like sitting in wind...you kind of feel a bit...tense.’

In contrast to B and C, A displayed an almost immediate dislike to the sound type. This is an interesting observation as it identifies a metaphoric relationship to the sound which evokes a negative response. This phenomenon may inhibit the success of the communicative intent of the auditory display, as the emphasis is on past cultural association rather than an ‘in the moment relation’ to the internet searching. This will be considered in the next iteration of the study when designing Prototype Two, and it may be concluded that to reduce the negative metaphoric response to the sound, is to reduce the familiarity of the sound, yet retain its ‘calming’ interpretation through the utilization of constructed synthetic sounds rather than actual environmental sound samples of the soundscape.

With respect to the sonification mapping model there is no evidence to suggest that it should be redesigned however refinements could be made to its activation threshold to decrease the audible saturation within the soundscape. This will discussed further in Chapter 6. Furthermore the field notes for both sound types and the video footage indicate that the participant’s centre of attention was not interrupted during the ambient study, and may have been during the salient study. This can be considered as evidence that the ambient sound type
did reside within the background spectrum of the soundscape, and that although being designed to reside in the background; the salient sound type proceeded from the background to the foreground of the soundscape.

With respect to the proposition, and from the results obtained, it can be established that by easing salient feedback towards ambient feedback will produce unobtrusive and pleasant information that does not divert the user’s centre of attention. However, the clarity of the communication in this auditory spectrum has been proven to be less successful than the salient feedback at this stage.

5.6 CONCLUSION

The purpose of this study was to gather initial insights on the nature of ambient and salient sonifications in relation to data, and how successfully these communicated as informative yet unobtrusive information as perceived internet CO₂ emissions. Its focus was to examine the relationship formed between searching the internet and designed sound as a measure of perceived internet CO₂ emissions. Through easing the amount of salient feedback towards ambient feedback, the intended outcome is that the information presented will progress from being intrusive to unobtrusive while remaining pleasant, informative and not divert the user’s centre of attention from their task at hand. In this chapter, I discussed the objective of Study One and the design methodology employed. Following this, I outline the participants observed, the physical test space and the equipment used. The procedure and questionnaire’s design are then discussed, followed by the analysis of the data obtained. From this analysis, the discussion explores the most successful of the sound types as an auditory display and how the sound types are perceived as information. These initial insights will inform the design iteration of Prototype Two, and its observation in Study Two respectively.

With consultation between my supervisors in relation to the initial insights, the following points define details to be addressed in the design. See below;

- To address the negative metaphoric relations drawn the sonification, tonal renderings will be explored in contrast to the environmental sounds tested in this field study. Through this approach it is envisaged that the negative responses can be reduced through lack of familiarity to the sound and the details of the tones constructed. Furthermore this approach will enable comparative analysis between the two sound types (environmental and synthetic) that may help to define which of the two is more successful for the sonification.

- On discussion with Dr. Lawrence Harvey (PhD RMIT University, Faculty of Architecture and Design) in relationship to participant A’s response;

  “If you know how the noise changes or doesn’t change, I think I would notice it more”.

  It has been decided that a training program will be developed for the participants to assist them in understanding the audio feedback within their environment prior to testing for the next field study.

- To reduce superfluous soundscape noise, the sonification will not run continuously, only at a pre-defined threshold. By doing this it is envisioned that the sonifications fluctuations will be easier to recognize.
Chapter 6
Designing Prototype 2
6.1 INTRODUCTION
In this chapter, I explore the design of Prototype Two, including an overview of the design iterations that have been informed from the observations made in the first field study. Next, I discuss auditory perception considerations and soundscape features that influence the sound design of the prototype. The sonification mapping models are then explained, which inform the sound design section in this chapter. The system development of Prototype Two includes an overview of the software used, together with the elements retained from the first Prototype. Each individual sonification engine is then examined, detailing the key aspects produced to define the five different engines. The chapter concludes with a short discussion on the initial observations of Prototype Two.

6.2 PROTOTYPE TWO DESIGN OVERVIEW
The first iteration (Prototype One) that was evaluated in the field explored the sonification of the auditory display as organic sounds through a trend estimation mapping model. This second iteration focuses on digital tonal renderings to convey the same information as an auditory display informed by the observations drawn from the first field study (Chapter 5). As with Prototype One, this system is an auditory display that exploits data exploration and parameter mapping sonification through the deployment of a concert mode design to test the user experience and interaction of the prototype in the field.

From a technical perspective Prototype Two retains the fundamentals of Prototype One’s system design and data gathering techniques where the software ‘sniffs’ the internet traffic on the network in real-time and represents this data as integers for sonification mapping. However the design of the sonification engines to produce the auditory feedback differs substantially in design and detail. This will be explored further in the system development section of this chapter.

The hardware for the prototype consists of the same PC laptop running the software that is connected to the office network, two tweeter monitors and a bass woofer, plus all of the relevant accessories. The prototype retains the PC running the Windows Vista operating system as in Prototype One.

6.3 AUDITORY PERCEPTION CONSIDERATIONS & SOUNDSCAPE FEATURES
In line with Prototype One’s theoretical and conceptual standpoint regarding auditory perception and soundscape features, Prototype Two enlists the same perspectives for the development of the sound design for the sonifications. That is;

By easing the amount of salient feedback towards ambient feedback, it is proposed that the communication of perceived internet CO\textsubscript{2} will progress from being intrusive to unobtrusive while remaining informative and not distracting the listener’s centre of attention.

This will be achieved by easing the salient attributes of a tone towards a more ambient sound quality by means of pitch, attack and decay, tempo and meter.

6.4 SONIFICATION MAPPING MODEL
Consequential from the conclusions drawn in the first field study is the refinement of the sonification mapping model for Prototype Two. Retaining the trend estimation model as in Prototype One, Prototype Two’s mapping reduces the audible saturation within the ambient spectrum of the soundscape by re-aligning the threshold at which the sonifications are activated.

Unlike Prototype One where the sonifications were driven by any packet received by the system from 1 byte and upwards, Prototype Two only takes effect at 57 bytes. This value has been determined through observation of the system and packet loadings when in operation. It was concluded that any value below 57 bytes could be considered negligible in the context of the study. Furthermore by taking this approach the audible spectrum of the soundscape is freed up for more relevant events of perceived CO\textsubscript{2} emissions. In doing so it is assumed that the sonifications will be more pertinent and potentially more legible to the participants regardless of their ambient or salient design. See below for a diagram of this model.
As an extension of this model is the introduction of secondary mapping model for the sonifications. The secondary model increases the activation threshold to 100 bytes, and when mapped to an alternate tone and integrated with the first model, a delayed effect of the secondary tone can be produced enabling greater detail to be achieved when designing the sonifications as salient or ambient. This will be discussed further in the sound design section of this chapter. See below for a visual description of this concept.
6.5 SOUND DESIGN

To address the proposition, four different tones have been developed for sonification to be studied further: Sounds 1, 2, 3 & 4 (as denoted by S1, S2, S3 and S4). These tones are mapped to the data in Pd, based on a volume-to-perceived quantity relationship. That is, at a defined data threshold the sounds increase or decrease in volume and effect with respect to the data obtained, implying to the participants an increase or decrease in internet CO\textsubscript{2} emissions generated while searching the internet.

The four sounds are categorized under the two themes established in Prototype One: ambient and salient. S1 & S3 focus on keynote inspired tones to produce ambient feedback. These are broadly characterized by a mid-to-low pitch, reduced attack (the time it takes to reach full pitch), and increased decay (the time it takes for the note to finish). Sound 2 and Sound 4 introduce higher pitch, modulation and musical timing to S1 & S3 as methods for producing salient effects within an ambient spectrum.

I consider S2 & S4 as salient feedback in comparison to S1 & S3; where S2 is the salient counterpart to S1, and S4 is the salient counterpart to S3.

It must be noted that all of the sound types are designed to reside in the ambient spectrum of the soundscape, where it is their musical attributes that render them as salient or ambient when compared within this spectrum. In so doing, it is envisaged that insights may be established on the easing of salient feedback towards ambient feedback for effective, unobtrusive communication within this spectrum when evaluated in Field Study Two.

6.5.1 SOUND 1

S1 is a resonant tone of a bass timbre in the note of C\textsubscript{2} with smooth attack and decay that subtly increases and decreases in volume with relation to the mapped data, implying amounts of perceived internet CO\textsubscript{2} emissions. This is the simplest of the four sounds. Please reference the CD appendix and play wav.file S1 for an audio example.

6.5.2 SOUND 2

S2 layers S1 with a secondary tone in A\textsubscript{4} that is of a higher pitch and has increased attack that pulsates in response to the mapped data based on the secondary mapping model. The feedback is similar to that of the Geiger counter whereby large amounts of data produces rapid pulses at increased volume. Likewise, reduced quantities generate a slower to neutral pulses at lower to zero volume. What may be heard by the participant is the introduction of a low bass tone (S1) implying low CO\textsubscript{2} and as the CO\textsubscript{2} emissions increase the secondary tone gradually increases in volume from beneath S1’s volume, which gradually gains parity with S1 at larger payloads. This effect is reversed as the perceived emissions decrease. When compared to S1, S2 can be considered as its salient counterpart through the addition of a higher pitch and pulsations. The diagram below illustrates this principle. Please reference the appendix and play wav.file S2 for an audio example.

![Diagram](https://via.placeholder.com/150)

FIGURE 24. SOUND 2.
6.5.2 SOUNDS 3 AND 4

S3 and S4 each consist of two identical tonal sets, and a secondary tonal set that is layered over the core set. The core tones consists of three lower to mid range tones; C1, C2 and C3 which are each an octave apart. When played together these tones are similar to a musical passage where they smoothly alternate between each other randomly in 4/4 timing, and selected on every quarter beat at 80 BPM (approximately the tempo of a relaxed human heartbeat). The effect of this treatment produces a warm and melodic rendering which is designed to be inoffensive to the listener and largely non-descript through its random composition. Musically it is set within the key of C. See below for a visual representation of this concept through adapted musical notation. Please reference the appendix and play wav.file S3 and S4 core tone for an audio example.

FIGURE 25. SOUND 3 AND 4 CORE TONES.

S3 layers a secondary tonal set (F1, F2 & F3) that is produced in the same manner as the core tones, but has a higher pitch and selects notes on every eighth beat. The culminating effect of this treatment retains the melodic aesthetic of the sonification yet enhances the salient attributes of the composition through the addition of higher pitch, and the gradual introduction of a faster meter in 8th beats over 4th’s.

As the sonification fluctuates from low to high perceived emissions the participant can expect to hear the core tones as an introduction indicating that the emissions of the search are low. Steadily as the emissions increase, the secondary tonal set is gradually introduced with volume to the core set. This treatment increases the musical density of the composition, which (together with an increase in volume) is designed to implying larger emissions. The process is reversed as the data reduces to zero. See below. Please reference the appendix and play wav.file S3.

FIGURE 26. SOUND 3.
Consisting of the same mapping as in S3, S4 introduces a set of higher pitch’s (F4, F5 & F6) than S3 that pulsate randomly on every sixteenth beat. When compared to S3, this sonification is interpreted as its salient counterpart through the higher pitch, and the increased tonal beat intensity, that it produces. See below. Please reference the appendix and play wav.file S4.

![Diagram](image)

**FIGURE 27. SOUND 4.**

### 6.6 SYSTEM DEVELOPMENT

#### 6.6.1 SYSTEM OVERVIEW

Prototype Two is a bundle of software that sniffs internet traffic and maps it to audio. The software employed is Processing (www.processing.org), Open Sound Control (OSC), and (Pd) (www.puredata.info). In the same manner as Prototype One, this system sniffs the network for all internet traffic through Processing, and passes it to Pd via the OSC protocol as packets of data in bytes. When this data is received, Prototype Two manipulates and scales the data, then forwards it to tone generators, modulators, random number generators and metronomes to produce the desired sonifications. Five different sonification engines were developed; namely S1, S2, S3 and S4 core tones, and S3 and S4 respectively.
6.6.2 S1

1.
The S1 patch receives the data payload that has been sent to Pd via OSC from Processing in the same manner as Prototype One (4.4.4). This value is then routed to the [- 57] object which subtracts 57 from the value it receives. In doing so any payload that is 57 bytes or less is reduced to zero or below which determines the activation threshold for the sonifications that was discussed previously in the sonification mapping models section of this chapter (6.4). At this juncture the [* 0.00166667] object takes this new value and multiplies it by 0.00166667 to produce an output value between the range of 0 – 0.5. This range has been determined in relation to the final output dB. Lastly the value is routed to the v slider object which is calibrated to 0 – 0.5 also. In essence, this section of the patch will output values between 0 – 0.5 for further manipulation in section 2 of the patch when packets of data are received.

2.
The next section of the patch defines the tone, its delay time, and its volume for output.

Firstly the output data from the v slider in 1 is received by the [$1 4000] message, which is then routed to the [line~] object. The [line~] objects function is to produce linear ramps whose levels and timing are determined by the [$1 4000] message. In this design the [$1 4000] sends a value between 0 – 0.5 via the $1 (level), and the 4000 sets the timing to reach the last received value in ms of $1. This produces a delay of 4000 ms to reach the received value from $1. Essentially this section of the patch adjusts the amplitude of the signal being sent from the v slider, which in turn produces a smoother transition between volume changes, and reduces the chance of digital ‘clipping’ in the path itself.
The tone of S1 is produced by the cosine wave oscillator object ([osc~]). Here [osc~ 65.41] defines a frequency of 65.41 hertz, or its musical note equivalent C2. When routed into the [*~] object together with [S1 4000] and [line~], the sonification engine is now ready to output this data as an audio signal when routed to the digital to analogue converter object ([dac~]). [dac~] is a predefined object in Pd that facilitates real-time audio output for Pd in mono or stereo.

To assist in the dB monitoring of the audio output I have enlisted the envelope follower object ([env~]). This object reads the amplitude of the wave from [*~] and routes it to the [-100] object. This step is critical as the [env~] object has an output range between 0 – 100 that needs to be re-scaled for the VU meter GUI, which has a 'useful' scale range between negative infinity and zero (0 in the digital decibel spectrum is considered ultimate loudness which should be avoided as it may cause hearing or equipment damage). This detail is important for the designer as it enables them to visually monitor the output dB of the patch as a safeguard against harm when testing the system.

6.6.3 S2

FIGURE 29. S2 PD PATCH.
As previously discussed, S2 layers S1 with a secondary tone that is of a higher pitch and has increased attack that pulsates in response to the mapped data based on the secondary mapping model. From a system design perspective, S1’s sonification engine is coupled with a secondary engine which produces the layered, pulsating tone. This layered tone (A4) has a musical relationship to S1 as a 4th.

1.

As in the design of S1, the secondary sonification engine produces the initial tone in the same manner. However the threshold has been raised to 100 bytes through [ -100] and the note has been defined as A4 in the [osc~ 440] (440 hertz) object. If played at this stage the engine would produce a steady tone at a higher pitch than S1, yet would not be activated until a packet load of 101 bytes or greater is received.

2.

This section of the patch produces the pulsating affect of the A4 tone by modulating the signals amplitude. [r F2] receives the scaled data from the v slider object where it is re-scaled through [* 20] to output a range from 0 – 10 that is received by the knob GUI. This object has been scaled to 0 – 10 and assists in the visual communication of the amplitude modulation when active. When routed to the [osc~ 20] object these values modulate the rate of the signal between 0 - 10 hertz. The depth of the modulation is defined by the v slider data also, where it is received by [r F2] and routed into the right inlet of the [*~] object. The culminating output of this section of the patch produces an A4 tone ([osc~ 440]) that modulates slower or faster (between 0 – 10 hertz), and at lower or higher decibels in response to the scaled data received from the v slider. For example; when the volume of data is low, the modulation and volume of the tone is slow and low. As the data increases, the modulation quickens and its volume rises.

6.6.4 S3 AND S4 CORE TONE GENERATOR

In its simplest description, the S3 and S4 core tone sonification engine is essentially a random tone generator. Comprising of the same data receiving and scaling methods produced in S1 and S2, this engine combines a metronome and random number generator to produce the desired effect. The threshold of the data is set at 57 bytes ([ -57]) and the amplitude smoothing has been reduced to 500 ms ([$1 500]) to decrease the tonal overlapping of the notes when played.

1.

To produce the tempo and time signature of the engine a metronome object [metro] is employed. This object synthesizes a traditional metronome in function however its tempo and time signature are defined by a ms value. Set at a value of 750 ms ([metro 750]), the metronome produces events (or ‘bangs’ in the Pd language) at 80 BPM’s, and on every ¼ beat. These events essentially instruct another object to produce an action at each event received, however they do not carry a value.

A random number generator object [random 3] receives these events from the metronome. Here the object generates numbers at random from 1 – 3 at intervals based on the event received. For instance the first event from the metro may produce a 2, the second a 1 and the third a 1 etc. This object continually outputs these three integers at random as long as it receives an event from the metronome.

2.

Section two of the patch produces the tones for the engine by assigning each of the integers to an individual note which is then to be output as an audio signal.

[r ndx] receives the random values from the [s ndx] object in section one of the patch. These values are then forwarded to the select object [select]. This object consists of one input and numerous outputs depending on its calibration. In this design the object has been defined to only accept integers 1, 2 and 3 ([select 0 1 2 3]) which automatically assigns individual outputs for each of these integers. In effect when a 1 is received this integer triggers C1. Integer 2 will trigger C2 and 3 will trigger C3.

In summary; the culminating output of this entire Pd patch produces tones C1, C2 and C3 at random in 4/4 timing on every ¼ beat, and at 80 BPM which rise and fall in volume that is mapped to the amount of data received.
6.6.5 S3 AND S4

S3 and S4 contrast their core tone set through their threshold, signal amplitude, time signature and tonal output.

Both engines have a threshold of 100 bytes and increase their signal amplitude from 500 ms to 2500 ms. These details result in a delayed response when compared to their core set, with a smoother attack and decay.

S3’s metronome is calibrated at 80 BPM with an output on every 1/8th beat ([metro 375]) which triggers the notes F1, F2 and F3. When coupled with its core tone set, S3 introduces a higher pitch and faster meter to the sonification.

S4’s metronome is calibrated at 80 BPM with an output on every 1/16th beat ([metro 187.5]) that triggers the notes F4, F5 and F6. When compared to S3, S4 is experienced as random composition with a higher pitch, and swift meter.
6.7 REFLECTION

To address the proposition of easing salient feedback towards ambient feedback, four sonifications have been developed and mapped to a trend estimation model. The redefined mapping model aimed at reducing the auditory saturation within the soundscape by introducing the threshold limit. Through this iteration it is envisaged that the sonifications will be easier to define and interpret within the ambient spectrum of the soundscape than in Prototype One.

With respect to the salient and ambient sounds designed, I must reiterate that the four sounds are all designed to reside in the background spectrum of the soundscape, and that to explore the easing from salient to ambient feedback, it is the design of the ambient and salient sounds and how they are perceived by the participants in context which will be evaluated to help garner further insights into the most successful of the sounds with respect to the proposition. The following diagram illustrates how the sound types are compared as ambient and salient through their auditory details. It is by easing the pitch downward, reducing attack, and decreasing the modulation and meter of the salient sonifications, that the ambient sound types are defined.

![Diagram of Ambient and Salient Sounds](image)

**FIGURE 31. AMBIENT AND SALIENT AUDITORY DETAILS.**

6.8 CONCLUSION

Chapter six explores the conceptual and theoretical standpoint for the development of Prototype Two along with the technical elements necessary to produce the prototype. An overview of the prototype discussed the data gathering elements retained from Prototype One along with the new directions conceived based on the findings from the first field study.

The auditory considerations and soundscape features were then explained resulting from the design of Prototype One also. This included the intention to retain the perspective that by easing the amount of salient feedback towards ambient feedback, it is proposed that the communication of perceived internet CO₂ will progress from being intrusive to unobtrusive while remaining informative and not distracting the listener’s centre of attention.
The sonification mapping models were developed from this concept and refined in response to the findings from the first field study. The corresponding sound design section explored the development of four individual designs outlining their conceptual and theoretical frameworks to address the proposition.

The system development section of this chapter included an explanation of the software used, together with the elements bought forward from the first Prototype’s design. Five sonification engines were developed for the prototype that where each discussed in technical detail to give an understanding of how the prototype produces the sonifications. The chapter concludes with a short reflection on the mapping models employed for the sonifications, and the auditory elements employed to explore the easing of salient feedback towards ambient.

This chapter details the theoretical, conceptual and technical elements considered in the design of Prototype Two that will be evaluated in the field through a second field study which will be presented in Chapter 7.
Chapter 7
Study 2: Synthetic Sounds in the Office
7.1 INTRODUCTION

In this chapter, I report on the design and concurrent findings from Study 2: Synthetic Sounds in the Office. I outline the research methodology and participants observed, together with the physical test space and the equipment used. The procedure and questionnaire's design are then discussed, followed by the user study findings, analysis and results. From these findings, I discuss, analyse and define the most successful of the sonifications in the context of this research.

7.2 THE DESIGN OF STUDY 2.

7.2.1 OBJECTIVE

The objective of Study Two is to observe and evaluate participants while using Prototype Two, within an office context, with a focus on understanding the combination of ambient and salient tonal renderings as an affective representation of internet CO₂ emissions. This field study endeavours to gain insights into the most successful of the sonifications in the context of the proposition.

7.2.2 METHODOLOGY

Study Two is the second observation and evaluation iteration of this project and repeats the methodological approaches as defined in Study One (Chapter 5); that being a qualitative observation method with an interpretive focus through an adapted Contextual Inquiry (Beyer & Holtzblatt, 1998). The observations of the participants are documented via video and analysed in response to the prototype’s sonification. A semi-structured interview was conducted with each participant after each test to confirm understandings of the video footage. The video and interview data was transcribed, coded and analysed with conclusions drawn. In addition, Study Two uses affinity tables to analyse the qualitative data through the development of identification and attribute ratings from Bonebright & Flowers (2011). The data gathered is video footage, questionnaires, interview responses and field notes that are compared to establish avenues for the additional refinement of Prototype One. See below.

- Video footage – Visual footage of the participants while performing the study.
- Semi-structured questionnaire - Participant’s verbal responses to the questionnaire to indicate how they perceived the sonifications.
- Field notes – Documentation of the study by the researcher which may include, weather conditions, how well the prototype is running and general notes of how the participants react while performing the test.

Please reference Study 2 in the appendix for all relevant documentation.

7.2.3 PARTICIPANTS IN THE STUDY

To evaluate the second prototype, the system was presented to the three participants from Study One who are commercial architects. Working in an open plan office arrangement, the participants utilize the internet for day to day business duties. These participants regularly discuss work-related issues without the need for eye-to-eye communication in this office arrangement.
7.2.4 FIELD TEST OFFICE LAYOUT AND EQUIPMENT

The inquiry took place in the participant’s office space where a laptop running the sonification engine was appropriately positioned on a desk, with the speakers situated and balanced for suitable audio clarity and volume in the context of the office’s pre-existing soundscape. The video recording equipment was located to gain a well-framed view of the participants during the testing procedure.

The equipment for the inquiry included:

- 1 * JVC digital video camera
- 1 * Digital still camera
- 2 * Stereo audio tweeter monitors
- 1 * Sub woofer
- 1 * Laptop running the prototype software and samples
- 1 * Digital audio recorder for the documentation of the verbal interview

7.2.5 PROCEDURE AND OBSERVATION PROGRAM

Conducted over a two-day period, the observation consisted of the study of each participant for a period of seven minutes as they performed internet searching on the laptop with each of the sonifications. From the recommendations in conclusion to Chapter 5; prior to each test, the participants undertook a short training exercise that explicitly informed them of the nature of the sonification, how it is interpreted when active, and what it sounds like at various packet loads. Each test was executed when there was a clear understanding from the participants of what the sonification is communicating. The participants were encouraged to work naturally, performing tasks as they would in a normal day’s work. Following each study, the participants responded to a short, semi-structured interview reflecting on their reactions to and experiences with each sonification type. These were documented with a digital audio recorder. The format for the two-day study is as follows.

- Training program / S1 & S2 sonification user study – Day 1.
- Training program / S3 & S4 sonification user study – Day 2.

7.3 SEMI-STRUCTURED INTERVIEW QUESTIONS

Study Two’s questionnaire includes an additional question to the original questionnaire designed for Study One. See Chapter 6.

7.3.1 DESIGN

- Could you please briefly describe what you searched on the internet during the test?

This question has been developed to complement the existing questions in the set and to assist in defining where the participant’s centre of attention resides during the observation and in relation to the sonification types. For instance, a participant may have a strong recall of their searching and can successfully interpret the sonification, indicating that their centre of attention remains on their searching task, and that the sonification is considered ambient in nature because it has not obstructed the participant’s centre of attention. In contrast, a poor recall and evidence of an intrusive response to a sound type may suggest that the participant’s centre of attention has been diverted from their searching task to acknowledge the sonification. This could suggest that the sound type is overly salient.

The complete semi-structured interview questions are as follows:

- Could you describe the nature of the sound heard?
- Was the sound familiar in any respects?
• What relationship did you make between the sound and your internet searching?
• Did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO\textsubscript{2} emissions?
• Could you please briefly describe what you searched on the internet during the test?
• If you were able to rate your experience out of 10 in relationship to the sound, what would that be?

Analysis of the qualitative data obtained has been conducted through an adapted affinity table focused on identification and attribute ratings adopted from Bonebright & Flowers (2011). Although very similar to Study One’s analysis, these measures were added to further assist in framing the semi-structured interview responses, in the context of the studies objectives. See below for these identification and attribute measures.

Identification as a measure of:
• The relationship between the sonification and the internet searching as CO\textsubscript{2} emissions.
• Evidence of higher-order understandings between the sonification and the internet searching as CO\textsubscript{2} emissions. That is, evidence of understanding moving beyond basic interpretation of data to sound as perceived internet CO\textsubscript{2} emissions, to in-depth interpretations of what loadings a particular web page might produce when compared with others.
• Evidence of the participant’s centre of attention during the observation.

Identification measures were gathered through the semi-structured interview responses, video footage and field notes. This was also evaluated by cross checking actual search history and recall.

Attribute rating as a measure of:
• Informative and uninformative information.
• Pleasant or unpleasant sonification - Participant’s feelings towards the sound.
• The overall experience while working to the sonification as positive, negative or neutral.

Attribute rating measures were gathered through the semi-structured interview responses.

7.4 RESULTS OF THE EVALUATION

I have summarized the findings based on verbal responses to the interview questions and evidence obtained from the video footage. Please refer to Appendix (Study 2) for the complete set of coded and transcribed data, and the affinity tables.

7.4.1 SUMMARY OF THE RESULTS AS IDENTIFICATION AND ATTRIBUTE RATINGS

The relationship between the sonification and the internet searching as CO\textsubscript{2} emissions:
All participants could accurately interpret the relationship between their internet searching and perceived CO\textsubscript{2} emissions when listening to S1. S3 was less accurately interpreted, with two out of three participants acknowledging the relationship. Sound S2 was interpreted by participant C. S4 was loosely interpreted by participant A. See Figure 34 and 35.

Evidence of higher-order understandings between the sonification and the internet searching as CO\textsubscript{2} emissions:
S1 encouraged the majority of higher-order understandings by the participants. For example:

"Pinterest has clearly got a lot more grunt to it...takes a lot more to operate it...Google images wants to be quick...Pinterest wants to look good...Google just wants to get you the answer quickly". (A)
“I was particularly interested to see that streaming video didn’t chew as much CO\textsubscript{2} as just putting something into a browser and the moment when the browser is doing the search chewed more CO\textsubscript{2} than streaming”. (C)

S4 prompted some signs of understanding, but less successfully.

“I searched cars and Facebook...and I was very surprised how low the sound was on Facebook...but as soon as you go to someone’s post on an architectural page...so go out of Facebook into something else there’s a massively louder sound for that...so Facebooks actually pretty low key...again like Google is probably...they want speed...they know if you have to wait very long...you’re not going to stay on it for half of the day on it at work”. (A)

S2 and S3 did not encourage any higher-order interpretation.

Evidence of the participant's centre of attention during the observation:

All participants retained their centre of attention on their searching task. This was evaluated through their recall of their searching activity. Every participant could restate exactly what they were searching during each observation. See Figure 32 and 33 below for more detail.

Informative and uninformative information:

S1 was interpreted to be the most informative of the sonifications. S3 was the next most informative, while both S2 and S4 were interpreted as being uninformative.

Pleasant or unpleasant sonifications - participant’s feelings towards the sound:

S1 was deemed the most unpleasant of the four sonifications with S2 a close second. S3 and S4 were regarded equally as the most pleasant. S1 triggered negative responses and metaphoric associations where participant B described the effect as “gassing off a lot”. Participant A implied a guilt association formed between the information and their searching. See Figure 32 and 33 below for more detail.

“Overall...freaked out...I don't know I would want to know about CO\textsubscript{2} emissions from a computer...from looking on the internet every day. I quite like my head in a brown paper bag on that front...so on that front is was not good...it was directly inversely proportional to how good I think the tool was”. (A)

The overall experience in relation to the sonification as positive, negative or neutral:

S1 and S3 were considered to be equally most successful in relation to the overall experience. S2 was considered the second most successful, while S4 was considered the least successful.

The sonifications evaluated to extract the majority of positive feelings in the participants are S3 and S4. They were described as; “pretty good” (A), and “not unpleasant (A) respectively. The lack of information uptake in S4 may imply the feedback was very ambient by design, rendering the information indecipherable. In a broader context, the video data and responses to the questionnaire did not show that any of the sound types interrupted the participants from their task at hand. For example, all participants could recite in detail all of their searching activities for each sound type evaluated. This may imply that all of the sounds tested reside in the background of the soundscape, however some proved more ambient within that spectrum.

The following two diagrams visualise these results.
Figure 3: Sound 1 and 2 Results
FIGURE 3. SOUND 3 AND 4 RESULTS.
7.5 DISCUSSION AND ANALYSIS – COMPARISON OF THE SOUNDS AGAINST THE THEMES

As an auditory display, participants considered S1 as the most successful in communicating perceived internet CO₂ emissions. Moreover, S1 encouraged higher-order understandings by the participants with regard to their internet searching and web page content, and was considered the most informative. However, participants also considered it to be the most unpleasant sound. This is an interesting result, as S1 was intentionally designed as ambient and pleasant feedback. The root of its perceived unpleasantness may be negative metaphoric relationships applied to it by the participants, which also affected the performance of the sonifications in Study One. Therefore it is theorized that by mapping sound to data, and the subsequent subject of communication, a negative experience beyond the scope of the sound itself may be constructed.

With respect to this study, a possible factor is that S1 was too explicitly communicative through its uncomplicated design and mapping. In contrast to the other sonifications, S1 consisted of pitch, note and volume only. Perhaps these factors helped the participants to clearly understand their emissions, which may have provoked guilt and other emotional responses that, I suggest, made it appear unpleasant. S3 was shown to communicate in an unobtrusive and pleasing manner.

Although not as successful as S1, this sonification reflects attributes closer to the study’s aims. S3 was successfully interpreted, was considered informative, more pleasant, and was also considered (along with S1) to be the more successful in relation to the overall experience. The reasoning behind these observations may lie in the details of the sound design and the musical qualities of the sonification.

7.6 CONCLUSION

The objective of Study Two was to observe and analyse four sonifications as representations of perceived internet CO₂ emissions. Its intention was to explore how these sonifications performed as informative yet unobtrusive information, and which of the sonifications displayed the most appropriate attributes in the context of the research. While being informative, the desired sonification should be unobtrusive while remaining pleasant, and not divert the user’s centre of attention from their task at hand.

This chapter outlined the intention of Study Two and defined the research methodology employed. An overview of the participants involved, the physical test space, and the equipment utilized in the study was then presented. Following this the procedure and questionnaire’s design were reported. The analysis of the data obtained was presented through identification and attribute ratings which were then analysed and discussed in relation to the themes. The results of this study define the most successful of the sonifications with respect to the research objectives.
Chapter 8

Conclusions & Future Work
8.1 EXPLORING INTERNET CO₂ EMISSIONS AS AN AUDITORY DISPLAY

The intention of this research was to explore the potential for an auditory display to successfully communicate quantities of perceived internet CO₂ emissions through sonification. The following chapter explores this proposition with relation to the results obtained from this iterative study and in the context of the proposition. Furthermore, higher-order understanding is discussed, along with considerations for future directions. The exegesis concludes with a reflection on the nature and progression of the project as a whole.

8.2 SEARCHING THE INTERNET AND DESIGNED SOUND AS A MEASURE OF PERCEIVED INTERNET CO₂ EMISSIONS

First and foremost it is evident from the analysis of the data that a relationship had been constructed between the participants and their internet searching as perceived CO₂ emissions through the auditory display and concurrent sonifications. Although ranging in success between the individual sound types and studies, the overarching premise does appear valid in that the auditory display prototype and sonifications have the ability to communicate perceived internet CO₂ emissions, and in this study S1 and S3 were the most successful.

This section of the exegesis focuses on the findings from Study Two to address the research questions. Study One was intended as a pilot investigation to resolve any preliminary concerns regarding the systems performance and to analyse how organic sounds performed as sonifications with respect to the context of the inquiry. Informed by conclusions drawn from Study One, Study Two focuses on the finer interpretations of the sonifications analysed and can be defined as a refined and adapted second iteration to the first study.

With respect to the concept of easing the salient feedback towards ambient feedback within the background spectrum of the soundscape, the initial insights appear promising. Both S1 and S3 were designed as ambient sounds and are considered the most successful over their salient counterparts. Furthermore through the analysis of the data obtained and in relation to the participants centre of attention, all of the sound types designed and mapped appear to reside in the soundscape’s background and, accordingly, the participant’s periphery. The differentiating factor between the success of the sound types in the context of this research appears to extend from the tonal range, musical aesthetic and complexity of their mapping design.

S1 for instance, was considered the most successful of the sonifications as information; however it also received the majority of negative responses. A contributing factor to this result could be the low tonal range and simplicity of the sound mapping – which – when displayed – presents an informative and legible sonification, however through its low and static tonality invokes an “uneasy” (A), or “threatening” (B) reaction from the listener. This is not to say that S1 was a salient sound vying for the participant’s centre of attention, however the negative connotations brought to it by the participant’s suggests that metaphor may be a crucial element to consider when designing sonifications.

S3 in contrast presented a more musical sonification than S1 which consisted of a higher tonal range, together with a more complex mapping model utilizing tempo and a randomized set of complementary tones. In totality, this sound when compared to S1 presents a sonification more akin to a musical passage rather than the drone effect in S1, and although not as successful as S1 in presenting information, S3 was considered more pleasurable to listen to by the participants and was described as “pretty good” (A), “very floaty” (B), and “like bubbles in the bath” (C). Through this observation it is plausible to suggest that a more musical approach to the design of the sonification, coupled with a higher tonal range than S1 can produce a sonification that is less threatening than the drone effect of S1, and closer to the studies objectives.

The following concepts outline avenues for further refinement that may draw the auditory display and its sonification closer to the proposition’s prerogatives. See below.

- To attempt to reduce S1’s negative responses yet retain its successful interpretation, a re-evaluation of the actual key the tone is in with reference to human psychology may prove beneficial. The model developed between Broadbent and Schafer for this inquiry has been of benefit to help frame the psychological approach to auditory perception, however further investigation is required on human auditory perception, psychoacoustics and cultural studies to determine stronger patterns for investigation with respect to tonal choice and human perception.
To increase S3’s clarity of communication yet retain its pleasant interpretation, a simpler sound design could be developed that reduces the number of tones present, and factors out the layered mapping of the tones. This concept would reduce the tonal density of the random composition — and in doing so - theoretically make it easier to recognize and interpret (based on the observations of S1) while retaining its pleasant aesthetic.

8.3 SONIFICATION AS PERIPHERAL COMMUNICATION

In this inquiry there is evidence to suggest that peripheral communication can be achieved with sonification. Through the examination of the participant’s responses and analysis of the video footage, all of the sounds designed did appear to reside in the ambient spectrum of the office soundscape. While the sounds produced varying interpretations and responses based on an aesthetic and physiological level, the results suggest through the participant’s clear and detailed recall of their search inquiries that the participant’s centre of attention while performing internet inquiries was not interrupted. This study presents initial understandings of sonifications as peripheral communication, however further work would need to be conducted and analysed based on this context more specifically to garner a greater understanding of peripheral sonification communication.

8.4 BEYOND SONIFICATION TO INTERPRETATION

A key finding from this inquiry was the higher-order understandings between the sonification and the internet searching as CO₂ emissions. Some participants moved beyond a basic understanding of the information relayed, to in-depth interpretations of internet searching as perceived CO₂ emissions. S1’s participant responses displayed the majority of higher order understandings. For example:

“Pinterest has clearly got a lot more grunt to it...takes a lot more to operate it...Google images wants to be quick...Pinterest wants to look good...Google just wants to get you the answer quickly”. (A)

“I was particularly interested to see that streaming video didn’t chew as much CO₂ as just putting something into a browser and the moment when the browser is doing the search chewed more CO₂ than streaming”. (C)

This data implies that the auditory display not only has the ability to convey internet CO₂ emissions to a participant (which is its primary objective), it also has the capacity to allow participants the opportunity to make sense of the information obtained in relation to the content of their searching. Regardless of the specific details of the participant responses, the key element of this insight points towards an auditory display that may help – and even educate – users with their internet searching with respect to the wider issue of carbon pollution.

8.5 LIMITATIONS AND FUTURE DIRECTIONS

This study was intended as a pilot investigation into the initial uptake of an internet CO₂ emissions as an auditory display. With the initial insights drawn from the data I now present my position for further work for the refinement of the display and the expansion of the project’s scope more generally.

The size of the study group was limited due to my desire to conduct the inquiry in a working architectural practice with participants doing their actual internet searching as part of their work practice. To explore finer elements of the sounds, particularly the reasons for sounds 1 and 3 having relative success over sounds 2 and 4, further studies need to be conducted with larger sample groups under more controlled laboratory style conditions which will produce quantitative results and the opportunity for greater comparison.

Acknowledging participant C’s indication of mental fatigue during the testing of sound 4; “It really didn’t register to be honest...It’s also because I have done it four times now with fairly subtle modifications between that one and the last one”. Therefore further work will include the refinement of the study program to reduce the possibility of this phenomenon occurring. This may include extending the studies duration.
By refining and testing S1 and S3 based on the insights obtained, it is hoped that a further iteration and observational study may produce greater knowledge of the easing of salient feedback towards ambient feedback, and the metaphoric implications of the sonifications design as synthetic sound, in the context of this project.

The projects scope can expand to also include:

- Network-based sonifications to explore how participants interpret the display knowing that the sonification is communicating the gross emissions of the participants searching activity in real-time.
- Personal sonifications which are allocated to each specific user. This exploration would observe the participants responses to the display with the knowledge that each participant’s internet CO₂ emissions can be monitored by their peers. Could peer pressure reduce the individual and or gross emissions of the participants?
- Gamifying the above concept where the auditory display sounds a soundscape sonification that is nominated by the participant with the most efficient searching. This exploration would explore the effects of a reward-based game in relation to internet CO₂ emission and how this is perceived by the participants.
- From an educational point of view and to raise the public awareness of the issue of internet CO₂ emissions, various initiatives could be developed in the form of exhibitions or public sonic sculptures which in their simplest form create a dialogue around such an issue. One scenario could see the system deployed within foyers of major public buildings for instance, where the public Wi-Fi produces the sonification.

8.6 CONCLUSION – REFLECTION ON THE PROJECT

The intention of this research was to explore the potential for an auditory display to successfully communicate quantities of perceived internet CO₂ emissions through sonification. In this exegesis I have investigated projects within the field of HCI, auditory display, and sonification together with soundscape theory as keynotes and signals. From this knowledge I developed a model to focus the sound design on a shift from salient to ambient information.

The methodological approaches of the study was based on Constructive Design Research which values the making of functioning prototypes that are tested and iteratively improved through further design development. The means of testing I used valued the qualitative approaches adapted from the ethnographic tradition of observing users in the actual their actual field of practice with the introduced technologies, in this case the design prototypes. My research plan and ethical considerations were then explained in relation to the field studies and the research more generally.

Designing Prototype One explored the concept of the prototype together with the theoretical approaches that informs the sound design of this project. This included an explanation of the software used, the coding developed, its function and the intended output. The sound design was then explained including the sourcing of sound samples that were observed and refined with the prototype in preparation for the first field test.

Study One reported on the objective and the design methodology employed, together with the participants observed, the physical test space and the equipment used. The procedure and questionnaire’s design were then explained, followed by the user study findings. From these findings, the discussion explored the most successful of the sound types as an auditory display, how the sound types are perceived, and the performance of the prototype with respect to the participant’s centre of attention. These findings then informed the design iteration of Prototype Two, and its observation in Study Two respectively.

Prototype Two re-imagined the design of the system which was informed by the findings from the first study. This included the intention to retain the perspective that by easing the amount of salient feedback towards ambient feedback, it is proposed that the communication of perceived internet CO₂ will progress from being intrusive to unobtrusive while remaining pleasant, informative and not distracting the listener’s centre of attention. The sonification mapping models were developed from this concept and refined in response to the
findings from the first field study. The sound design section reported on the development of five individual
designs outlining their conceptual and theoretical frameworks to address the before-mentioned proposal.

Study Two reported on the objective and the design methodology employed, together with the participants
observed, the physical test space and the equipment used. The procedure and questionnaire’s design were
then explained, followed by the user study findings. From these findings, the discussion explored the most
successful of the sound types as an auditory display, how the sound types are perceived, and the performance
of the prototype with respect to the participant’s centre of attention.

This final chapter of this exegesis presented and discussed the findings from this inquiry in the context of the
proposition. These findings show that successful communication can be formed between ambient sonifications
and users. By shifting from salient modulation approaches in S2, to a more musical salience in S3 and S4
through subtle timing variations, easing salient feedback towards ambient feedback can be achieved. The
findings gained in the context of the proposition are:

- That a relationship can be constructed between participants and their internet searching as perceived
  CO₂ emissions through the auditory display and concurrent sonifications.
  In this inquiry S1 and S3 were the two most successful sonifications with S3 being the more
  appropriate in the context of the research as it was considered informative, did not obstruct the
  participant’s centre of attention and was considered more pleasing to listen too than S1.
- That by easing the salient properties of a sound towards ambient can produce an unobtrusive and
  pleasant experience and not divert the user’s centre of attention, however the communicative
  intention is more difficult to achieve.
  This is evident in the results as S1 and S3 were the two most successful sonifications and were also
designed as the ambient counterparts to S2 and S4 through their reduced salience. S3 produced more
pleasing responses when compared to S1; however S1 produced more legible information.

Further insights include:

- Higher-order understandings can be achieved between sonifications and internet searching as perceived
  CO₂ emissions.
  The results suggest that participants can move beyond a basic understanding of the information
  relayed, to in-depth interpretations of internet searching as perceived CO₂ emissions. S1’s participant
  responses displayed the majority of higher order understandings.
- Metaphoric interpretations a sound promotes may be just as important a consideration in the design
  as the auditory details of the sound design itself.
  An observation in the analysis of the data suggests that the potential for a sonification to promote
  negative metaphoric interpretations may play a larger role in the interpretation of a sonification than
  its sound design and mapping alone. In this inquiry S1 was considered the most successful in
  communicating, however the negative metaphoric responses rendered it unpleasant.
- Larger sample groups will produce stronger results.
  To further clarify understandings and produce more robust results for analysis, future studies will
  employ larger sample groups for testing.

These findings will inform the design iteration of this study, and future work which considers different areas of
opportunity within the context of ‘Exploring Internet CO₂ Emissions as an Auditory Display’.
9 Bibliography
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WEBSITES

Carnivore. http://r-s-g.org/carnivore/

Sniffing (network wiretap, sniffer) FAQ. http://cs.baylor.edu/~donahoo/tools/sniffer/sniffingFAQ.htm

FL. www.flistudio.com

LoopBE1. www.softpedia.com

Open Sound Control. www.opensoundcontrol.org

Processing. www.processing.org

Pure Data. www.puredata.info


Soundbible. www.soundbible.com
10 Appendix
10.1 SUPPLEMENTARY DOCUMENTS TO THE STUDY

ETHICS APPROVAL

DEMOGRAPHIC INFORMATION

STUDY 1

- An observation procedure for the researcher to reference during the inquiry.
- An observation overview for the participants as their own reference for the inquiry.
- A semi-structured questionnaire for the researcher to reference during the discussion.
- Transcribed and coded results.
- Field notes.

STUDY 2

- An observation procedure for the researcher to reference during the inquiry.
- An observation overview for the participants as their own reference for the inquiry.
- A semi-structured questionnaire for the researcher to reference during the discussion.
- Transcribed and coded results.
- Field notes.

PROCESSING CODE

PROTOTYPE ONE PURE DATA PATCH
12 September 2012

Mr Stuart McFarlane
School of Architecture and Design
RMIT University

Dear Stuart,

**Ethics Clearance**

**Project title:** An exploration into the means of representation and interaction with calm technology to promote a greater awareness of e-waste in the office context

**Applicant/s:** Mr Stuart McFarlane (Student Researcher) and Mr Frank Feltham (Supervisor)

**Register Number:** CHEAN B-2000717-06/12

Your ethics application has been approved by the Design and Social Context College Human Ethics Advisory Network (CHEAN). Your application has been approved at a Low Risk classification and will be reported to the RMIT Human Research Ethics Committee for noting.

**Your ethics clearance expires on 11 September 2015.**

**Data storage**

Please note that all research data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CDs and memory sticks is valid for archiving, data transport where necessary and some works in progress. The authoritative copy of all current data should reside on appropriate network systems and the Principal Investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

**Annual/Final report**

You are reminded that an Annual /Final report is mandatory and should be forwarded to the Ethics Officer in December 2012. This report is available at: [http://www.rmit.edu.au/governance/committees/hrec](http://www.rmit.edu.au/governance/committees/hrec)

**Amendments**

If you need to make any amendments to your project please submit an amendment form to the Ethics Officer. This form is available at: [http://www.rmit.edu.au/governance/committees/hrec](http://www.rmit.edu.au/governance/committees/hrec)

Should need any further information please contact Lisa Mann on (03) 9925 2974 or lisa.mann@rmit.edu.au

On behalf of the DSC College Human Ethics Advisory Network I wish you well in your research.

Yours sincerely,

Lisa Mann
Ethics Officer
DSC College Human Ethics Advisory Network (CHEAN)
Demographic Questionnaire

Researches
Stuart McFarlane, Frank Feltham

Questions

1. Name: Participant A.
2. Age: 39
3. Gender: Female
4. Occupation: Architect
5. Do you rely on the internet for the purpose of business and research?
   a. Yes.
6. How long each working day would you spend on the internet?
   a. 2 minutes in every 10 minutes, but quite constant over the whole day.
7. Briefly describe your understanding of carbon emissions:
   a. A sum or calculation of the carbon based pollution emitted into the atmosphere in
      the production of things (generally from fuels).
8. Do you have an affinity with music and or sound?
   a. Nil.
9. Have you had previous experience in studies like this?
   a. Nil.
Demographic Questionnaire

Researches
Stuart McFarlane, Frank Feltham

Questions

1. Name: Participant B.
2. Age: 40
3. Gender: Male
4. Occupation: Architect
5. Do you rely on the internet for the purpose of business and research?
   a. Yes.
6. How long each working day would you spend on the internet?
   a. 1 hour.
7. Briefly describe your understanding of carbon emissions:
   a. Are created through the use of fossil fuels and are responsible for global warming.
8. Do you have an affinity with music and or sound?
   a. A bit.
9. Have you had and previous experience in studies like this?
   a. No.
Demographic Questionnaire

Researches
Stuart McFarlane, Frank Feltham

Questions

1. Name: Participant C.

2. Age: 45

3. Gender: Male

4. Occupation: Architect

5. Do you rely on the internet for the purpose of business and research?
   a. Yes.

6. How long each working day would you spend on the internet?
   a. 45 minutes.

7. Briefly describe your understanding of carbon emissions:
   a. Carbon emitted as a result of human activity.

8. Do you have an affinity with music and or sound?
   a. Yes.

9. Have you had and previous experience in studies like this?
   a. No.
Study 1.
Study 1. Activity Running Order – Researches copy

Monday 26th November 2012 – Friday 30th November 2012.
9am - 10am.

Researches
Stuart McFarlane, Frank Feltham

Participants
3 commercial architects aged between 30 & 45. All participants have no hearing impairment.

Pre-study

MEET AND GREET THE PARTICIPANTS (20 MINUTES)

Welcome to today’s pre-study of the system, a software system designed to produce sound feedback (as CO₂) in relation to your internet searching.

Study 1. is an investigation into the effectiveness of sound feedback as an ambient information display with respect to human perception and attention. Specifically the research focuses on the issue of internet e-waste (CO₂ emissions) and how this information is conveyed to the collective office through sound.

The data gathered will be video footage, questionnaires and interview responses that will be analysed to determine avenues for additional refinement of the prototype.

1. First we need to confirm the time of day to perform the study. 10 minutes per participant over a two day period, followed by a semi-structured interview that will be audio recorded.
2. Secondly, you need to read carefully and sign the ethics consent form along with the ethics participation form. Feel free to ask any questions. (5 minutes)
3. A pre-connection study will be undertaken to ensure the correct setup and operation of the prototype with in the office space. This does not involve the participants. (30 - 60 minutes)

Observation Program

INTRODUCTION

1. Meet and greet the participants.
2. Talk through the procedure including the system and what may be expected when activated. Handout to the participants a simplified version of the procedure for their own reference. (Day one only) (5 minutes)
3. Ask each participant to complete a brief questionnaire to gather their demographic information. (Day one only) (5 minutes)
4. Inform each participant that they will be video recorded for a period of 10 minutes per day as they perform internet activity. (Day one only)
5. Encourage each participant to work naturally performing tasks as they would in a normal days work. This will include internet research as a part of the participant’s professional obligations. (Day one only)
6. Inform the participants that they will need to answer short semi-structured questions to reflect on the study that is documented with a digital video recorder after the internet searching.
7. Answer any further questions from the participants. After all questions have been answered a video camera and the prototype will be activated and the participants will be encouraged to commence working.

FOLLOWING THE INTERNET SEARCHING (20 MINUTES)

8. Following each study the participants will answer short semi-structured questions to reflect on the study that is documented with a digital video recorder. These include:

- Could you describe the nature of the sound heard?
- How did you feel about the sound? Please elaborate.
- What relationship did you make between the sound and your internet searching?
- In the context of the office, did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO₂ emissions?
- If you were able to rate your experience out of 10 in relationship to the sound, what would that be?

ON CONCLUSION TO THE STUDY

9. Mention a session of transcription verification.
10. Another session will be organized to reflect on aspects of the footage with each of the participants. This reflection will be digitally recorded in audio.

Thank the participants for their time and effort.
Study 1. Observation Overview – Participant copy

Purpose
Study 1. Is an investigation into the effectiveness of sound feedback as an ambient information display with respect to human perception and attention. Specifically the research focuses on the issue of internet e-waste (CO₂ emissions) and how this information is conveyed to the collective office through sound.

The data gathered will be video footage, questionnaires and interview responses that will be analysed to determine avenues for additional refinement of the prototype.

Location and time
Monday 26th November 2012 – Friday 30th November 2012.
9am - 10am.

Researches
Stuart McFarlane, Frank Feltham

Pre-study
1. Participants will be asked to read carefully and sign the ethics consent form along with the ethics participation form. Any questions pertaining to the forms and study will be answered in full.
2. An initial interview will take place with the participants to establish the most appropriate time of the working day to video record them for 10 minutes each.

Observation Program

A. INTRODUCTION
1. Complete a brief questionnaire to gather demographic information. *(Day one only)* (5 minutes)

B. FOR THE DURATION OF THE INTERNET SEARCHING (10 MINUTES)
2. Each participant will be video recorded for a period of 10 minutes per day as they perform internet activity as arranged.

C. FOLLOWING THE INTERNET SEARCHING (20 MINUTES)
3. Following each study the participants will answer short semi-structured questions to reflect on the study that is documented with a digital audio recorder.

ON CONCLUSION TO THE STUDY
4. Mention a session of transcription verification.
5. Another session will be organized to reflect on aspects of the footage with each of the participants. This reflection will be digitally recorded in audio.
**Study 1. Semi-structured questions**

**Researches**
Stuart McFarlane, Frank Feltham

**Participant:**

**Questions:**

1. Could you describe the nature of the sound heard?

2. How did you feel about the sound? Please elaborate.

3. What relationship did you make between the sound and your internet searching?

4. In the context of the office, did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO₂ emissions?

5. If you were able to rate your experience out of 10 in relationship to the sound, what would that be?
Study 1. Ambient semi-structured questions transcribed and compiled

Location and time
Tuesday 27th November 2012
9am – 12pm.

Sound type: Ambient / Nature / Rain / Running water

Researchers
Stuart McFarlane, Frank Feltham

Participants: A, B, C

Questions:

1. Could you describe the nature of the sound heard?
   
   A. Like rain in a rain forest or a trickling brook...water related or something.
   
   B. It sounded like running water.
   
   C. It was like a burbling brook. It just sounded like water.

   Summary: All participants had a clear understanding of the nature of the sound.

2. How did you feel about the sound? Please elaborate.

   A. Slightly agitated because it's a dominant sound... Normally we would have music playing while we are working and that sort of thing. A new sound you are more aware of it...

   That's interesting because I didn't specify you couldn't have music. Was it just foreign?

   A. Yes, but also maybe it's like sitting in wind...you kind of feel a bit...

   Tense?

   A. Yes. It may be the newness of the situation or it may be the sound it's hard to necessarily know?

   B. It was very calming.

   C. It made me feel calm.

   Consistently?

   C.Yes.

   Summary: Participant B considered the sound to be calming in nature as C found the sound to be calm. A however considered the sound to be slightly agitating and related it to the un-nerving sound of the wind which does draw parallels with Schafer’s observations that wind does have an un-nerving effect on human perception.

   Key words: agitating, dominant sound, calm.

3. What relationship did you make between the sound and your internet searching?

   A. None except a paranoid induced...is that getting louder? So I didn’t actually notice if it was getting louder.

   What made you think it would get louder?

   A. Well I just wondered...and I became more aware of it so I was wondering if it was actually getting louder or not. And, I was looking at images at that stage so I don’t know if there was a relationship or not. I don’t think there was.
B. I tried to make the sound go louder but it didn’t...seem too. It sort of seemed to a bit. I am wondering how you can get a lot of sound out of it.

C. None.

Could you explain?

B. I tried to listen for a relationship but I couldn’t detect one.

Summary: No relationship was detected between the sound and internet usage though the common expectation was that there should have been an increase in the sounds volume to express the amount of traffic being used. An interesting observation is that the video footage demonstrates fluctuations in the audio feedback and may indicate that the participants need to be trained to know what to expect from the audio feedback and what it indicates in relation to their internet searching.

4. In the context of the office, did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO2 emissions?

A. No. It could but I don’t know how to interpret it, and I’m not nuanced to have that as a kind of background sensorial information feed.

B. Probably yes considering you have explained the link between the two. And by trying to get more sound out of it I was trying emit more CO2. I wanted to find out which websites go higher and therefore involved more bandwidth therefore involved more CO2. I did not find that in my little experience just then.

C. No.

Summary: Only participant B had some experience of understanding of the audio feedback as an illustration of their internet CO2 emissions.

Key words: interpret.

5. If you were able to rate your experience out of 10 in relationship to the sound, what would that be?

A. 4. It was a bit close to dolphin sounds for my liking. Maybe it’s the new age shop sound that slightly annoyed me?

Are you drawing a personal perspective to that sound then?

A. Yes. For me it’s not the sort of sound I would ever have going in the background and because it was a background noise and because it was very quiet, normally the office is more chaotic or I’m a bit more focused on what I am doing I was more aware of it and it’s not a sound I would choose to play. I can’t understand how anything but that would be personal? But maybe it can be? But people must have personal preferences.

B. 2.

C. 7. I made me feel relaxed.

Average: 4 + 2 + 7 = 4.333 (below 50 percent)

Summary: The overall experience was deemed below 50%. Participant A expressed the notion of personal choice of the particular sound to be beneficial in the understanding and desirability of such feedback.
**Study 1. Salient semi-structured questions transcribed and compiled**

**Location and time**
Thursday 29th November 2012
9am – 12pm.

**Sound type:** Salient / Percussive / Gongs

**Researches**
Stuart McFarlane, Frank Feltham

**Participants: A, B, C**

**Questions:**

1. Could you describe the nature of the sound heard?
   
   A. I am going to say it was like tom toms. Like a drum beat of some sort.

   **Rhythmic?**

   A. I wouldn’t say rhythmic... No it sounded like drums.

   B. Drums and bells. Buddhist drums. Tibetan drums. I thought it was less effective than the last one. If I put two utubes at a time I get less variance than the last one.

   I thought the one on Tuesday was more effective the way it amplified and de-amplified as opposed to today’s sound that seemed to be a lot more constant and dongy.

   C. Percussion. Not exactly a cymbal but some version thereof.

   **Summary:** All participants had an understanding of the nature of the sound though their responses suggest a lack of knowledge in the terminology of sound or instrumentation.

2. How did you feel about the sound? Please elaborate.

   A. Less good than I felt about the other sound.

   That’s interesting because you had distain for the other sound.

   A. The other sound is looking comparatively a lot better.

   A. To some degree it’s a bit like when you’re looking through the phone ringtones your phone comes with, and you go no, no, no, then you reassess and go...ok maybe I could live with that one.

   A. I think it’s a really hard challenge finding a good noise that’s incidental.

   B. Dongy.

   C. I found it less relaxing than the previous sound. It was a bit more distinct and variable as a sound and seemed to reflect the searching intensity a bit more.

   You mentioned intensity? How did you relate that to the sound?

   It was easier to determine the relationship to the sounds.

   **Summary:** The consensus is that the sound wasn’t as pleasing to listen to as the Ambient variation. However the participants seemed to have a greater awareness of its presence which may confirm its deliberate Salient nature. Also participant A alluded to the situation of comparative reassessment. Although A disliked both sounds as feedback, having a choice widened their perspective forcing them to re-access their perspective towards the sounds.
3. What relationship did you make between the sound and your internet searching?

A. None.

Nothing at all?

A. I have been wondering if it increases in frequency. But I didn’t observe any of it. Today I hardly paid any attention while I was on the internet to it. Without having a cause and effect...if you know how the noise changes or doesn’t change, I think I would notice it more.

B. Very little. I couldn’t perceive any change. Today’s sound didn’t seem as effective as Tuesdays or didn’t alter as much to reflect the usage.

C. The intensity of the sound would fade as the searching did and increased as the intensity increased.

Summary: No relationship was detected between the sound and internet usage by participants A and B although C drew a direct correlation.

4. In the context of the office, did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO2 emissions?

A. No.

B. Yes, but not as effective as the previous sound.

C. Yes.

Summary: participants B and C had some experience of understanding of the audio feedback as an illustration of their internet CO2 emissions. B considered it less effective as the Ambient version. Participant A didn’t draw any relationship what so ever.

5. If you were able to rate your experience out of 10 in relationship to the sound, what would that be?

A. 2. Not so much when I am on the internet but when I am working...but you get use to it...when I first heard it I thought I wasn’t going to last.

Did you want to talk a little more about that?

A. Yes. It’s a little more obtrusive, the other noise made me a bit anxious, this one didn’t. But it was horrible with the music playing. I think in an office you would tend to have it under noise like phones and music, so...the other ones gone way up in comparison.

B. 3. Kind of irritating. If the sound had of been Tuesdays sound and I had of been able to make it go faster or do something I think I would have rated it slightly higher.

It’s an irritant.

C. It’s hard to say...It wasn’t as relaxing as the other sound. It’s probably a lot more negative and neutral than the other one.

Average: 2 + 3 + 5? = 3.333r (below 50 percent)

Summary:

A: 2
B: 3
C: 5? However they did not specify a number they did say it was lower than the Ambient version.

Average: 2 + 3 + 5? = 3.333r (below 50 percent)
The overall experience was deemed below 50%. Participant A expressed the experience as more obtrusive in relation to the Ambient version. B described the experience as irritating, and C described it as less relaxing in comparison to the Ambient version.
Study 1. Field Notes

Location and time
Tuesday 27th November 2012
9am - 12am.

Researches
Stuart McFarlane, Frank Feltham

Participants
4 commercial architects aged between 30 & 45. All participants have no hearing impairment.

Field Notes Tuesday 27th November 2012

Weather

Heavy rain – loud rain sounds in the office interior.

Natural Auditory Environment

Local traffic, delivery vans, foot traffic, mobile phone alarms, printer hum, telephone conversations, general office discussion.

Sound Description and Treatment

Title: Nature – a mix of rain/running water and bird noises
Treatment: Ambient
Volume: Mixed accordingly with the dominant sound of the rain from outside as to feature as an accent within the pre existing or present sound environment.
Technical issues: Nil.

Initial notes for instillation refinement through observation

Increase the spatial display with respect to the sound source. From observation better results may be achieved by decentralizing the sound source as not to lead the occupants to the sound which may lead to distraction. A wider (3-dimensional) display should diffuse the location or origin of the sound.

Place the bass system under the desks or further away from the participants to reduce the bass resonance.

Install all speakers out of sight by the participants as not to distract their attention or to give any visual ques.

Initial notes of participants actions through observation

The participants didn’t seem to be distracted or their centre of attention swayed when the system was running.

The system was working correctly however the participants failed to recognise the sound fluctuations.
Study 1. Field Notes

Location and time
Thursday 29th November 2012
9am - 12am.

Researches
Stuart McFarlane, Frank Feltham

Participants
4 commercial architects aged between 30 & 45. All participants have no hearing impairment.

Field Notes Thursday 29th November 2012

Weather
Dry and mild.

Natural Auditory Environment

Local traffic, delivery vans, foot traffic, mobile phone alarms, printer hum, telephone conversations, general office discussion, The rolling Stones playing at low volume.

Sound Description and Treatment

Title: Bottle Hit Slow down – Audibly sounds like percussive gongs.
Treatment: Salient.
Volume: Mixed accordingly with the dominant sound of the office equipment.
Technical issues: Nil.

Initial notes for instillation refinement through observation

The tweeters locations were widened significantly from the first test. The right was placed out of sight on a bookshelf and the left tweeter was placed hidden within a brick material sample away from the participants.

The bass system was also decentralized by placing it almost in the centre of the studio under the central meeting desk.

All monitors where approximately 2 meters away from the participants with no obvious sound centralization.

Initial notes of participants actions through observation

The participants didn’t seem to be distracted or their centre of attention swayed when the system was running.

The environmental sound seemed more decentralized through the altered arrangement.
Study 2.
Study 2. Activity Running Order – Researches copy

Location and time
Tuesday 19\textsuperscript{th} February 2013 – Wednesday 20\textsuperscript{th} February 2013.
9am - 10am.

4 day duration:


Researches
Stuart McFarlane, Frank Feltham

Participants
4 commercial architects aged between 30 & 45. \textit{All participants have no hearing impairment}.

Awareness Procedure - DAY ONE

Purpose
To give the participants an overview of the prototype from a aural, functional and tactile perspective and what is to be expected while testing is conducted.

A. INTRODUCTION
1. Explain the training procedure and why they are doing it. (5 minutes)

B. THE SYSTEM
2. Explain the system and what it aims to communicate. (5 minutes)

C. EXAMPLES OF THE SOUNDS
3. Give examples of the sounds they may here and examples of what they may mean in relation to internet CO\textsubscript{2} usage. Internet traffic flow. (10 minutes)

SOUND VARIETY STUDY – 20 MINUTES
4. Run a short test whereby the participants must respond to individual sounds played until they gain an understanding of what they mean in relation to internet CO\textsubscript{2} emissions.

Observation Program

INTRODUCTION
1. Meet and greet the participants.
2. Talk through the procedure including the system and what may be expected when activated. \textit{Handout to the participants a simplified version of the procedure for their own reference. (Day one only)} (5 minutes)
3. Inform each participant that they will be video recorded for a period of 7 minutes per day as they perform internet activity. \textit{(Day one only)}
4. Encourage each participant to work naturally performing tasks as they would in a normal days work. This will include internet research as a part of the participant’s professional obligations. *(Day one only)*

5. Inform the participants that they will need to answer short semi-structured questions to reflect on the study that is documented with a digital video recorder after the internet searching.

6. Answer any further questions from the participants. After all questions have been answered a video camera and the prototype will be activated and the participants will be encouraged to commence working.

**FOLLOWING THE INTERNET SEARCHING (20 MINUTES)**

1. Following each study the participants will answer short semi-structured questions to reflect on the study that is documented with a digital video recorder.

*Thank the participants for their time and effort.*
Study 2. Observation Overview – Participant copy

2 day duration:
9am - onwards.

Researches
Stuart McFarlane, Frank Feltham

Pre-Study

1. An initial interview will take place with the participants to establish the most appropriate time of the working day to complete the training program and to video record them for 7 minutes each while performing internet searches, and to respond to an informal questionnaire that will be audio recorded. (Expected time: 10-20 minutes) Also the participants will be asked for a date when they can be interviewed after reviewing the video footage.

Training Procedure

1. A training procedure will be conducted prior to each test to help familiarize the participants with the refined prototype and to gain information regarding their uptake on sound observations.

Observation Program

A. INTRODUCTION

1. Explain what is expected from the participants and answer any questions. (Day one only) (5 minutes)

B. FOR THE DURATION OF THE INTERNET SEARCHING (10 MINUTES)

2. Each participant will be video recorded for a period of 10 minutes per day as they perform internet activity as arranged.

C. FOLLOWING THE INTERNET SEARCHING (20 MINUTES)

3. Following each study the participants will answer short semi-structured questions to reflect on the study that is documented with a digital audio recorder.

ON CONCLUSION TO THE STUDY

4. Mention a session of transcription verification.

5. Another session will be organized to reflect on aspects of the footage with each of the participants. This reflection will be digitally recorded in audio.
Study 2. Semi-structured interview questions

Sound type:

Researches
Stuart McFarlane, Frank Feltham

Participant:

Questions:

1. Could you describe the nature of the sound heard?
2. Was the sound familiar in any respects?
3. Could you explain how the sound made you feel? Please elaborate.
4. What relationship did you draw between the sound and your internet searching?
5. Did you feel the sound helped you gain a greater understanding of your internet usage in relation to internet CO2 emissions?
6. Could you please briefly describe what you searched on the internet during the test?
7. If you were able to rate your experience out of 10 in relationship to the sound, what would that be?
Study 2. Field Notes

Location and time
Tuesday 19th February 2013
9am - 12am.

Researches
Stuart McFarlane, Frank Feltham

Participants
3 commercial architects aged between 30 & 45. All participants have no hearing impairment.

Field Notes

Weather
Sunny and hot.

Natural Auditory Environment
Local traffic, delivery vans, foot traffic, mobile phone alarms, printer hum, telephone conversations, general office discussion.

Sound Description and Treatment

Title: S1.
Treatment: Ambient.
Volume: Mixed accordingly with the dominant sound of the office equipment.
Technical issues: Nil.

Title: S2.
Treatment: Salient.
Volume: Mixed accordingly with the dominant sound of the office equipment.
Technical issues: Nil.

Initial notes for instillation refinement through observation
The tweeters locations were widened significantly from the first test. The right was placed out of sight on a bookshelf and the left tweeter was placed hidden within a brick material sample away from the participants.

The bass system was also decentralized by placing it almost in the centre of the studio under the central meeting desk.

All monitors where approximately 2 meters away from the participants with no obvious sound centralization.

Initial notes of participants actions through observation
The participants didn’t seem to be distracted or their centre of attention swayed when the system was running.
Study 2. Field Notes

Location and time
Wednesday 20th February 2013
9am - 12am.

Researches
Stuart McFarlane, Frank Feltham

Participants
3 commercial architects aged between 30 & 45. All participants have no hearing impairment.

Field Notes

Weather
Sunny.

Natural Auditory Environment
Local traffic, delivery vans, foot traffic, mobile phone alarms, printer hum, telephone conversations, general office discussion.

Sound Description and Treatment

Title: S3.
Treatment: Ambient.
Volume: Mixed accordingly with the dominant sound of the office equipment.
Technical issues: Nil.

Title: S4.
Treatment: Salient.
Volume: Mixed accordingly with the dominant sound of the office equipment.
Technical issues: Nil.

Initial notes for instillation refinement through observation

Initial notes of participants actions through observation
The participants didn’t seem to be distracted or their centre of attention swayed when the system was running.
QUESTION 7

If you were able to rate your experience out of 10 in relationship to what you searched on the internet made you feel? Please elaborate.

Could you explain how the sound you heard during the test?

QUESTION 6

Could you describe the nature of internet usage in relation to your experience of the sound heard?

QUESTION 5

A threatening low frequency vibration…

On their individual computers.

C and B talk about project details undeterred while working on their individual computers.

Observation

A: Oh god, now I’m even more freaked out.

C: A… You really want to think about black balloons.

B: A… Sounds like you’re off gassing a chemical.

Oh god, now I’m even more freaked out.

B: A… You really want to think about black balloons.

It’s getting hard to breathe in here.

C: A… You really want to think about black balloons.

If you were able to rate your experience out of 10 in relationship to what you searched on the internet made you feel? Please elaborate.

Could you explain how the sound heard during the test?

I found it good… I would give it 8…

Response

I was kind of neutral… 5

Response

Diotalia… on utube…

Then I searched a little bit for 8 speed Campagnola parts… bike parts… and then I watched a bit of the Commonwealth private banking which made me feel kind of bad about that.

Response

Images on how to arrange tiles.

My experience of the sound as a tool to understanding the CO2 consequences of one altered… effective in teaching me CO2 consequences of different searches.

Yes it did. I was particularly interested to see that streaming video didn’t chew as much CO2 level related…

Response

The louder the sound the more CO2 emissions occurring.

No. I would have had to do different types of searches to interpret the display.

Not particularly anxious.

Like a feedback buzz… low… bassy…

It didn’t allude to anything else?

A low hum sound... and very threatening noises... and debt…

On their individual computers.

C, B and A talk about project details undeterred while working on their individual computers.

C talks on the telephone regarding a project enquiry.

Observation

A threatening low frequency vibration…

On their individual computers.

C and B talk about project details undeterred while working on their individual computers.

Observation

A threatening low frequency vibration…

On their individual computers.

C and B talk about average debt undeterred while working on their individual computers.

C: A… You really want to think about black balloons.

It’s getting hard to breathe in here.

C: A… You really want to think about black balloons.

If you were able to rate your experience out of 10 in relationship to what you searched on the internet made you feel? Please elaborate.

Could you explain how the sound heard during the test?

I found it good… I would give it 8…

Response

I was kind of neutral… 5

Response

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C talks on the telephone regarding a project enquiry.

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On their individual computers.

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C talks on the telephone regarding a project enquiry.

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On their individual computers.

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On their individual computers.

C and B talk about average debt undeterred while working on their individual computers.

C talks on the telephone regarding a project enquiry.

Observation

A threatening low frequency vibration…

On their individual computers.

C and B talk about project details undeterred while working on their individual computers.

Observation

A threatening low frequency vibration…

On their individual computers.

C and B talk about average debt undeterred while working on their individual computers.

C talks on the telephone regarding a project enquiry.
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**EMOTIONAL PERCEPTION**

**ATTRIBUTE**

**IDENTIFICATION**

**INTERPRETATION**

**METAPHORIC**

**TRANSCRIPTION**

**FIELD STUDY 2. SOUND 3**

**SEMI-STRUCTURED QUESTIONS AND VIDEO DATA**

**TABLE 3**
QUESTION 1
Could you describe the nature of your internet usage in relation to the sound?

A
B
C

QUESTION 2
Did you feel the sound helped you while you searched on the internet?

A
B
C

QUESTION 3
Could you explain how the sound made you feel? Please elaborate.

A
B
C

QUESTION 4
If you were able to rate your experience out of 10 in relationship to the sound, what would that be?

A
B
C

QUESTION 5
If you searched cars and face book...are you familiar with how low the sound was on face book...so as you go to someone's post on an architectural page...so go out...where did it sound like noises you might hear in the back of a 1980's arcade game...bobble bobble or something...not unpleasant...it didn't really make me feel anything...It made me think of water music...but no...it wasn't unfamiliar but I couldn't pick what it was...

A
B
C

QUESTION 6
Did you feel the sound helped you related to your internet CO2 emissions?

A
B
C

A and B discuss a project detail.

Observation

A

A talks on the phone with a sales representative.

Observation

A

B and C discuss a project detail.

Observation

A

Quotes

A

B and C discuss a project detail.

Observation

A

B and C discuss a project detail.

Observation

A

Field Study 2. SOUND

SEMI-STRUCTURED QUESTIONS AND VIDEO DATA TRANSCRIBED - TABLE
import org.rsg.carnivore.*;  // IMPORTS THE CARNIVORE LIBRARY TO PROCESSING
import org.rsg.lib.Log;
import org.rsg.p5.*;  // IMPORTS THE OSC LIBRARY TO PROCESSING
import netP5.*;

OscP5 oscP5;
NetAddress myRemoteLocation;
CarnivoreP5 c;
void setup(){
  Log.setDebug(true);
  c = new CarnivoreP5(this);
  c.setVolumeLimit(4);  // limit the output volume (optional)
  c.setShouldSkipUDP(true);  // tcp packets only (optional)
  oscP5 = new OscP5(this,9000);
  myRemoteLocation = new NetAddress("127.0.0.1",9001);  // SENDS THE INFORMATION OVER PORT 9001
}
void draw(){

void packetEvent(CarnivorePacket p){
  println("(" + p.strTransportProtocol + " packet) " + p.senderSocket() + " > " + p.receiverSocket());
  println("Packet as Bytes:" + p.data);
  OscMessage myMessage = new OscMessage("/Payload:");
  myMessage.add(p.toString().length());  // PACKET STRING LENGTH AS BYTES
  myMessage.add(p.senderPort);
  oscP5.send(myMessage, myRemoteLocation);  // SEND THE STRING LENGTH TO PURA DATA VIA OSC
}