A Participatory Design Method for Qualitative Data Sonification

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DECLARATION

I hereby declare that the contents of this thesis have not been submitted in whole or in part for the award of any other degree or qualification, at this university or elsewhere. To the best of my knowledge this thesis does not contain any materials previously published or written by another person, except where due reference is made in the text. This thesis is my own work and contains nothing which is the result of work carried out in collaboration with others, except as specified in the text and Acknowledgements.

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ABSTRACT

Sound is an emotional driver that can stimulate and shape our responses to create highly engaging and immersive experiences. As such, sound design plays a major role in media and games, yet often remains an afterthought in the design of interactive systems. Sound ideas are difficult to communicate without familiarity with audio terminology, consequently, sound design briefs are often poorly described. While sketching and *quick and dirty* prototyping is widely practiced in visual design, there is a lack of comparable tools for communicating and exchanging ideas about sound, leading to time-consuming design and re-design processes.

Research in the Sonic Interaction Design and Data Sonification fields has led to the development of sound design toolkits enabling faster experimentation with sound, however these proprietary tools offer digital interfaces which are restrictive and unintuitive for the novice user. There are calls in these communities for accessible methods for *designing through physical sound making*, with studies exploring the use of vocalisation and Foley-based techniques to mitigate against the inherent technical biases associated with existing solutions.

Using a Research *through* Design approach, this thesis explores Foley-based sketching and establishes that designing through sound making can benefit participatory design processes; support knowledge exchange; and inspire new and divergent ideas. By putting sounding materials directly in the hands of individuals, this work examines the concept of *qualitative data sonification* through embodied kinaesthetic action, which can produce meaningful sonic representations of experiential phenomena. The trialling of accessible group-based activities to support this rapid experimentation with sound led to the formulation and development of a new method, 'Embosonic Design'. The method was trialled in two major design projects, 'Her[sonifications]', where it was employed as an arts-based approach in the participatory design of an interactive sound installation; and 'Emotional Machines', where it formed a major part of a mixed modal interaction study in an industry-based innovation context, facilitating ideation and interaction design for future smart speakers at BBC Research and Development.

The conceptual frameworks, practical tools and guiding philosophies contained in this thesis will help researchers and designers employ the thinking and methods in their design-led innovation work and participatory design practice.

For Rosemary (Marie) Wilson – my mum and best friend.

Fit's fir yi, winna gi by ye

(Doric)

Sound is what brings the far, near;
collapses distance to intimacy;
reverberates what was once external,
deep inside.

Angus Carlyle*

* Excerpt from *Orang Aljeh, Mountain Ghost*, Velocity installation, London Design Week 2018.

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PREFACE

This work was informed and inspired by my creative experience in the audio industry as well as my academic interests, which span the fields of media, digital technology and design. I'd like to share a little bit about my background and the journey that led me here, if you are interested. It is not prerequisite for understanding the ideas in this thesis but more a self-indulgent overview of my meandering route to enlightenment, possibly interesting for any future grandchildren and possibly helpful for my future self, if I happen to grow old enough to forget. In any case, feel free to skip it and move on to Chapter 1.

…

For my four years of undergraduate study between 2008 and 2012, Lancaster University's department of Communication Systems was my home. I had returned to full-time education aged twenty-eight, with my then eighteen-month-old daughter in tow, literally - Alyssa travelled to campus with me every day and played at the university's Preschool Centre whilst I attended lectures. The 4-year integrated Masters in Information Technology and Media Communications course, nurtured my love of media and digital tech whilst giving me some basic software engineering skills and abundant opportunities to hone my skills in creative media production. I finished the degree around the same time as the Communication Systems department was merging with the Computing department to become the School of Computing and Communications, and was off to the Lancaster Institute of Contemporary Arts to start my PhD journey. This was not only a geographical shift, with the two departments sitting at the opposite ends of the university campus, but it signalled a colossal shift in mindset and academic influence, while I simultaneously negotiated the customary imposter-syndrome-inducing realisation that I had, to use the gaming term, levelled up. The HighWire Centre for Doctoral Training offered an cross-disciplinary program that united Lancaster's departments of Design, Computing, and Management. The integrated Masters of Research in Digital Innovation spanned the first year of the 1 + 3 doctoral program which I was working through with a tightly bonded cohort of thirteen very lovely and insanely clever PhD candidates[1]. There was an urgent need to get to grips with new concepts central to design, and something I found particularly challenging, the need to understand philosophical concepts, not only related to knowledge acquisition but the nature of knowledge itself. In this new landscape I found myself in, one

[1] Joseph Lindley, Robert Potts, Louise Mullagh, Lisa Thomas, Dhruv Sharma, Daniel Kershaw, Barney Craggs, Myles Kilgallon Scott, Paul Kelly, Justin Larner, Mari Thynne, Ian Aspin and Amanda Ordish

thing persisted, from which I drew comfort and maintained motivation, and that was a focus on the future, on innovation and emerging digital technology. I really enjoyed working on my dissertation, which explored the transformation of regular sound effects into acoustic-based NFC markers. I tested the concept by designing and building an interactive experience at Lancaster City Museum, where inaudible markers to cloud-based video and audio content were blended with soundscapes I'd designed for some of the exhibits on display (see Appendix B.9 for more information). That same year, I got the opportunity to work on an industry-based project with MakieLab, a manufacturer of customisable 3D-printed dolls, where I explored possible features for an internet-enabled doll of the future with onboard micro-computers and sensing technologies. That first year was filled with the climbs of steep learning curves, the thrills of intensive design deep-dives and a plethora of wicked design challenges, working in collaboration with my HighWire colleagues and friends. I was in my element but at the same time it was the worst year of my life. It was during this time that life as I had always known it, ended, when I lost my lovely mum to breast cancer. I really struggled with the loss and took an extended period away from my studies, finishing up the MRes quite a bit later than planned.

It was my MRes dissertation project on acoustic-based NFC markers that motivated me to pursue my love of sound during my PhD studies. I loved designing the experiment, producing the assets, developing a bespoke smartphone app and user testing the experience in the wild. I enjoyed observing people interacting with a sound environment in a playful way and finding out that it truly enhanced the museum experience for many of the people who took part.

My love for sound started young, when my parents gave me karaoke system (Christmas Day 1989, aged eight), which crucially, as well as mic input, had a double tape deck. It was through many hours of experimenting with this shiny device that I discovered the joys of overdubbing and it was never used for karaoke again. I would record my guitar playing and add *many* layers of vocals and guitar – this became a favourite activity of mine all through my early teens, where more often than not, my homemade 'Keep Out - Recording In Progress' sign was blue-tacked to my bedroom door. My other hobby at the time was playing with an old Dictaphone with which I spent an inordinate amount of time recording the sound of household objects, garden ambiance and cat purrs (Cleo). This passion for sound and music stayed with me into my late teens. I started university in 1998 (studying Forensic and Analytical Chemistry) and swiftly after settling in, I joined a band as lead singer and gigged regularly with them for the next few years. In the early days, I was unfamiliar with DAWs (Digital Audio Workstations), and we

relied on our guitarist (Tucker) to record and mix our songs in Cubase. Over time I realised that 1) I didn't want to work in forensic science and 2) I wanted to learn how to produce music, as although Tucker was doing an acceptable job, I hated the amount of reverb he would apply to my vocals and no amount of feedback would make him change it. That particular frustration ended up setting the course of my career. In 2002 I spent a year in Sydney studying at the School of Audio Engineering (SAE) then worked on a range of creative projects all over the UK. I started on Front of House sound initially, mixing live music at various venues in Glasgow and lots of theatre productions including an exhausting six weeks at the 2005 Edinburgh Festival, where I mixed daily shows for some well-known comedians. I then started picking up sound recordist jobs, working on two films before moving to London for a sound operator job in TV. I stayed in London after my contract ended and started doing sound design for a marketing company, producing the audio for a Müller advert and a series of online games for Microsoft and Intel. The sound work was exciting and thoroughly enjoyable but it wasn't reliable and required a lot of moving around to find work, which became more difficult after getting married (to Graham), moving to Lancaster and welcoming our beautiful baby daughter (Alyssa) into the world. Additionally, one thing had always nagged at me with the sound design work – the fact that a sound designer is often the last person to join a creative project, and sometimes only if there's budget left. I found more and more that I wanted to be *in the room* right at the beginning of creative projects, to help formulate and develop ideas. Not long after Alyssa's first birthday I applied to Lancaster University and started my undergraduate degree in Information Technology and Media Communications (with a minor in Music Technology).

So perhaps when it came to formulating my MRes dissertation project at HighWire, it was little wonder that I chose to focus on something that was audio-based. After confirming my PhD status, Alyssa was eight years old and Graham and I welcomed our second beautiful daughter, Annelise, into the world - once again I had a travelling companion who attended the Preschool Centre while I carried out my research. I won't go into my research topic here as you're going to read a lot about it, I'll just say that it took a long, arduous and enriching journey to get here. Life has changed immensely (aside from the global pandemic!) - Alyssa is now thirteen and thinking about her GCSE options, and Annelise is five and has just started primary school. The last thing to add is that two years before writing this preface, I started working at BBC Research and Development where formulating ideas; developing new innovative technology; and producing new interactive media experiences, describe a typical day in the lab…

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1 INTRODUCTION

Sound elicits emotion

Sound elicits emotion. Any newborn baby's hungry cry can stimulate the flow of milk for a nursing mother passing by, a surge of oxytocin released upon simply hearing a sound. A loved one's voice can provide light in the darkest of times, for it is not the words spoken, but the familiarity of the unique tones of their voice that provides reassurance.

Sound elicits emotion. It is the reason that hearing a certain piece of music can make your hairs stand up and put a lump in your throat. It is the premise upon which entire sections of the audio industry were built and why they continue to thrive.

Sound is an emotional driver that can stimulate and shape our emotional responses to create highly engaging and immersive experiences. As such, sound design plays a major role in both film and game production, yet still often remains an afterthought in the design of interactive systems. This is demonstrated by current under-representation in research in both the HCI and interaction design fields in comparison to visual-based research.

Let us briefly consider the audio research linked to the resurgence of consumer interest in augmented reality (AR) and virtual reality (VR) systems, along with major corporate investment in technology to deliver and consume mixed reality media. There is much work being done to advance the field of spatial audio, in order to increase immersion in these existing formats and to design new mainstream mixed reality experiences, *e.g., in the area of Audio AR, enabled by the availability of affordable consumer technology such as the Bose Frames and the Apple AirPod Pro earbuds*. In light of this, much research is being undertaken to design new mechanisms for the delivery and control of audio in interactive systems and also to advance the physical characteristics of audio playback in immersive systems through improved spatialisation techniques linked to head-tracking, such as in the areas of Ambisonics[2].

While research in audio is making great progress for the state of next generation immersive and interactive systems in certain fields, sound has mostly remained an afterthought in the field of HCI. Although sound can serve a number of diverse roles within human-computer systems, it remains an underused and underdeveloped dimension for communication and information delivery [77].

The bulk of research in the HCI literature over the last thirty years has focused on exploring the use of non-speech sound as auditory cues in user interfaces and the extent to which these sounds can assist user interaction.

Outside the Data Sonification and Sonic Interaction Design communities, there has been a lack of focus on sound design techniques and approaches that relate to improving design outcomes, especially in designing sound for events and processes without an attached sonic convention and furthermore, a distinct lack of research that specifically examines the early conceptualisation stages of the sound design process.

[2] Although I am now exposed to and involved with this type of applied research in my role in the Audio Team at BBC Research and Development, I was firmly rooted in the field of HCI for the four years of my undergraduate degree and at the beginning of this PhD research, as well as in the field of Design. I'm writing this introduction prior to submission, and many, many months after carrying out my research. In the interim, I have experienced a sizeable shift in my research interests and feel that if I started all over today, this thesis would look quite different (I have heard that this is a common feeling amongst doctoral candidates!).

Sound elicits emotion. Can emotion elicit sound?

I had been thinking a lot about this question and at the same time reading about some of the data sonification work going on in the HCI community. I had become conscious, perhaps due to my background as sound designer, that I was underwhelmed by most of the results I had heard, most of which had been produced using parameter mapping techniques *i.e., the mapping of discrete quantitative data points to perceptual parameters such as pitch and amplitude*. I could not decide if it was the sonification designs or the datasets themselves that were the issue.

This led me on to wondering why the sonification community only ever sought to sonify quantitative datasets. I then began pondering what might happen if we attempted to sonify qualitative data. Instead of listening to say, some beeps and bops that convey how sea levels have changed over time for example, what if we could instead listen to a soundscape that conveys how a person feels anger rise inside them or externalises a particular experience they have had.

The more I thought about it, the more it felt worth exploring[3] how we can design audio that captures and translates lived human experience.

[3] I realise that the most common process of starting a PhD research project is to firstly identify a gap in the literature and a specific problem that needs to be solved. I recognise that I went about things a bit differently in that I had potentially created a problem that didn't necessarily need to be solved (for the advancement of knowledge in HCI or perhaps in any other field!). I found this to be the major challenge of the HighWire programme in fact - we had the freedom to set our own research topics (pending supervisor approval) while other doctoral students who enrol on specific PhDs are given a topic to address an identified gap, usually based on the needs of a wider research project.

I was driven by the notion that much exists beyond sight, beyond measurement and beyond the physical domain, that remains undiscovered. Every person has untold stories, some are living with issues that are not immediately apparent and if we think of each having their own rhythm in space and time, how can we translate them?

How can we capture and preserve them? And how can we communicate them to others through the medium of sound so that they can start to appreciate the untold stories and issues that exist in our society: the myriad rhythms to which people live their lives?

1.1 RESEARCH BACKGROUND

Sonification is the process of conveying information with non-speech audio and, as described in the previous section, is predominately used to sonify quantitative data *i.e., information that is physical, measurable and quantifiable*. My extensive use of the term in relation to this research could be considered highly controversial to some HCI researchers, given that I am proposing that we can sonify qualitative data *i.e., non-numerical data describing qualities and characteristics*.

My work and interest in the beginning was inspired by William Gaver's early research, specifically his work on auditory icons where he explored the representation of computer functions and events with natural everyday sounds. Sounds that we have become accustomed to in today's computer interfaces, such as the iconic paper scrunch that we hear when moving files to the Trash in Mac OS. Gaver articulated something that I had well been aware of and had exploited in my craft as a sound designer but had never contemplated from a cognitive perspective.

Gaver described an ecological approach to sound perception [58, 59]. I was already aware of Gibson's ecological approach to visual perception [63], from the user interface design modules I studied during my undergraduate degree. Gibson's approach described how the relationships between human beings and their environment are understood in terms of our perception of an object's affordances *i.e., the objects potential for action,* and not its particular qualities. In the ecological approach to sound perception, when we are not specifically engaged in focused listening *e.g., when we listen attentively to the sonic qualities of music or when a sound engineer works on tweaking the constituent elements in an audio mix*, it is sound events and more specifically, the sources, materials and actions in play, that we perceive.

My thinking was that if it is sources, materials and actions that we perceive from sound to form knowledge about physical phenomena, then similarly we should be able to convey information about physical phenomena through sources, materials and actions. Indeed, this is the foundation of the well-known and effective technique of Foley sound production used in the Film industry. Foley sound refers to sounds that represent sound events in a scene that are either associated with the sounds people make (non-speech) or the sounds that objects make and are produced by manipulating sounding objects and props, which are often wildly different from the on-screen action and objects they represent.

In my craft as a sound designer, I regularly used Foley techniques for creating sound to accompany and complement visual action but could the technique support sonification of non-physical phenomena or subjective notions such as visceral sensations or imagined sound? And further, given that sounds in HCI such as auditory icons, are designed for functions and events that already exist, could such a technique support the design of sounds at the early conceptual and exploratory stage in the design of new systems and interfaces?

Sketching in visual design is an accessible and valuable method of quickly externalising and exchanging ideas but there is no established equivalent in sound design. Examples in the literature that seek to fill this gap include work by Rochecco and Monache [92] in the field of Sonic Interaction Design (SID), where they have explored vocalisation as an embodied form of sound sketching and describe the need for more cooperative ideation and group sketching methods.

With respect to the use of Foley, Pauletto explored theatrical methods for sonic interaction design that employed Foley techniques offstage to complement visual scenes onstage, but did not focus on the sound design itself. Although Pauletto established that the greatest value in her methods was found to be the strength of Foley sketching for supporting *"*rich discussions among stakeholders*"* [97], no formal methods were developed or transferred to the research community.

Similarly, Hug and Kemper [72] recognise the value of Foley for sonic interaction design tasks, having experimented with its use in providing real-time sound feedback to a user interacting with a user interface mock-up. They describe how Foley opens up a rich and virtually unlimited range of sonic possibilities.

There are calls in the SID community for "designing through sound making to be advocated" [96] in order to establish the approach as legitimate methods. Such methods are considered to have the potential to mitigate against the inherent technical bias associated with existing digital sound sketching toolkits (some of which are described in section 2.3.1).

1.2 Research Aims, Objectives and Contributions

The focus of this research was to find out whether there is value in designing through sound making and if so, to establish group-based methods to enable other researchers and designers to benefit from the concept in design-led innovation work and in participatory design practice.

In order to explore designing through sound making as a collaborative process, the objectives of this research project were as follows:

1. **Determine suitable group-based activities to support non-sound experts to start thinking about and experimenting with sound.**

2. **Examine engagement with group-based sound making activities in arts-based workshop and industry-based workshop settings.**

3. **Assess the effectiveness of Foley-based sound sketching in enabling people to express mental models; qualities and characteristics of lived experience; and imagined sound.**

4. **Evaluate the effectiveness of sound sketches produced using Foley-based techniques.**

5. **Identify ways in which sound making can support design-led innovation work and participatory design practice in industry.**

As a result of working towards the objectives outlined above, my findings are that embosonic design is not only applicable as an arts-based approach for sound design but is a valuable method that can be applied more generally as part of overall interaction design and design-led innovation in industry contexts.

Its use in a mixed-modal interaction study in the BBC's Research and Development lab (BBC R&D), shows that the method is flexible enough to support complex design tasks in groups with diverse experience and skills.

Specifically, this research has produced the following contributions:

1. **The proposal of the novel concept of *Qualitative Data Sonification*:**

    a. A theoretical definition of a process where sound is used to represent non-numerical data that is specifically associated with lived human experience
    b. Demonstrated to be a useful and feasible concept for the communication and interpretation of qualitative data which led to the development of new methods

2. **A new participatory design method (*Embosonic Design*) for generative ideation through group-based sound sketching and guidelines for designers looking to employ the method:**

    a. Uses sound-making as inquiry to enhance qualitative data collection in group-based settings
    b. Enables the creation of self-actualised sonifications of experiential phenomena
    c. Minimises designer bias and supports the exchange of ideas in both arts-based and industry-based settings
    d. Is accessible and useful to non-sound experts
    e. Encourages playfulness and promotes heightened participant engagement
    f. Informs and facilitates exploratory innovation work
    g. Supports mixed-modal interaction design

3. **A demonstration of how Embosonic Design has been applied in practice for two distinct use cases:**

    a. As an arts-based approach: for the participatory design of an interactive sound artwork that represents the lived experience of a sample group (project: 'Her[sonifications]', Lancaster University)
    b. As an applied design approach in industry: for mixed-modal interaction design in a public service media research and development setting (project: 'Emotional Machines', BBC R&D)

4. **Design patterns, models and guiding philosophies:**

    a. In-depth accounts of design processes provide means for replication of the design projects described in this thesis
    b. Rich insights from observations and reflections on the making of artefacts gained from a Research *through* Design approach, are articulated and accessible

c. Guidelines for a Foley Palette to help designers and workshop leaders prepare for employing the method's sound making activities
d. A model for cross-modal interaction design and a demonstration of its use as a design tool for extending embosonic design ideation outcomes across the modalities of sound, light and gesture

5. Knowledge dissemination to the academic community where material from this thesis was peer-reviewed and published:

Emma Young, Alan Marsden, and Paul Coulton. 2019. **Making the Invisible Audible: Sonifying Qualitative Data.** In Proceedings of the 14th International Audio Mostly Conference: A Journey in Sound (AM'19). Association for Computing Machinery, New York, NY, USA, 124–130.

The following sections describe the research design with regards to my epistemological standpoint and philosophical stance; the overarching methodological approach to the work; and the methods I employed, which helped achieve the above research outcomes and contributions to knowledge and design practice.

1.3 Research Design

At every stage in the research process and with each decision taken, we make a number of types of assumption. These include epistemological assumptions *i.e., our assumptions about human knowledge*; ontological assumptions *i.e., the realities we encounter in our research;* and axiological assumptions *i.e., how our own values influence our research process and activities.*

Crotty defined the research design process as comprising four distinct elements that must be considered by any researcher attempting to plan and carry out an effective research study [33]. These four elements are described in the following section to provide the reader with some background on how a researcher can develop a design appropriate for a research objective, that accepts their personal assumptions and beliefs about human knowledge.

1.3.1 Crotty's Four Elements of Research Design

Crotty's framing of the research process as composing four basic elements clarifies some of the terminology around knowledge that is often used synonymously in the research literature *e.g., approaches, methodologies, philosophies etc.* Crotty's knowledge framework is useful in aiding appreciation of the interplay between each distinct type of decision making that occurs in the research design process and the types of assumptions that result.

Initially, and dependent upon the nature of the problem space, a researcher naturally adopts a particular standpoint or '**epistemology'** towards the nature of knowledge that can be learned *e.g., subjectivist or objectivist*. This standpoint underlies the entire research process and guides the particular '**theoretical perspective'** selected *e.g., positivism or interpretivism.* This theoretical perspective is embedded in the formulation of the research questions and determines the choice of '**methodology'** *e.g., ethnography or action research*. And ultimately, this methodology will inform the research **'methods'** employed *e.g., questionnaires or interviews.*

Crotty excludes 'ontology' (our knowledge of what is real) from the research process with the view that ontology and epistemology are difficult concepts to distinguish and are symbiotic in their relationship: *"*to talk about the construction of meaning [epistemology] is to talk of the construction of a meaningful reality [ontology]*"* [33].

The following sections describe the philosophical standpoint and approach I elected to adopt for this work with reference to Crotty's four research design elements.

1.3.2 Epistemology

The theory of knowledge that defines
what kind of knowledge is possible and legitimate [33]

Epistemology is concerned with *"*how we know what we know*"* [33] or *"*the nature of the relationship between the knower or would-be knower and what can be known*"* [68].

With regards to creative practice and research, it is beyond the scope of this thesis to examine all the subtleties between the different epistemological perspectives described in the design research literature. Instead I will briefly review what the literature shows are the three main positions which build on theories of design and their corresponding epistemologies:

1. Direct making relates to *subjectivism*: The subjectivist position is taken by researchers who believe that all practice is research and that knowledge exists in the designed artefact [46, 100]. Meaning is imposed by the mind without the contribution of the object i.e., what we perceive is what is real, and there is no objective truth that exists outside of our perception.

2. Reflective practice relates to *constructionism*: The constructionist position is that designing in itself is not research and that knowledge is produced through reflection upon the process of making [106, 32, 38]. Meaning is constructed out of the engagement of our minds with the world, where different people may construct meaning about the same phenomena in different ways.

3. Rational problem-solving relates to *objectivism*: The objectivist position is based on the logical construction of theories based on empirical evidence and facts [95, 8]. Meaning exists in objects independently of consciousness and experience and the objective truth of all things can be discovered.

The epistemological position I have taken in this doctoral research is primarily constructivism, where truth and meaning do not simply exist in some external domain, waiting to be discovered, but instead truth and meaning is constructed from within, through our engagement and interactions with the world and the phenomena that occurs within it. As a result, multiple divergent but equally truthful accounts of the world can exist and is dependent on individual experience.

With this work driven by a motivation to construct an impression of the world it was clear that a constructivist approach was required with regard to the knowledge constructed by people actively participating in a process focussing on their own lived experiences.

The work was further driven by the aim of communicating the constructed knowledge to others through sound art. Through reflective practice, in the pursuit of developing a meaningful impression of some human experience as an artefact, I (as the researcher) would be the primary interpretive instrument, effectively reconstructing the constructions of others. This shift from individual constructions to shared ones, through my personal interpretation in creating the sound art, means that reality in this problem space exists through social construction.

This brings a second epistemological position to the forefront in this work: *intersubjectivism*. In intersubjectivism, meaning arises from the second-person perspective, that is *my* perspective as the researcher, on a subject's construction of their own lived experience.

In these shared constructions, I am able and required to be attached, empathic and engaged with the subjects. Intersubjectivity encourages the researcher to take direct experience and interaction with the subjects as the primary way of knowing [55]. For the reasons outlined above, I regarded constructivism with a significant degree of intersubjectivism as the most appropriate epistemological approach to this research, which felt natural for me personally as a researcher at the outset and for the duration of the work.

1.3.3 Theoretical perspective

The philosophical stance informing the methodology, providing a context for the processes and grounding its logic and criteria [33]

Positivism as a philosophy has no place in this type of research and has always felt wholly unnatural to me as a researcher in general, given a profound personal view that more exists than that which can be observed, measured and proved as objective truth. Social reality was the object of study – it was not physical laws or consistencies in data to be established, but instead it was the ideographic constructs of the social mind and as such required me to take an anti-positivist philosophical approach, specifically an interpretivist approach.

There are many flavours of interpretivism which allow for inductive reasoning and theory-building to emerge from reflection and analysis following data collection *e.g., symbolic interactionism, realism, hermeneutics and naturalistic enquiry.* The interpretivist perspective considered most appropriate in the case of this research however, is phenomenology. In phenomenology, any attempt to find meaning and understand social reality has to be grounded in peoples' experience of that social reality [65].

1.3.4 Methodology

The strategy, plan of action, process or design lying behind the choice and use of particular methods, linking the choice and use of methods to the desired outcomes [33]

The inspiration behind this research started when I became motivated to produce an artistic work that could communicate some experiential phenomena. There was desire to create something that would stimulate an observer with sound in order to evoke a sense of presence within an alternative reality, affording the submission of oneself into another's worldview.

From this initial focus of creating something that was both immersive and communicative, I realised that an artwork such as this, could only be achieved from truth. How can one transport another into an alternative reality without first-hand experience and intimate knowledge of the truth? And further, how can one convey truth, if the truth is not their own?

> "[Phenomena] have something to say to us - this is common knowledge among poets and painters. Therefore, poets and painters are born phenomenologists. Or rather, we are all born phenomenologists; the poets and painters among us, however, understand very well their task of sharing, by means of word and image, their insights with others - an artfulness that is also laboriously practised by the professional phenomenologist."
>
> - Van den Berg on Phenomenology, translated by Van Manen [120]

Phenomenological research aims to elicit people's *lived experiences* of a particular concept or phenomenon and emphasises inductive logic. Methods are selected for their ability to collect the opinions, subjective accounts and interpretations of participants, and as such rely on qualitative analyses of data.

From this it became evident there was a need for me to devise some phenomenological method of inquiry in the challenge space: some way to explore experiential truth and sound, to know deviation from and convergence towards authenticity, in order to reach a truthful representation of an as yet unknown reality.

I knew that the aspects of this explorative method could only be established through the creative process of iteratively designing a future artwork. For it is through the pursuit of truth to realise a potential future *i.e., the finished artwork*, that the revelation and understanding of the intricacies of the journey required to reach that potential future, can exist. We have to reach an unknown before we can start to know <u>what</u> it is and consequently, <u>how</u> to reach it.

With a personal background in a design-related field (sound design), a designerly approach to the research felt wholly natural and it was clear to me that the nature of the project would require research to be design-led from the outset and throughout. With this work stemming from the realisation of a potential future (the design goal) and the need of a design-led route to achieve this future (the design activities), I anticipated that the main research findings would "emerge from the design process" [43].

With reference to the interplay between academic research and the "doing and craftwork" of design, Frayling wrote the seminal pamphlet 'Research in Art and Design' [51] in which he derived the terms Research *for*; *into*; and *through* Design. These terms built on Herbert Read's original definition of the relationships that exist between education and art [102], terms which were later redefined by Findeli [46] as follows:

> *'Research for design'* aims at helping, guiding and developing design practice. Those researches document the processes and concerns of professional designers and treat designers and their practice as the object of their study.
>
> *'Research into design'* is mainly found in universities and research centres contributing to a scientific discipline studying design. It documents objects, phenomena and history of design.
>
> *'Research through design'* is the closest to actual design practice, recasting the design aspect of creation as research. Designer/researchers who use RtD create new products, experimenting with new materials, processes, etc.

Although Findeli's definitions are useful and provide a clear and concise distinction between the three relationships that exist between research and design, his definition of Research *through* Design is rather simplistic and perhaps supports a common misconception that the knowledge produced in this type of research is embedded in the artefact.

If we consider Frayling's original definition, we find that Findeli fails, in his brief definition, to impart the most vital characteristics of knowledge production in RtD: that design practice is a methodology for producing entirely new knowledge and it is through reflection on the making of an artefact that makes this knowledge accessible.

With reference to the three classifications of how design relates to research, outlined above using Findeli's definitions (which are, for the most part, usefully concise for the needs of this thesis): Research *into* Design is not relevant in this case, as it looks at design from outside of the discipline *e.g., from historical or theoretical perspectives on design practice.* Research *for* Design is concerned with practices within the design profession and some small aspect could have played a part in this work, namely that some knowledge may have been embodied in the resulting artefact; however, I felt strongly that more useful knowledge may be generated in the *process of creating the artefact* and that the resulting knowledge would exist beyond the artefact and be communicable outside of the artefact itself.

As a reflective practitioner, I was carrying out design activities to create an artefact, with an understanding that if I reflected upon and articulated the design processes employed, it may generate some transferrable knowledge, which clearly aligns with many aspects of what Frayling terms as Research *through* Design (RtD).

Much of this understanding came from Gaver's writings on RtD [60], whose constructivist approach to knowledge production through design practice, along with his ideas for communicating such knowledge *e.g., through annotated portfolios*, have always inspired me.

I felt that RtD would support the needs both <u>of</u> and <u>for</u> this PhD research and although other approaches similar to RtD were considered *e.g., constructive design research, project-grounded and practice-led research*, I concluded that RtD was the most appropriate overarching methodological approach for this work.

1.3.5 Research through Design

With RtD being a reflective practice, the methodology promotes learning through making. This allows us to consider the experiences, successes and issues as they emerge through the design process and with the continual evolution of the artefacts created. With design research practices now established in disciplines beyond design, most notably within the HCI community, the literature shows there are calls for the integration of design methods, approaches and outcomes to establish standards and common theoretical foundations.

Zimmerman et al. describes RtD as the *"*process of iteratively designing artefacts as a creative way of investigating what a potential future might be*"* [131] but at the same time, advocates for RtD to follow a more positivist paradigm with formalised methods that produce expected outcomes, which is very much in contrast to Gaver's, and indeed my own, constructivist approach to inquiry through RtD.

To outline the critical perspectives that exist in the discourse around RtD, the major criticisms are as follows:

Firstly, that there have been no formal methodological approaches defined that come from a particular epistemological standpoint [47]. Secondly, that it *"*lacks clear expectations and standards for what constitutes 'good' design research*"* [48]. Thirdly, it is widely cited that validity of results can be an issue with the RtD approach, where no systematic processes exist or are not communicated effectively [31] *i.e., different designers will envisage different potential futures given the same problem space and will therefore produce different artefacts, based on their own experience and tacit knowledge*. And lastly, that RtD may well produce loose conceptual frameworks but that by its very nature, cannot generate generalisable theories [52].

Zimmerman and others in the HCI community, view RtD as purely a method, a tool used for collecting data in order to answer a research question [131], however, in alignment with the view of those in the design research community, I consider RtD a methodology in its own right. RtD as a methodology provides a strategy for the research approach, has an impact upon the methods selected and is a lens through which research outcomes are analysed.

On the relationship between RtD and epistemology, Gaver's standpoint is notable, suggesting we are cautious of convergence and standardisation in RtD, and instead *"*take pride in its aptitude for exploring and speculating, particularising and diversifying, and - especially - its ability to manifest the results in the form of new, conceptually rich artefacts*"* [60].

With respect to validity and extensibility, RtD outcomes cannot be measured upon reproducibility, in the way we evaluate scientific research contributions, but instead we can ensure that the design process is recoverable through rigorous documentation. The sequential order and nature of all observations, conversations, tacit knowledge, decisions, actions and reflections, must be well documented.

Biggs and Büchler propose that *"*rigor in research is the strength of the chain of reasoning, and that has to be judged in the context of the question and the answer*"* [8]. If the RtD process between each design decision is recoverable and *"*each chain of reasoning is strong, then the process can be considered rigorous*"*. A rigorous process then leads to valid outcomes whereby if one can recover the RtD process and establish its rigour, validity can be granted to the outcomes of the research process.

Rigorous documentation is therefore essential in RtD in order to demonstrate a clear and logical path to the research outcomes and contributions. It is worth noting that Findeli suggests a far simpler criterion for validity, namely that "validity comes with the success of the design project" [46], suggesting that where a RtD process *"*produces an artefact which is acceptable, then the knowledge produced through that process is valid*"*.

The success of the design project in the context of this research however would have been sufficiently difficult to measure in these simplistic terms, given that I had not released a product with wide-scale user testing and evaluation nor had I been working to a design brief with clearly defined and measurable outcomes against which to measure success.

1.3.6 Theory-building

On the matter of theory-building and universality, Stolterman suggests that because the goal of design is to create something that is non-universal but instead, highly specific (for a particular purpose, client, user, function etc.), RtD generates '*ultimate particulars'* [115]. He suggests that although it is difficult to develop generalisable theories about ultimate particulars, they have "the same dignity and importance as truth in science".

Zimmerman et al. acknowledge that theory-building is rarely an intended outcome at the start of a RtD project but rather remains implicit or only emerges from reflection after a design project has concluded [131]. I was aware and mindful throughout the research that deep reflection on the design process was crucial as it would enable me to uncover the relationships between the particular phenomena at play, recognise commonalities and the impact of my design decisions.

With new observations made at each stage of the research, I remained optimistic throughout that the work would naturally lead to the production of some kind of nascent theory, only possible due to the nature of the research design and the use of the RtD approach.

Gaver and others suggest that when the conceptual thinking, reflection and framing, in which a practitioner of RtD commonly engages, is clearly articulated to the research community *i.e., describing influences, design decisions, evaluating design artefacts and their importance*, and when they are considered "in general terms and applied to multiple examples, they become recognisable as theories in their own right" [60].

Similarly, Stappers argues "the designing act of creating prototypes is in itself a potential generator of knowledge (if only its insights do not disappear into the prototype, but are fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory)" [113].

If we consider the role of tacit knowledge, Friedman argues that one of the major problems in design research is that practitioners often fail to take a grounded, inductive approach to theory building *i.e., theories that emerge from direct empirical experience*. This is attributed to

failures in articulating the way in which tacit knowledge and intuition directs inductive inquiry [54]. Tacit knowledge includes the behavioural patterns and personal actions we take unknowingly and the ideas and information we build throughout our lives that we draw on without realising. It is the way we know to take an action because intuitively, it feels like the right thing to do.

Schön considers tacit knowledge or '*knowing in action'* crucial to design practice [106] and advocates a process he terms as '*reflection in action'* - a process that accepts uncertainty and personal ways of knowing, where each new design decision yields new discoveries which call for new reflection in action. This iterative process of appreciation, action and re-appreciation in unique and uncertain situations allows us to understand these situations through our attempts to change them. Reflection in action serves to extend one's repertoire of tacit knowledge which can be drawn on in future unique and uncertain situations.

Friedman suggests that this tacit knowledge and intuition can be rendered explicit knowledge through processes of deep reflection and articulation at every stage of the design process [52]. If, as RtD practitioners, we are reflective and open about our tacit knowledge, capturing and articulating the junctures where tacit knowledge dictates the route to discovery, we can be grounded in our approach to contributing knowledge [53].

To quote Friedman:

> "To reach from knowing to doing requires practice. To reach from doing to knowing requires the articulation and critical inquiry that leads a practitioner to reflective insight… It is not experience, but our interpretation and understanding of experience that leads to knowledge." [52]

This research was not undertaken with a clear route or intention to produce specific knowledge and as such, no hypotheses were declared at the outset. Instead I took an inductive approach to theory-building, ensuring I remained fully aware of the role and effect of my tacit knowledge, and was able to develop nascent theory from the outcomes of the research activities.

My theoretical contributions are in the form of conceptual frameworks and guiding philosophies for design, and the specification of design methods that support them. Through the conceptualisation and articulation of these aspects of the research and from subsequent testing of the design methods, the produced theory is shown to hold in a broad range of specific instances and can therefore be abstracted from these ultimate particulars and considered a valuable contribution to knowledge.

1.3.7 Methods

The techniques or procedures used to gather and analyse data related to some research question or hypothesis [33]

With RtD selected as the overarching methodology for this work, this informed the methods I employed in order to meet the research objectives. Adopting a RtD methodology enabled me to take an interdisciplinary approach to achieving the design goal, drawing methods from artistic research, programming and computer sciences, statistical analysis, gender studies and most significantly, methods of design practice.

In my mixed methods approach and in line with RtD, at each stage of the design process, I chose to employ the methods that I felt would be most effective for each particular design activity. The methods employed over the course of the research project include qualitative interviews; focus groups; surveys; exploratory workshops; prototyping; user testing; design practice; sound design practice; sound and dialogue recording; data coding and thematic analysis; participant observation; and reflection in action.

For certain design activities, there were a lack of suitable methods through which to achieve the design goal and in response to this need, I developed a new set of methods which were found to be effective for the design activity they enabled.

Some elements of these new methods were informed by my tacit knowledge and experience and on the surface, could be regarded as similar to the human-centred design (HCD) method

of guided introspection, where participants were guided to introspect in order to examine and express their subjective inner experiences and emotional perceptions, however in HCD this is traditionally performed by the researcher from a positivistic, third-person perspective whereas I remained actively aware of how and where my self-introspection played a part in the selection of existing methods and in the development of new ones.

The need for devising new methods and the knowledge produced in the process of developing them, altered the focus of my research from what I had envisaged at the beginning of my doctoral training journey and subsequently, transferring this knowledge to the design community became the principal purpose of this thesis.

1.3.8 Summary of Research Design

The research design selected for this doctoral research has been described in terms of Crotty's four elements. Firstly, that I approached the research from a constructivist epistemological standpoint with strong elements of intersubjectivity, in support of the belief that reflection upon the process of making with others would produce knowledge. Secondly, that the philosophical stance I adopted was that of phenomenological interpretivism where meaning-making is grounded in peoples' experience of phenomena and theory-building emerges from reflection and qualitative analysis of experiential data. Thirdly, that my philosophical stance informed the selection of Research through Design as my overarching methodological approach to the work, which in turn informed the methods I employed to reach the design goal, namely the use of methods employed in design practice as well as a mixed method approach to data collection and analysis during the design process.

The implications for the use of Research through Design as a methodology were explored with regard to the major criticisms described in the literature, stemming mostly from disciplines outside of design where the RtD approach to research is relatively immature compared to more established methodologies. Finally, in order to ensure rigour, recoverability and validity of the research process, a number of strategies in mitigation of these criticisms were described. To ensure a successful research outcome in this regard, rigorous documentation is vital, capturing

not only each detail of the design process but the junctures where *'designerly ways of knowing'* contribute to the research outcomes and to the knowledge produced.

1.4 THESIS OVERVIEW

I have explained the motivation and background to this research, and have outlined my aims, objectives and overall approach to the work. I will now provide a brief overview of what you will encounter in the remaining chapters of this thesis.

Chapter 2 provides context for this interdisciplinary work, integrating concepts from diverse fields including cognitive science, design and HCI. Through discussion of the background and foundational texts that support the theoretical underpinnings of this research, I provide an account of how this work is situated in relation to existing work and discuss the implications for design and sound design practice.

Chapter 3 is an introduction to the new participatory design method, Embosonic Design. I describe the need for such a method and my approach to its development, as well as detail its benefits and implications of use. I provide a set of guidelines to enable other designers and researchers to employ the method in their own design and innovation work.

Chapters 4 and 5 provide accounts of how the embosonic design method was employed in practice, describing rich insights I gained from its use in group-based design tasks for two very different design goals. Firstly, for the design and development of an interactive sound art installation and subsequently, for some exploratory design and innovation work in industry.

Chapter 6 concludes this thesis with a discussion on the outcomes of the research, revisiting the aims and objectives; evaluating the contributions with reference to my practice-based work; and identifying areas for potentially useful future work.

2 BACKGROUND AND RELATED WORK

This work is interdisciplinary by nature, integrating concepts from human perception and cognition, acoustics, human computer interaction and the arts, while also being rooted in design and sound design practice. In this chapter, I provide an account of how my research is situated in relation to existing work in the aforementioned academic fields.

2.1 HCI PERSPECTIVES ON SOUND

The proliferation of technology in public spaces, at work and at home has transformed numerous aspects of our lives. With the use of mobile devices in particular, limited screen space and operation via touch-based input means that interaction with these types of device commands much of a user's attention.

While one's attention is focused on screen-based activities, their interaction with the real world and with each other, is greatly inhibited. Defined as *'absence presence'* by Gergen, "one is physically present, but is absorbed by a technologically mediated world of elsewhere" and people "cease to be full participants in their immediate context" [61].

Notwithstanding the inherent risks to safety in certain contexts, such as driving or crossing the road, users are inadvertently partially blinkered to transpiring events, people, landscapes and to the beauty that surrounds them in the real world. Think of the child on a car journey who is shut off from the passing splendour of a mountain range because they are completely focused on completing a game level on a tablet or smartphone.

The vast majority of human-computer interfaces are mostly graphically-based with very little information communicated via alternative modes [14]. Games, social networking apps and locative services such as electronic maps and navigation aids, are almost always presented

visually. With the granularity of information constantly increasing; new technologies enabling additional features; and the contexts of use becoming more varied, many researchers in the field of HCI have been exploring the extent to which other, non-visual modes can aid our interaction with technology while navigating and interacting with the world.

With regard to the human senses, it is widely accepted that the auditory and visual senses in particular, have a symbiotic relationship in providing detailed information about our environment [14]. Vision provides large amounts of fine-grained data about an area of focus along with some low-level information regarding the periphery, performing foreground and background analysis; object recognition; and interpreting spatial cues. Audition uses both direct and ambient sounds to provide omnidirectional data about the surrounding environment, alerting us to events both within and outside our field of view. When combined, these senses provide us with a detailed understanding of our environment and the world around us at a given time.

There are several advantages to exploiting the symbiotic relationship between vision and audition within human-computer interfaces, as sound can communicate information without interfering with a user's interaction with an application [11], much like the use of sound in film and in games to effectively convey aspects of a scene that are not communicated visually.

Sound can serve a number of roles within human-computer systems however it remains an underused and underdeveloped dimension for communication and information delivery [77]. The following list gives an overview of the diverse roles that sound can play in HCI:

Utility: when screen-based activities are not the optimum mode of interaction i.e. in minimal attention contexts [19].

Aesthetics: when sound can make an application more appealing or can disseminate certain information more elegantly than a visual representation *i.e., in part the motivation behind data sonification* [5].

Immersion: when sound can enhance user immersion within VR and AR environments [107] as well as in real world spaces [39].

Accessibility: when sound can communicate fine-grained detail to users with visual impairments and provide alternative interaction modes [88].

Shared Experience: when experiencing visual content as a group is not ideal *i.e., on mobile devices designed for single-user interaction, sound content can be experienced by all in the immediate vicinity* [2].

Novelty: where a system employs sound as a novel medium for engagement or entertainment [35, 86].

The bulk of research in the HCI literature over the last thirty years has focused on the role defined above as *sound as utility*, exploring the use of non-speech sound as auditory cues in user interfaces and the extent to which it can assist user interaction. *'Auditory icons'* and *'earcons'* are two different types of auditory cue that have been researched extensively in the field of HCI.

An earcon is a short pattern of synthesised tones or a musical phrase, which can carry connotations of its meaning through its musical structure *i.e., positive, negative, or urgent*. The term was devised by Sumikawa et al in 1985 [10] as the auditory equivalent to the pictorial icons seen in computer interfaces.

An auditory icon, as defined by Gaver in 1986 [57], differs in that it represents computer functions and events with corresponding natural, everyday sounds. For example, when a Mac user places a file in the *'Trash'*, they hear the familiar sound of paper being scrunched up. Mynatt investigated how well we can identify auditory icons by asking users to listen to and describe everyday sounds [93] and found that users had low ability in identifying everyday sounds without context, correctly identifying a sound only 15% of the time, but that users were able to effectively discriminate whether sounds were produced by an object or were the result of human action.

Fernström et al carried out similar user studies [44] [45] examining the extent to which people can effectively identify auditory icons. Similar to Mynatt's results, they found that users

experience great difficulty in identifying sounds without context and suggest that auditory icons should be designed to reflect as closely as possible the function they represent.

Earcons have no association with everyday sounds and it is up to the designer to infer meaning through musical parameters, such as the use of major and minor chords to convey positive and negative qualities [17], however definitive meanings ultimately have to be learned by the user through repetition, as no natural links exist between sound and event.

Brewster et al examined how the musical attributes of earcons determined their effectiveness by carrying out a series of user studies [15, 16], results show that more complex and structured musical tones are more effective than unstructured patterns of pure tones. Both types of auditory cue have been found to be useful in human computer interfaces, each with their own benefits and limitations, however there is no evidence that earcons are more effective overall than auditory icons, or vice versa, but rather a combination of the two types would be most useful in the design of complex user interfaces.

Lucas evaluated the communicative ability of both auditory icons and earcons by asking users to choose sounds that they thought most closely matched various computer functions and events [87]. Users were most successful in matching auditory icons with the corresponding function or event for which they were designed.

Bussemakers et al presented users with a series of line drawings, where some were displayed with accompanying earcons and others with auditory icons, users were asked to determine if they depicted animals or non-animals [22]. The findings suggest that for image categorisation, the use of auditory icons has a facilitating effect.

In summary, while people are better at matching auditory icons to corresponding functions than earcons, they find it difficult to identify either in the absence of context therefore auditory cues should be designed to reflect as closely as possible the function they represent.

2.1.1 Data sonification

The complex nature of sound and the diversity of associations it can have to a visual element enables sound to have immense expressive potential and in certain situations sound can disseminate information more elegantly than visual representations.

The term sonification was initially defined by William Buxton at the 1989 CHI conference as "The use of sound for data representation [being] the auditory counterpart of data visualization" [103] however the concept had been around and employed in various hardware products long before this.

One of the most well-known products to perform sonification is the Geiger counter, which since 1917 has been translating detected radiation into audible clicks at a rate that fluctuates in response to the amount of radiation detected. It sonifies small incremental changes in the radiation reading as either an increasing or decreasing click rate, which upon detecting high levels of radiation, gives the user, and others in the vicinity, a greater sense of being in close proximity to life-damaging radiation levels than silent incremental changes on a numerical display.

Soon after Buxton's first use of the term, the topic gained importance as a research area in its own right with the formation of the first conference dedicated to auditory display (ICAD) where several other definitions of sonification started to emerge. Following ICAD 1997, Kramer and other leading sonification researchers had formulated a new definition that was published in the NSF Sonification report [82] as: "The use of non-speech audio to convey information. More specifically, sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation."

There has been some discourse around a need to tighten the boundaries of this definition of sonification, with some researchers in the community suggesting that a stricter definition is required [69]. In a sociological study of the ICAD community [117], Supper described the controversy created by Hermann's attempt to "narrow down the boundaries of the field" in response to the increasing body of sonification research attached to artistic works.

I imagine that Hermann and others in the HCI research community with similar views, would greatly disapprove of my use of the term *'sonification'*. Sonification as a research topic is traditionally reserved for quantitative data, that which is physical, measurable and quantifiable and applying it to an area such as *sound as art* and proposing that we can sonify qualitative data, is in effect, an attempt to stretch those perceived boundaries even wider.

Sonification itself is not a technique, but rather sonification is a process, it is "the direct linkage process between the data itself and some technique for rendering it in a sound space" [66]. In terms of the sonification of quantitative data there are a number of techniques that are well documented in the literature, for the purposes of providing some context around the principal research activities in the field, I will give a brief overview of the techniques currently in use. Hermann and Ritter propose a classification for the existing sonification types as: Audification, Parameter-mapping Sonification, Auditory icons (including Earcons), and Model-based Sonification [70].

2.1.1.1 Audification

Audification is a technique where numerical data is mapped directly to sound pressure levels to produce an audio waveform. A well-known example is the Electroencephalogram (EEG), the electrophysical monitoring method to record electrical activity of the brain, where brain wave frequencies are made audible. The audification of brain waves is described as a relatively simple process that involves compressing the duration and amplitude of the original waves and transposing them to within the human hearing range [127] (*for information the human hearing range is between 20Hz and 20kHz, notwithstanding degradation at the upper end, which increases with age*). Audification can be powerful on an emotional level due to the listener having direct physical experience of a physical phenomenon through the direct translation of data to audio. The limitations of audification as a technique for sonification is that it "is only applicable for limited sorts of data sets and requires many data points to deliver reasonably long sounds" [70].

2.1.1.2 Parameter Mapping Sonification

The most frequently used technique for sonification is parameter mapping sonification, where the sonifications are generated by arbitrarily mapping data features onto sound events e.g., instrument sounds, or onto acoustic attributes such as pitch, tempo and timbre. It offers more flexibility than audification since the designer can specify both the underlying sounds and/or acoustic attributes in addition to the data-to-parameter mapping according to the data set they are dealing with and the needs for understanding or exploring it [70]. The produced sounds are somewhat organic, in that although the system's designer maps core parameters to certain behaviours, the resulting sound is constructed by the system itself, determined entirely by the nature of the sensed data that enters the system.

Parameter mapping is often used in interactive sonification where aural feedback is given in response to how a user interacts with a data set, defined as "the use of sound within a tightly closed human computer interface where the auditory signal provides information about data under analysis, or about the interaction itself, which is useful for refining the activity" [69].

2.1.1.3 Auditory Icons

Auditory icons and earcons have long been a prevalent sound-related research topic in the field of HCI, with the extensive research in auditory display informing the design of the sounds we hear on our laptops, mobile phones and tablets today. Auditory icons, as previously described in section 2.1, can be considered aural metaphors, sounds that represent the action or event of interest, that we have a priori knowledge of and therefore do not need to be learned [70]. Where there is no intuitive linkage between sound and event, an earcon can become an aural metaphor as we learn to associate a certain sound with a particular event, such as the sound of a text message or email notification.

2.1.1.4 Model-based Sonification

This technique differs from the previous three approaches in that it uses acoustic models which are based on environmental sound production in the real world, which generate a response when excited by a data set, rendering a sonification that "is directly linked to the temporal evolution of the model" [70]. Model-based sonification is most useful for data with no time domain e.g., cluster analysis or particle trajectories and the sonfications produced can be useful for rapid screening of data if analysts were trained in how to "distinguish the sonifications and interpret them correctly" [127].

2.1.1.5 Related techniques

A number of further techniques are described in the literature, which are all essentially variations of the parameter mapping technique using different sound sources: MIDIfication maps data to MIDI notes; sinification maps data to sine tones; musification maps data to musical scales and chords; vocalisation maps data to synthesised vowel sounds; and stream-based sonification uses granular synthesis [5].

2.1.1.6 Aural Metaphors

Smith proposes that different data should sound distinctive from each other [110] but with no specific rules on the '*sound of*' data, these decisions fall on the sonification designer. There is a case for using sounds that, based on human experience, are attributable to specific data. There is some evidence in the literature that shows sonification designers employing parameter mapping techniques can be influenced by design considerations related to auditory icons, using aural metaphors to help create more intuitive linkages between data and sound in their designs.

Polli highlights the significance of emotional connections to the data as *'memory aids'* that can "increase the human understanding of the forces at work behind the data" [62]. These emotions can then inform sonification techniques in order to communicate them.

This concept, seen in Polli's 'Sonic Antarctica' which features field recordings, sonifications of scientific data and interviews with climate scientists, could be considered similar to the use of auditory icons, being that they are aural metaphors for the transmission of information. Barrett used this approach for the sonification of rock fragmentation data in her piece 'Aftershock', exploiting emotional connotations through the use of recordings of rocks being crushed as the sound source [6].

The challenge comes when sonification designers are tasked with sonifying data which are inherently silent e.g., astronomical data, because they lack sonic connotations and we have no experience of the forces at work behind the data. This lack of emotional connection between data and sound [110] hinders the transmission of information.

One particular criticism of sonification research suggests there is an element of *'conversion hysteria'* attached to the method, Conner describes this as an obsession with converting anything to sound, even where there is no *'sound of'* something [28] and concludes that information is rarely transmitted effectively.

Wolfe goes so far as describing sonification as *'mystical'* in that that we attempt to understand data that "are incomprehensible through traditional analytic means and can only be understood through experience" [125]. Wolfe elaborates, calling the ear an *unreliable witness* for the "experience of sound is demonstrably subjective", associating sonification with the mystical, as we experience the information rather than process it logically.

2.1.2 Ecological Listening

The use of emotional connotations in selecting sounds that are attributable to specific data relates to our human capability for ecological listening. Acoustic ecology relates to the study of relationships, mediated through sound between human beings and their environment. When thinking about human perception and acoustic ecology it is useful to consider the knowledge about human perception mediated through visual cues, since the field of study on visual perception is more advanced.

Gibson's ecological approach to visual perception, his most radical and controversial work, posits that we perceive an object affordances as opposed to its specific qualities [63]. Developed by Gibson over a number of years, an affordance is a particular property of an object that characterises how it can be used. As Turvey et al explain, "affordances are dependent upon the structure of the organism… referred to as the organism's effectivities; its size, shape, muscular structure, movement capacities, needs and sensitivities that make action in the environment possible" [119].

It may be that Gibson's ecological approach to perception is not often applied to sound, given that there is very little original research in the literature I examined, that uses the concept of affordances to understand the relationships between sound perception and action.

Gaver provides the closest example of an ecological approach to sound perception, with his description of "the notion of affordances perceived through auditory information" [58, 59].

Gaver argues that we do not perceive the psycho-acoustic properties of pitch, loudness, and timbre, unless we are actively engaged in musical listening, but instead we are mostly in *'everyday listening'* mode, where we perceive everyday events such as the sound of people and things moving, changing, beginning and ending.

In everyday listening, it is not the rhythm or melodic content of sound that we perceive, but rather we perceive the event responsible for producing the soundwave. According to Gaver, we can perceive the event by detecting causal relationships that are governed by physical law *e.g., through the action of striking a stick upon the skin of a drum head, the resulting compression*

of air inside the shell produces a particular pattern of air disturbances, that can only be attributed to a limited number of objects and events, allowing us to perceive the hit of a drum.

In everyday listening, according to Gaver, "humans perceive everyday sounds in terms of the sources, materials and actions that made them, rather than the individual sound attributes such as pitch and timbre" [58].

It was his ecological approach to sound perception that inspired Gaver to conceptualise and develop the use of auditory icons in the computer interface, as described earlier, these are "sounds that are intended to provide information about an event or object in the interface by representing the desired data using properties of the sound's source, rather than properties of the sound itself" [57]. The particular characteristics of a sound source that auditory icons convey *e.g., materials, motion, size and proximity,* are "features that can be useful in providing multi-faceted information in human-computer interfaces" [14].

There are limitations to consider with respect to sound's effectivities for example; high frequency sounds may afford something to young children who possess the full range of human hearing but nothing to an aging adult who cannot detect the same range of frequencies. The size (loudness) of a sound may afford something to a person with normal hearing but may afford something different to someone with reduced hearing capabilities and to a deaf person, nothing at all, unless they can feel it *e.g., through low frequency vibrations*.

Also, it is widely accepted that sound perception depends on conventions that exist within different cultures *e.g., a siren in the Amazonian rainforest may not be perceived as a token of emergency;* in addition to what people are conditioned to within their environment *e.g., a certain sound could be perceived as a firework, a gunshot or a car backfiring.* Mundane sounds like a pedestrian crossing alert can sound different depending on the country you reside, and whether you recognize such tokens can be based on how well travelled you are.

With respect to musical listening, in which Gaver suggests we engage when actively listening to music, we perceive acoustic attributes such as pitch and timbre, however the significance of sound source identification in music is evidenced in the literature. Dibben conducted a study and her findings suggest that while listeners often describe music in terms of "abstract acoustic properties of sounds", their descriptions are "more often related to objects and events" [37].

Similarly, in a perceptual listening study examining Trevor Wishart's 'Red Bird' [34], Dean and Bailes found that in music perception, the physical origin of sound events can impact a listeners perception more than abstract acoustic properties.

2.1.3 Sonification toolkits

A number of researchers have focussed on creating sonification tools, not only to facilitate their own research but to enable others to more easily employ sonification techniques in their own projects. Pauletto and Hunt created the 'Interactive Sonification toolkit' [98] in the Pure Data development environment, that enables real-time sound synthesis which allows a user to adjust parameter mappings as required to reach a desired sonification output.

Yeo, Berger and Lee created the 'SonART' framework [128] which takes image-linked data parameters such as RGB pixel values, and maps them to sonification parameters using OSC (Open Sound Control) protocol. Worrall created 'SoniPy' [126] which is an open-source python framework that allows software developers to contribute to the project by creating additional Python modules for data sonification, with many modules now available for parameter mapping on a large range of dataset types.

Although these tools have been designed to open up sonification to researchers from other disciplines, based on their instructions for use I argue that none of them are as easy-to-use as their creators claim, but rather they require considerably more than a basic level of knowledge and experience with data sonification.

Furthermore, as Walker and Cothram point out, these toolkits are either proprietary in that they depend on specific hardware or software or are "built for the expert sonification designer, and not the schoolteacher, student, or average researcher" [122]. In the same paper, Walker and Cothram describe their attempt to address these issues in their design of the 'Sonification Sandbox', which runs on a Virtual Machine to ensure universality of access and processes input data that must take the form of a CSV file containing only numerical values. The user can select parameter mappings on the graphical user interface and can export the output as a MIDI file.

An updated version, the 'Web Sonification Sandbox' [81], employs web technologies including the Web Audio API for sound synthesis as opposed to MIDI however it's functionality and dataset ingest capabilities do not diverge significantly from its earlier equivalent.

All of the tools described were designed solely for processing quantitative data sets and a relatively small number of the publications reviewed describe research, tools or techniques for the sonification of qualitative data or emotion. Those publications that do mention qualitative data and emotion describe assigning numerical values to the input data.

One example from the literature describes the development of LifeMusic [78], an Android app that generates sound based on a users' rating of their life events and memories which although designed to reflect emotion, relies on users self-assigning ratings of their qualitative experience by expressing their level of happiness or sadness for each event/memory on a "sad-happy scale between one to ten".

2.2 Sound Sketching

Regardless of the objective or material outcome of a design project, the process involves moving from the conception to the realisation of an artefact. Brown describes design projects as having four stages: 1) Inspiration; 2) Understanding the context and the problem; 3) Ideation as an iterative process of generating and evaluating ideas; and 4) Implementation of concrete solutions [20]. In each of these stages, in order to externalise, exchange and archive ideas, designers will produce a number of physical and/or digital 'quick and dirty' mock-ups, sketches, paper prototypes etc. In visual design, these *'intermediary objects'* [36] or *'boundary objects'* [114] are profuse and widely known to be incredibly useful for supporting dialogue around early ideas with collaborators or stakeholders; as a springboard for inspiring new and divergent ideas; and for recording ideas for future reference. Schön describes the act of sketching as purposefully provisional and transient, and it has become widely accepted as an "embodied means of design thinking" [106].

In sound design, the equivalent to a roughly drawn visual sketch is a rough sound sketch, however when sharing ideas about potential sounds with stakeholders, sound designers tend not to craft rough sketches but instead spend time tweaking and refining sounds so that they are closer to a potentially final proposal.

There is not the same granularity in sound design that there is in visual design, with respect to a back-of-an-envelope sketch all the way to a highly detailed CAD (Computer Assisted Design) drawing.

One project that stands out in the literature is the 'Sound Design Toolkit' by Delle Monache et al [36] in that its design is informed by the ecological approach to sound perception and everyday listening. As described in the previous section, in everyday listening, it is not the rhythm or melodic content of sound but rather it is the event responsible for producing the soundwave that bears most significance in our perception of sound.

The Sound Design Toolkit describes itself as a "virtual Foley box filled with a rich palette of virtual noisemakers, readily available to the sound designer to sketch and prototype sonic interactive behaviours" [36]. The toolkits purpose is to synthesise sound events based on the real-world physical manipulations *e.g., "impact, friction and derived processes such as crumpling, rolling and bouncing"* of real-world physical objects.

This approach diverges greatly from the data sonification toolkits described previously, in that it enables generation of sound not from discrete data points as a product but rather from physics-based behaviours and processes, exploiting an *action-object paradigm* as demonstrated in the taxonomy shown in Figure 1 [36]. A number of similar tools created for perception-based sound synthesis include Andy Farnell's Pure Data patches that accompanies his book *Designing Sound* [42], Pruvost et al's procedural audio framework [101] and Cook and Scavone's 'Synthesis Toolkit' [29].

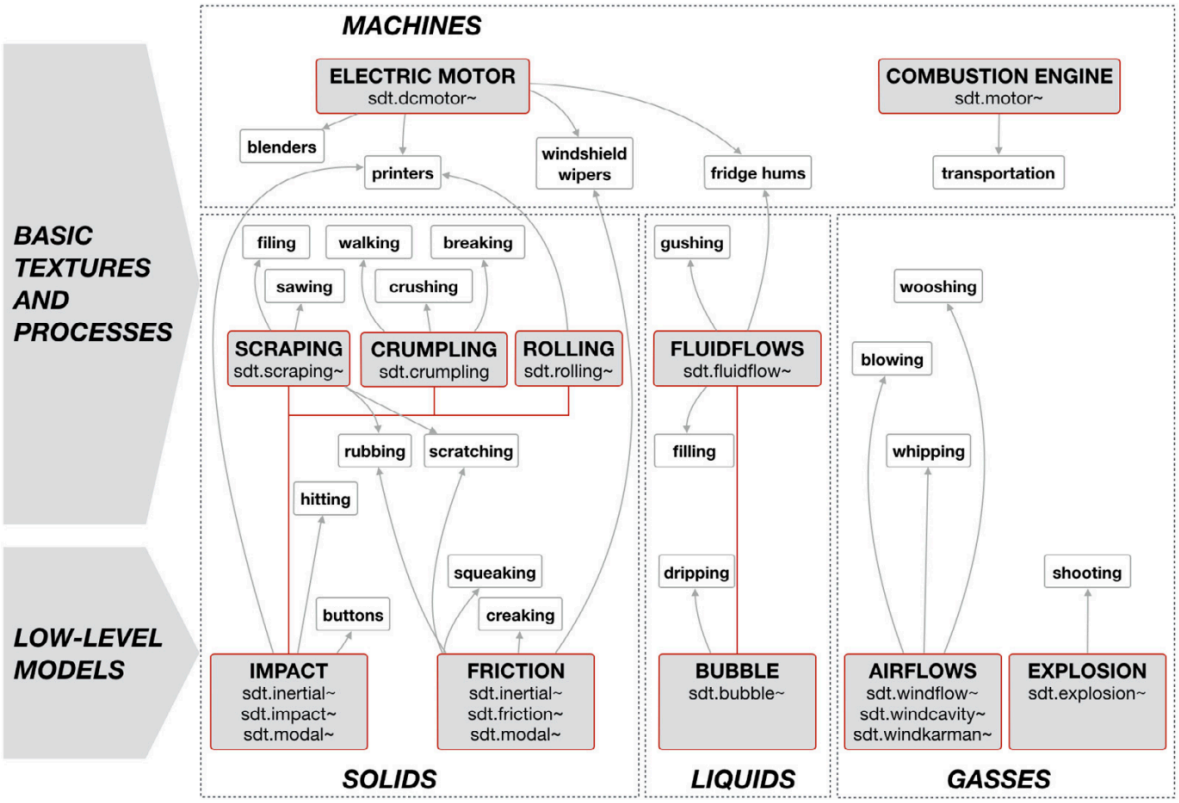

Figure 1: The Sound Design Toolkit's taxonomy of sound models

In all of these tools described, the user, via a graphical user interface, is able to select a physical object *e.g., solid, liquid, gas*; adjust the associated physical parameters *e.g., shape, stiffness, resonance;* select an action to apply to the target object *e.g., striking, scraping, crumpling;* and adjust the force of the applied action *e.g., strike velocity, surface pattern*.

The authors behind the Sound Design Toolkit describe it as "a family of sound models based on physical descriptions of sound producing phenomena, organized in a taxonomy that makes sense to humans… the sound models do not need to be programmed, but only acted on through continuous manipulation" [36].

These tools are the result of significant research efforts and I recognise that they may be useful tools for sketching sounds however I argue that they are in themselves, a barrier to rapid experimentation with sound.

The reason being that they are essentially middleware and although I see them as useful for synthesising the sound of, and actions upon, potentially inaccessible materials and objects, I propose that in order to sketch the sounds of accessible materials we literally take matters into our own hands by picking up and manipulating real-world objects, not virtual ones.

Furthermore, use of such tools assume that the early stage of conceptual thinking about sound, those comparative back-of-an-envelope sketches that inform the *'action-object'* choices, have already been made insofar as the designer must select an *object* and *action* upon it to produce a sound that exists firstly (and only) in the designer's mind.

Rocchesso and Monache, two of the researchers involved with developing the Sound Design Toolkit, have done some work on more embodied forms of sound sketching. Their work on vocalisation and gesture [71] examines cooperative sound design processes when sketching sound through vocalisation (gesture in this case, relates to accompanying hand gestures that people sometimes make while vocalising sounds). They propose that sonic interaction design methods would benefit from greater levels of cooperative ideation and sketching but recognise the need to facilitate individual reflection and refinement to improve design outcomes [41].

Buxton proposes that designs can only be considered sketches when they are quick, timely, economical, and disposable in that they can be produced on the spot and then thrown away because they carry a concept and not an execution [23].

Goldschmidt regards the intrinsic value of sketching is its ability to "modulate the design problem space" [64], in that the production of a sketch is provisional and inspires additional connections, layers and new perceptual and cognitive associations that expand and shrink the boundaries of the design space so that it is progressively understood and resolved.

There are also constraints on the effectivity of sketches which are dependent on the skill of the person producing the sketch, where an articulate sketcher is not consumed by the intricacies and challenges of the sketching medium but is instead focused on the externalisation of their idea [118].

Svanæs argues that for this reason, the tool should be so transparent that it is embodied in the sketcher's kinaesthetic creativity. This supports my earlier argument that sonification and computational sound design tools are middleware that constitute barriers to our ability to rapid experiment with sound and therefore our ability to produce effective sound sketches.

Vocalisation has gained significance amongst the sonic interaction design community for its ability as an intuitive and immediately available sketching tool, with Rocchesso and Monache describing the human vocal apparatus as analogous to the pen and ink of the visual sketcher [92], in that no specific skills are required and humans are adept at mimicking sounds (assuming they have no hearing impairments or health conditions that impair vocalisation).

Rocchesso and Monache describe the dialectic relationship between the sketcher and the sketch as "a continuous feedback loop of new knowledge creation (hearing as) and form production (hearing that)" [92], as illustrated in Figure 2.

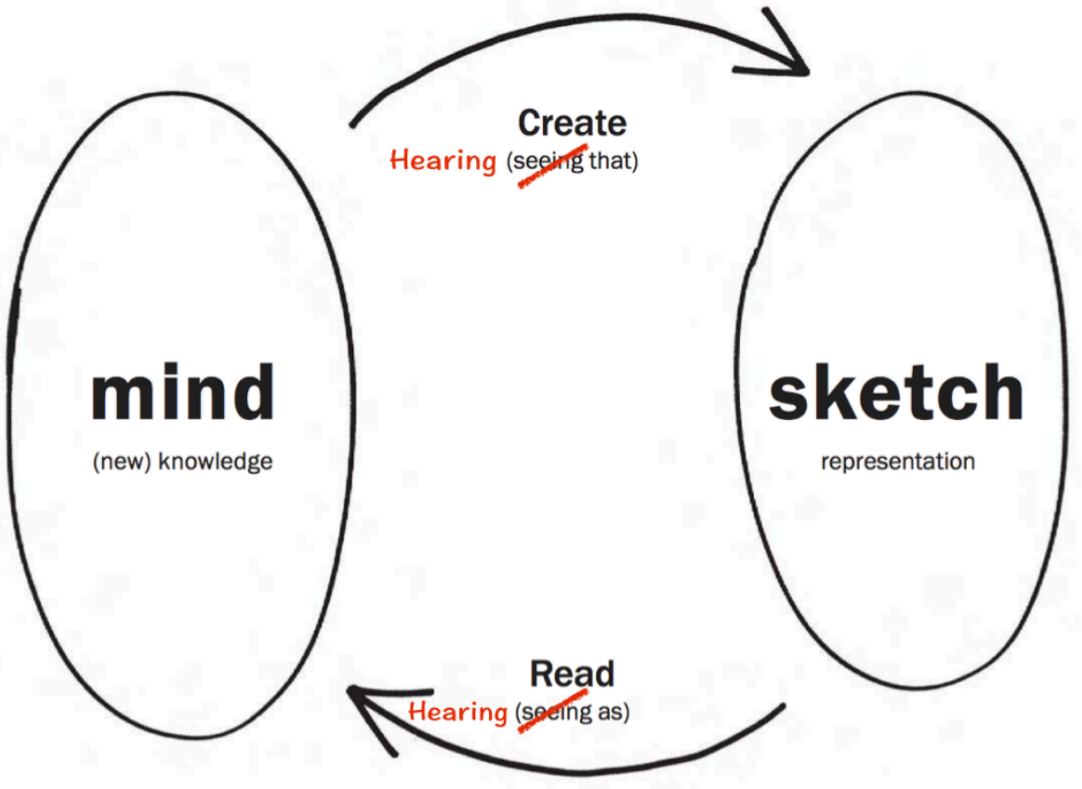

Figure 2: Sound sketching loop by Delle Monache et al, adapted from Buxton

There is an internal negotiation that continuously transistions between *'reading'* and *'creating'* in relation to listening while sketching. If we consider Svanæs argument that sketching should be so transparent that it is embodied in the sketcher's kinaesthetic creativity, there is a need for low-fi sound sketching methods that promote performativity and improvisation as part of sketching-in-action dialectic loop as described above.

2.3 The Art of Foley

From her extensive research in the area of sonic interaction design, Pauletto recognises the opportunities brought about by our ability to perceive the physical properties of sound sources in designing effective sonic interactions. She also describes the primary challenge in her field being the limitless possibilities associated with choosing a starting point for a sonic interaction and a lack of established methods "to go from an idea, concept or context to a sound" with no tools "to inspire creativity, sketch new sounds and communicate them to others" [97].

In attempts to address this lack of methods and tools, some researchers have been exploring the transfer of knowledge from film and theatre sound design to inform novel practices in the areas of sonic interaction design and auditory display.

When viewing a play or film, or listening to a radio drama, audience expectations are based on everyday experiences of sound, with aural metaphors playing a key role in not only supporting the narrative but drawing the listener into the story world and suspending their disbelief so they become fully immersed in the story [3].

Sound affords a level of ambiguity and it is the association between sound and vision, or sound and mental image if we are considering acousmatic sound, that creates meaning. Acousmatic sound is a term introduced by Schaeffer[4], that refers to sounds that are part of a scene but we

[4] As an interesting aside, the term *acousmatic* originated from *akousmatikoi*, these were pupils of the philosopher Pythagoras, who insisted they sat in silence while he delivered his teachings from behind a curtain "in order to not distract from the voice and to lend it a rather divine authority" [99].

do not see their source [104] *e.g., when we hear the sound of offscreen or offstage action, this is acousmatic sound*.

This association between sound and image (or acousmatic sound and mental image) is exploited to great effect in film through the use of Foley, where the original source of a sound can be wildly different from the object it represents.

Foley sound in film refers to sounds that represent events in the environment, that are either associated with the sounds people make (non-speech) or the sounds that objects make, and are added to film in post-production. They are added in post-production not only as a cost-saving approach that avoids the need for high quality capture of incidental sound during expensive film shoots, but to enable creative sound design to complement the aesthetic styling of the director's final cut of the film.

Foley sound and the Foley technique gets its name from the pioneer of the practice, Jack Foley, who in the early days of film sound recording, became an expert in performing incidental sounds in live synchronisation with the action as films were played back during post-production.

Foley artists, from those working on early films to those working today, are highly skilled performers who fully engage in the artistic process of finding just the right sounding material and physical action to produce sound that does not necessarily emulate the acoustic characteristics of the target action or event faithfully, but that delivers the right affordance through creating sounds that conform to our perceptual expectations.

It is a highly theatrical method of creating sound effects, if you have never watched a Foley artist at work, I recommended viewing some of the content that captures the practice which is widely available online[5]. Seeing a Foley artist in action gives some insight into the bodily processes involved in conveying the personality of a character in motion through the creation of conceivably unremarkable and insignificant sounds like footsteps, and the imaginative and creative ways that other worldly, sci-fi and gore sounds are made.

[5] Inside the Pinewood Foley Studio by BAFTA Guru: https://www.youtube.com/watch?v=tQl_-MghIjo

Foley artistry involves performing an action, while concurrently maintaining awareness of the material object affording the action, and continuously reflecting on the sound produced. This level of attention and immersion in the task at hand could be considered as fairly analogous to a skilled and well-practiced musician playing an instrument.

Franinovic describes Foley performance as "enactive sound design" [50] as it cultivates bodily skill in sound performance through exploration and improvisation while listening to self-produced sound.

Pauletto has employed theatrical methods based on Foley artistry for sketching and exploring sonic interaction design. In her experiments, participants watch an actor act out a scene while sound designers sketch sounds for the scene using Foley techniques *i.e., the sound designers live sketch sounds by manipulating sounding objects that are deliberately different to the objects the actor interacts with*. The tests were carried out twice with the participant group, firstly with the sound sketching in view of the audience and then from behind a screen so that the sounds were acousmatic.

Pauletto found that meaning making was strongly impacted by synchronicity between action and sound, regardless of whether the sound sketcher was in view, and even when there were unrealistic matches between the sounds heard and the objects seen, the causal relationships created by synchronisation were maintained. Interestingly, of the several insights Pauletto gained from this study, she describes the greatest value was found in the sound design process itself.

By using Foley artistry to explore what the final sounds should be, the sound designers went through "an iterative process of interpretation where meanings were re-established many times" [97]. Pauletto concludes that the strength of this sketching method is "its ability to support rich discussions among stakeholders".

In a similar set of experiments, Hug and Kemper describe how they produced sketches using a Wizard-of-Oz[6] approach and Foley approaches in a sonic interaction design task, where an invisible performer played the role of the user interface and manipulated sounding objects to provide real-time sound feedback to the interacting user [72]. They found that Foley-based, 'quick and dirty' low-fi sketching methods are accessible, in that they do not require the extensive training or experience with customised tools inherent in other SID methods, yet they offer a rich and virtually unlimited range of sonic possibilities – "they allow us to deal with performativity and are open for improvisation and dialogical exploration" [72].

This agrees with Ament, who describes Foley techniques, in addition to the sounds that can be made with the voice and the body, as offering vast sonic potential with a very simple technical setup [1].

With respect to the value of Foley-based techniques, Hug and Kemper describe how they "encourage exploration and ad-hoc ideation, especially at the beginning of the design process" [72], and regard this form of sound sketching as equivalent to established methods such as moodboards and sketching in visual design. They suggest that although the "ease of use" of Foley enables participants to start sketching sound immediately, there is a requirement for participants to overcome inhibitions at the start of the process, in order for them to settle into a mode that enables playful sound making.

The effectiveness of Foley, according to Hug and Kemper, is that it allows all members in a group, regardless of background and area of experience, to develop and implement convincing sonic ideas. In this regard it is useful for facilitating non-sound designers to exchange ideas about sound, when they can quickly sketch a sound as opposed to attempting to describe it through use of natural language.

[6] A Wizard of Oz approach describes an established technique employed in the user testing of digital or physical prototypes, where one or more components are not functional but are instead simulated by an assistant so as to appear functional to the user. The simulated components may include the system's underlying processes, its responses to user interaction, or the conditions of the environment itself. The approach enables early identification of issues relating to the user experience or core functionality of a product, system or service.

Chion describes observations where participants in their attempts to describe sounds flip continuously between the sound's content, source and meaning, he found that listeners find speaking about sound incredibly difficult when required to describe it independently of cause, meaning, or effect [27].

Foley-based techniques are clearly well regarded by the relatively small number of researchers who have employed them as a method for sonic interaction design and who consider them equivalent to conventional prototyping methods.

There are calls in the community for "designing through sound making to be advocated" in order to establish the approach as legitimate methods [96] as "they are not always taken seriously" [72] but have potential to mitigate against the inherent technical bias associated with most sound sketching tools and be more flexible to changes in aesthetic direction.

2.4 Sound Can Elicit Emotion

In film, the musical score is a powerful medium through which we experience the emotional intent of the narrative, however it is through Foley sound that we feel the characters actions within the story world and come to know their emotions. For this reason, Ward suggests that Foley sound design is "first and foremost, a form of emotion design" [124]. Successful designs depend on the Foley artists ability to understand the emotions of the character on screen and their "talent to utilise their embodied knowledge of how these emotions manifest themselves in sonic interactions with objects" [96].

Pauletto suggests that Foley artists possess "a wealth of knowledge to be unpacked […] that can tell us about our perception and understanding of ourselves and the world we inhabit, how we create meaning, and induce and react to emotions through interactions" [96].

It is widely known and accepted that music can provoke strong emotions in listeners. Juslin and Västfjäll developed a model of seven distinct psychological mechanisms through which music can accomplish this, called the BRECVEM model [74].

To provide a brief overview, the mechanisms are:

1) *Brain stem reflex*: which refers to acoustical characteristics of music that are instinctively read as urgent and threatening and include sudden, loud, cacophonous, sounds that provoke feelings of unpleasantness.

2) *Rhythmic entrainment*: whereby strong rhythms in the music act as stimuli that effect bodily rhythms of the listener including their heart rate and breathing, effecting changes to bring us closer to rhythmic synchronicity, which elicits feelings of excitement.

3) *Evaluative conditioning*: which refers to music that, through experience, the listener associates with certain positive or negative emotions, for instance a genre of music that a mother and child always enjoyed together will spark positive emotions when they hear it in isolation long after that child has grown up.

4) *Emotional contagion*: which describes the ability of the listener to perceive the emotional expression of the music and that same emotion is internally activated.

5) *Visual imagery*: whereby the music causes the formation of specific mental images which in turn induces specific emotions in the listener e.g., visualising a sun-soaked, idyllic beach brings positive feelings like warmth and happiness.

6) *Episodic memory*: refers to emotions being induced because the music reminds the listener of a specific event in their life.

7) *Musical expectancy*: which refers to specific features which either defy or confirm the listener's expectancies over what comes next in the music.

In 2013, Juslin created an additional mechanism to the model, extending it to BRECVEMA, termed *aesthetic judgement* [76]. This refers to the metrics listeners use to determine the aesthetic value of a piece of music, which involve a number of factors including genre, musical skill as well as the listeners judgement of idea, style and originality.

Although this model was developed in relation to music I suggest that a number of the factors defined can also apply to sound effects. Indeed, Juslin and Västfjäll acknowledge this: "music evokes emotions through mechanisms that are not unique to music" [74], and some of the mechanisms "involve low-level processes that developed before music even existed, and that consequently don't treat 'music' as a distinct type of event" [75].

If sound events carry emotional information, then sound can be considered a method of communication that can elicit an emotional response in the listener. It is well established from studies in the field of psychology that sound that arouse emotions can cause changes on a physiological level, including changes in electrodermal activity, pupil dilation and heart rate *e.g., unpleasant sounds can trigger the startle response which results in heart rate deceleration* [12].

In the fields of affective computing and HCI, the communities agree it will be highly beneficial to understand the qualities of general sounds that provoke specific emotional responses for the design of future systems, *e.g., social robots and companion technologies, that seek to integrate well into people's lives.*

This research does not attempt to address this challenge but instead considers that *if sound can elicit emotion, can emotion elicit sound?* and according to the literature discussed in the previous section, through the performative practice of Foley, emotion can and does elicit sound.

2.5 CONNECTING *WITH* AND *THROUGH* SOUND

Collaborative design activities that aim to produce innovative solutions or the generation of new ideas, rely on effective knowledge sharing between participants from multiple backgrounds and disciplines. The importance of tacit knowledge in design and innovation is widely understood and it is these highly subjective insights that are difficult to capture and share that are extremely valuable [94].

In order to facilitate the transfer of this tacit knowledge to explicit knowledge that is objective, we can employ methods such as creation of metaphors to assist in the shared understanding of concepts between participants from different disciplines and backgrounds, which is particularly difficult in collaborative design activities between actors from disciplines that are far apart [114].

A potential means for collaborative knowledge creation and sharing is the use of boundary objects in context [4]. Boundary objects are objects or concepts which are both plastic enough to adapt to specific needs of the multiple interacting individuals, yet robust enough to preserve a shared identity across boundaries (or disciplines, backgrounds etc) that it can be interpreted and transferred.

Some examples of boundary objects are user interface wireframes and low-fi prototypes used for knowledge sharing between designers, users and programmers; in an agile team, task lists and kanban boards are boundary objects that help programmers, project managers and product owners keep track of the progress of a development project; and in computer science, standardisation documents are boundary objects used to communicate protocols to engineers, software developers and hardware manufacturers.

The idea of the boundary object was conceived by Star and Griesemer from insight on a process used at Berkeley's Museum of Vertebrate Zoology [114], where maps were used to organise, contextualise and locate found objects for mutual sense-making and meaning for both amateurs and professionals in the field. They propose that the creation and maintenance of boundary objects is key to enabling coherence across intersecting disciplines.

The creation of sound as a type of boundary object is under-researched in the field of design and has potential to be a useful tool in promoting understanding between interacting individuals from divergent disciplines.

The concept of a *sonic boundary object* was proposed by Grond and Devos [67] as a specific and shared knowledge transfer process between two actors, in their work investigating the use of binaural sound recordings as a tool to help the sharing of listening experiences between blind and sighted individuals. In their research, binaural recordings made by the blind individual that were only partly meaningful to the sighted listener led to shared conversation that bridged the differences in their individual listening experience and promoted increased mutual understanding between the two parties of their lived realities.

In previous sections I described how Foley artistry is an effective way to sketch sounds that gives access to a wealth of sonic possibilities with a low barrier to entry. I described how Foley sound design is a form of emotion design which relies on the embodied knowledge of the sketcher with respect to how emotions are manifest, to bring about bodily action upon the sounding materials in hand.

I proposed that such a sketching technique can support the sharing of sound-based ideas that remove the need for specific descriptive language about the characteristics of sound. I extend this statement and propose that sound sketches produced through Foley artistry that are emotion driven, are boundary objects that can support the communication and sharing of ideas, not only about sound but of the visceral phenomena and lived experience that a person might like to share with another.

I suggest that this form of sound sketching as expressions of self can support deep discussion and facilitate creative processes in participatory design environments.

2.6 Embodied Cognition, Intersubjectivity and Empathy

Embosonic design combines thinking on emotion and sound design with theories of embodied cognition. Embodied cognition is a theory in cognitive science that rejects the mind-body dualism of Cartesian theories, such as Rene Descartes's Theory of Mind, which describes the mind as a substance that is separate from the body and that all real knowledge is acquired through direct perception of the mind [7].

In contrast, embodied cognition favours the corporeal and the affective in attempting to understand human behaviour and thought. It is the idea that the body and bodily experiences, influence the mind, and that the mind and body are inseparable [84].

Embodied cognition stems from phenomenology, a philosophical approach established by Edmund Husserl in the late nineteenth century. Phenomenology regards the intricacies of everyday human experience as sources of insight into consciousness and behaviour. In Husserl's phenomenology of embodiment, the body is the lived centre of first-person subjective experience, registering movement possibilities and sensations that can only be experienced first-hand. It is concerned with the meaning and significance we apply to the things we experience as they arise, which include the self, others, events, objects and the passing of time.

For Husserl, lived embodiment was an essential part of knowing and his findings were taken up by later figures in the phenomenological tradition, where the study of human experience focuses on our interactions with objects and technologies. Heidegger formulated theories about human experience of tool use and Merleau-Ponty proposed that the *lived body* is influenced by the environment around it and the knowledge and experience it has already accumulated [91]. This idea led to the theory of enactive cognition, which frames human beings as constantly engaged in sensorimotor activity in order to perceive the world around them [121].

In the case of sound sketching through Foley artistry, I have already described that it relies on the embodied knowledge of the sketcher to bring about bodily action upon the sounding objects in hand, coupled with self-reflection on the sounds produced. The phenomenological approach

establishes the body as the centre of first-person lived experience, of movement possibilities and sensations, and that this embodied knowledge is accumulated through bodily action in the world.

As I described previously, based on the ecological approach to listening, human perception of sound is linked to action, the action and motion of sounding objects. Sound and action are inextricably linked. I believe that embodied knowledge can drive and guide bodily action upon sounding materials to sonify first-person lived experience.

There is increasing acceptance of the embodied approach to sound design, as seen in the previous work I described that employ Foley and theatrical techniques in the area of sonic interaction design. I align with McNerney's view on embodied cognition and design, that the actions of the body can play a role in the development of thought and ideas [89].

I propose that the action of the body *in producing sound* can not only play a role in the development of thought and ideas, but can bring what is known, through first-person subjective experience, out in to the physical world.

Through continuous action and listening to self-produced sound, which Chion terms *ergo-audition* [26], the performer creates sound that has meaning. If another is listening to the performance, but the performer is not visible and so the listener does not see the action that is producing the sound, the action still has meaning, based on the listeners capability for everyday listening. In everyday listening, as I described in a previous section, it is not the rhythm or melodic content of sound that we perceive, but rather we perceive the event responsible for producing the soundwave.

The sounds the performer produces are themselves rich sources of information about the sounding object's material and weight as well as the action and force being applied by the performer. The listener perceives all this information, not as a sound but as an event and through ecological listening, we have vast embodied knowledge of event-based sounds, for which we have an innate perceptual ability to ascribe meaning. If an embodied sound sketch carries meaning for the performer and similarly, the listener can ascribe meaning to the sound heard, then there is potential that this exchange might lead to shared empathic understanding.

Empathy plays a fundamental role in how people engage with narrative in media and art, in how we develop an understanding of the emotions of others. The term empathy was originally translated from the German *Einfuhlung* or *'feeling into'* by Edward Titchner in 1909 [112]. It was Theodor Lipps who first related empathy as extending to intersubjectivity between minds from a process of inner imitation as the grounds for understanding another's experience.

Lipps argued that the mind of another cannot be presupposed to be like our own mind and so empathy, in nature, is more than just projection [73]. Lipps described empathy between minds as reliant on the gestures and expressions that indicate our emotional states, the projection between interactors' gestures allows for interpersonal understanding, and thus, he states, explains the instinctual drive toward expression in order to communicate our experiences [130].

In contrast to Lipps, Scheler argues we are empathetically able to experience the mind of another, not just as an encounter with outward bodily gestures and behaviour devoid of psychological properties, but instead as an embodied mind [105]. Relying on expressive unity to form the basis of our experience of another in the realm of expressive phenomena.

Foster adds to this view by pointing out that a reaction to the world is manifest physically and emotionally and that these manifestations are perceived unmediated others [49]. Langer points out that it is in these manifestations, the dynamic forms of our direct, sensuous, mental, and emotional life are congruent with artistic and expressive form [85]. This form is not thought, but felt and experienced.

Shepherd speaks of emotions as if they were performative bodily expressions, arguing that through the bodies' direct experience of both the emotional and unconscious realms of the psyche, movement is endowed with a special charge and emotional states are transmitted through bodily movement [108]. The emotional or mental state of each other comes inherent in interaction, which is composed of gestures, signals and bodily movements.

If understanding the emotion of others entails experiencing the emotion observed [18], sound lends itself as a highly viable experiential medium for a number of reasons. Firstly, sound is intuitive: acoustic ecology renders us experts in listening, we have inherent capabilities to produce sound through voice, body and gesture. Secondly, sound is not bounded by limitations of language. Thirdly, sound is largely universal, although cultural differences do exist.

I propose that when another experiences the embodied sonification of ones lived experience, it can stimulate forms of intersubjectivity. Specifically, I propose that embodied sonification and consumption can facilitate what Vittorio Gallese terms as Embodied Simulation [56], building on Merleau-Ponty's theory of Intercorporeality [90], *i.e., intuitive recognition of another based on embodied interaction, to help one understand and relate to the experience of another.*

3 A New Participatory Design Method: Embosonic Design

Embosonic design is a method that I have developed to help formalise the approach of designing through sound making, which will be helpful for researchers and designers who are looking to employ the thinking and approach in their own research and practice.

As described in the background and related work discussed in Chapter 2, sketching in visual design is an accessible and valuable method of quickly externalising and exchanging ideas but there is no established equivalent in sound design.

Pauletto explored Foley techniques for sketching sounds and found value in its strength for supporting "rich discussions among stakeholders" [97], however no formal methods were developed or transferred to the research community. Rocchesso and Monache explored vocalisation as an embodied form of sound sketching and describe the need for more cooperative ideation and group sketching methods [92]. Hug and Kemper [72] describe the value of Foley for opening up a rich and virtually unlimited range of sonic possibilities.

In the following sections I will describe exactly what Embosonic Design is and the kind of use cases to which it can be applied; discuss its potential benefits and limitations; and specify the methods through which it can be used as a way of approaching a design problem. Before we begin, we must establish, what exactly is Participatory Design?

3.1 PARTICIPATORY DESIGN

Participatory design originated in Scandinavia in the 1970s, where it was developed to empower people at a time where new workplace technologies and computer automation raised concerns in many workers [40]. The fundamental central goal of participatory design was to enable the design of technologies to complement workflow and the tacit knowledge of workers rather than making them obsolete [111].

Participatory design, (also termed cooperative design and shortened to co-design), is a collaborative approach to design that brings a wide range of stakeholders and end users into the design process in order to bring diverse perspectives for a bigger picture view of the challenge space. Engaging diverse stakeholders as designers creates a public space of design, a space that accepts heterogeneous perspectives and encourages blending and modification of ideas towards alignment of "conflicting objects of design" [9].

In participatory design approaches, ideas are envisioned and explored early on in the design process, through the creation of prototypes, representing ideas in forms that can be experienced (e.g., low-fi paper prototypes, sketches, mock-ups and models), which open up new ways of thinking and allow new ideas to emerge. These representations are traditionally regarded as increasingly refined iterations of the designed object-to-be, however in participatory design their focus is more as "material presenters of the evolving object of design supporting communication or participation in the design process". These "presenters" have a performative dimension and carry the potential of binding different stakeholders together and therefore can be viewed as boundary objects [114] (described in section 2.2) in participatory design.

Participation is the fundamental core of participatory design, where participants in the design process are not only informants, describing their point of view or knowledge of a particular area, but instead are asked to actively contribute and participate by "taking the pen in hand and stepping up to the whiteboard to draw and sketch" to share their perceptions, lifeworld experiences and ideas [109].

Participatory design approaches involve people with everyday knowledge of a particular aspect of human experience or human activity in the design process in order to improve the quality of design outcomes.

As Ehn describes, the origin of design is in involved practical use and understanding, not detached reflection, and design is seen as an interaction between understanding and creativity [40]. Where Schon describes the 'reflection-in-action' that experienced design practitioners engage in, there must be space in participatory design processes for collective reflection-in-action between multiple participants.

Participatory design methods offer prescriptions and guidance for how to do participatory design and include tools, techniques, guidelines and principles, which can be combined, adapted, extended and appropriated to the specific project and design situation.

All participatory design methods must have a coherent description and include the following elements: *Application area* (the scope of the method and type of activities the method is intended for); *Perspective* (guiding principles that constitute the backbone of the method and design perspectives that favour user participation); and *Guidelines* (the *techniques*, *tools* and *principles* with which to carry out the design process). Within the Guidelines, *techniques* describe how to carry out specific activities; *tools* are concrete instruments supporting the techniques; *principles* are how to organise and coordinate the planned set of interrelated activities [109].

3.2 THEORETICAL DEFINITION OF EMBOSONIC DESIGN

> "What is real? How do you define real? If you're talking about what you can feel, what you can smell, what you can taste and see, then real is simply electrical signals interpreted by your brain. This is the world that you know."
>
> -Morpheus in The Matrix, 1999

Embosonic design enables the sonification of qualitative data and the sonification of *qualia* (the subjective properties of experience), a concept I have explored in my research that looks at designing audio that faithfully translates lived human experience.

Every person experiences the world in their own way, some have untold stories or are dealing with issues that remain hidden from society but can have significant impact on their lives. I have explored whether sound could have a role to play in helping to communicate highly subjective, visceral phenomena through the medium of sound, primarily in order to design artistic works.

Beginning to sketch meaningful sounds is a challenging task, for example how does one start layering sound objects to express the feeling of something abstract such as *loss* or *joy*? Firstly, we require the ability to describe the visualised sound. All natural (non-digital) sounds that we hear are a direct result of action; some motion of some entity occurs that causes vibrations in the air, which causes changes in the pressure in our inner ear, resulting in us hearing sound.

Sound is a natural carrier of information, information we can understand based on ecological acoustics, everyday sound perception and categorisation. With regard to ecological acoustics and everyday listening, sound plays a significant role in our ability to identify and characterise objects based on experience of use. With lexical descriptions of sound, it is logical to convey information about the perceived sounding object in terms of the familiar physical events that occur in everyday life.

As humans, we base our deductions of perceived sounding objects and compose descriptions of them with simple concepts which are familiar to us. Both the imagined physical properties of the sounding object and the kinaesthetic action system in play that is producing the sound, are useful terms we employ to describe sounds. To provide an example, we may describe a sound we hear as a large, empty, metallic object being dragged along gravel.

Through our experience in everyday listening, it brings us to naturally talk about sound in terms of physics *i.e., the materials, properties, geometry and dimensions of the entity in motion which, in real world terms and reduced to its simplest form, exists as either a solid, a gas or a liquid*. It is then possible to describe the type of action performed upon the entity *e.g., rolling, scraping*, and the dynamics and force with which the action is carried out.

Whether it is a keypress on a laptop, the blowing of a packet in the wind, stream water flowing or a human whisper, some type of action has been applied to an entity to create motion.

A physics-based approach provides representations with which to describe sounds, it also affords methods for the visualisation of sounds, which is a beneficial tool in the sound sketching process. Furthermore, a physics-based approach to the description and visualisation of sounds inherently lends itself to sense-making. If we can visualise a sound in physical terms, we can intuitively visualise how physical manipulations will affect that sound and infer these in the sound design process.

If the goal is to translate lived human experience with sound, we might suggest that a sound designer that is skilled in sculpting worlds with sound, should be called in as the intermediary, to listen to the stories people share and to craft a suitable sonic representation. The reality is that sound design as a process is highly subjective and the sound content produced would vary widely between designers, particularly with regard to embodied, visceral or imagined sounds, as this is where designers' intuition, predilection and design style, feature most prominently.

Sound designers rely mostly on their experiential knowledge of a particular phenomenon, which is intrinsically limited and perceptually unique. In addition, sound is often poorly described in a project's design brief as sounds are difficult to describe without familiarity with the appropriate vocabulary.

As previously stated, sketches and 'quick and dirty' prototyping are useful techniques in visual design, but in sound design there is a lack of comparable tools. When working with people who lack the vocabulary to describe sound attributes *e.g., frequency*, *transients etc*, translating their vision into sound can be a challenging job for the sound designer and consequently a time-consuming process of design and re-design.

Embosonic design instead turns those with direct experience into designers of their own sound worlds. The method uses accessible Foley-based techniques (section 2.3) which exploit our innate capability for perceiving sources, materials and actions from the sounds we hear, as Gaver defines in his ecological approach to sound perception [58, 59].

This perception of sound governs the way we understand our environment and in this same way, we are be able to produce sound through sources, materials and actions to convey information about the non-physical phenomena we experience. As Foley-based techniques are highly accessible, they enable people with no sound production experience to start rapidly experimenting with sound.

Although initially trialling Foley-based techniques for the production of sound art, I found that this type of sound sketching had an unexpectedly profound effect in enabling people to very deeply reflect on their own direct experience.

The immediacy of sound as an expressive medium in this embodied approach can support communication and help people to open up about their experiences. For this reason, the method may be particularly useful in situations where feelings about direct experience are wilfully suppressed or not easily communicated with words, including working with potentially vulnerable groups.

I used Foley-based techniques in the design project Her[sonifications], which I provide a full account of in Chapter 4. A participatory approach emerged as a way towards capturing a fuller spectrum of the phenomena experienced by a particular subset of people, and this took the form of a workshop. The workshop was designed to crowdsource a set of descriptors, powerful words to convey subjective, visceral phenomena associated with the groups own personal experiences, which were used to produce a set of conceivable sound objects through Foley-based sketching.

The workshop element allowed the group to participate in the creative process, following a set of exercises designed as a collaborative sound design process to enable the participatory design and production of sound objects as meaningful representations for each descriptor generated. This process provided valuable opportunities for reflection, enabling the evaluation of the planned design ideas and concepts, and establishing and refining new ideas that emerged.

The primary value in the technique was found to be its ability to facilitate and enhance qualitative data collection processes in addition to the production of a set of rich sound sketches which informed, and were incorporated into, the resulting sound art.

Through this work and the subsequent trialling of a condensed version of embosonic design with a larger group in the BBC R&D Emotional Machines project, described in Chapter 5, I established a set of 'Embosonic Design Principles', which are set out in the following section.

3.3 Embosonic Design Principles

In order to help researchers and designers prepare for employing embosonic design in a workshop environment, I have established the set of principles shown in Figure 3.

These guiding principles were initially derived through my own tacit knowledge and experience of running workshops and were developed further based on the outcomes of iteratively trialling embosonic design sessions with friends and family. This set of principles should be adhered to during all activities in the workshop session.

Figure 3: A set of guiding principles for embosonic design

These guiding principles are essential for the facilitation of a successful embosonic design workshop. Firstly, regardless of the type of design project and intended outcomes, participants must feel fully involved from the beginning and feel empowered that the stories they share will shape the outcome of the work, whether their sound sketches are part of the final artefact produced or are used solely to enhance data collection.

In addition, participants must be fully aware of what the design goal and intended outcomes are, not simply invited to contribute to general research about a specific area, there should be creative output and tangible artefacts that communicate the data they have shared, whether for public consumption or to inform further research.

On the subject of taboos, participants should be able to talk freely and share their experiences without worry of judgement or saying the wrong thing, however if a participant is observed to be deliberately attempting to offend others or is critical towards others in any way, the workshop facilitator should take action to resolve the issue.

On the flow of discussion, the facilitator should let conversation flow naturally and not nominate participants to speak, the workshop should be an open forum for sharing experiences and ideas.

When planning a workshop, consideration must be given to the space and environment where it will take place, the space must be defined as safe, supportive and private (see the rules set out in Figure 4) so that participants can feel free to share stories and also take part in the sound making activities without fear of being heard by people outside the workshop space.

Figure 4: A set of ground rules for establishing a 'safe space'

When sound making activities are underway, participants have ownership over the stories they share and must only sketch their own experiences, there may be similarities in the phenomena being sketched, however people experience things in their own way, there should be no attempts to correct or improve a participants sound sketch.

Similarly, the validity of sketches and descriptions of phenomena should not be questioned by other participants, the qualia of experience are subjective, individual and perceptually unique, and the facilitator should take action to resolve this type of behaviour if observed. In order to help participants start thinking deeply about sound, an ear-cleaning/deep listening activity should be carried out prior to the sound making activities. This focuses attention on the materials and motion of sounds in the environment, which can help participants immerse themselves and tune into the sound making activities.

In addition, the facilitator should choose an environment for the workshop where extraneous sounds and distractions are minimal, this will improve immersion in the workshop activities as well as providing a clean recording environment for capturing the sound sketches, which is crucial if the sound sketches are to be directly incorporated as design artefacts.

Finally, as workshop facilitator, it is acceptable to be curious and to gently probe participants in order to help them form deeper descriptions of qualia, both during ideation activities and translation (sound-making) activities. Forming a good relationship, showing interest and connecting with participants early on in the workshop will result in improved data collection and more successful design outcomes.

With respect to workshop size, aim to work with smaller groups. The suggested optimum number of participants for an embosonic design workshop is around three to five which allows plenty of scope for participants to interact and learn from each other, larger numbers can produce a greater number of potential ideas but will limit the depth of self-reflection and impact the quality of the sound sketches produced.

In order to carry out the sound making activities, organisers will need to provide access to a set of *Foley Tools,* this is a broad-spectrum palette of sounding objects with which participants will sketch sounds. In preparation for a workshop, organisers should begin gathering a range of materials to be used as sounding objects, taking the guidelines specified in Figure 5 into account.

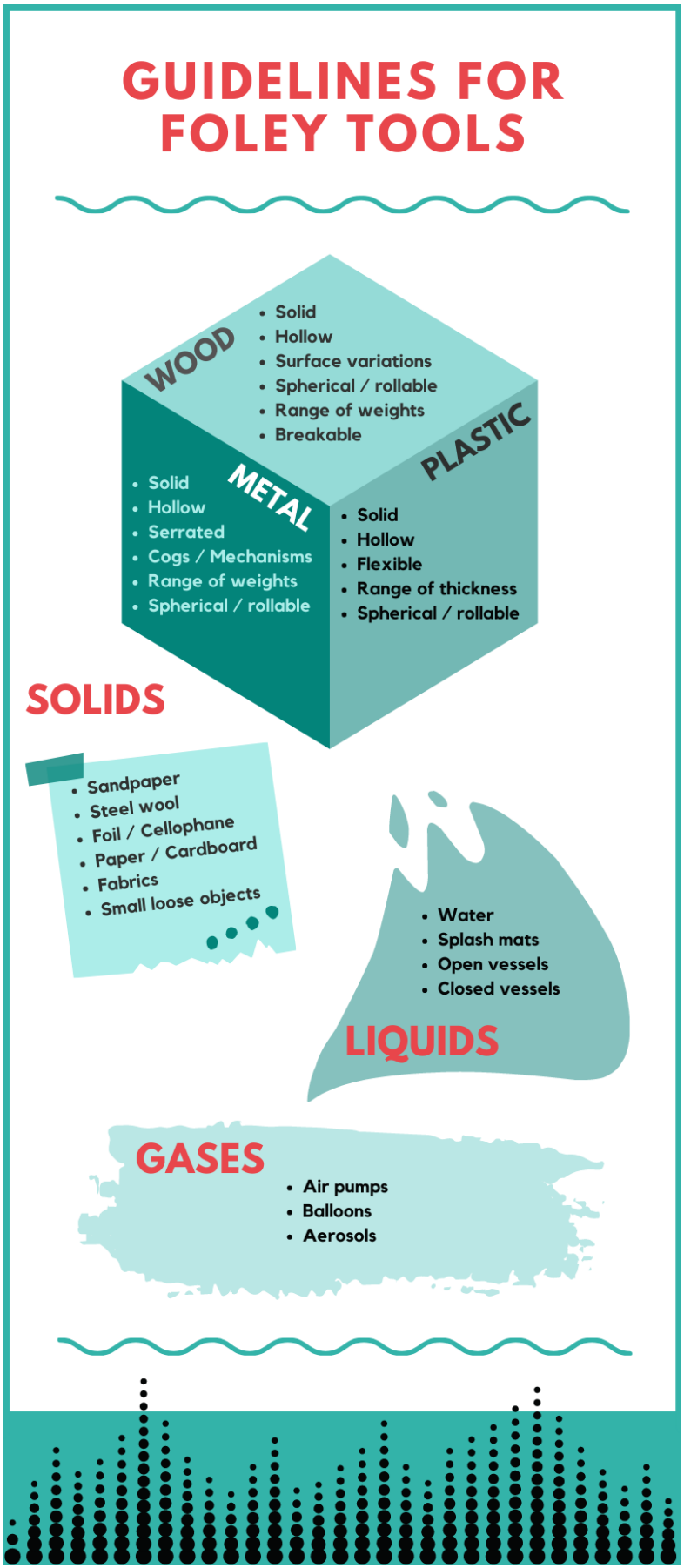

Figure 5: Guidelines for the types of objects to include as Foley tools

3.4 EMBOSONIC DESIGN: METHOD SPECIFICATION

The embosonic design method is composed of three distinct, sequential stages: an *Ideation* stage; a *Meditation* stage and a *Translation* stage. These stages were derived and informed by my own practice however on reflection there are similarities to the *Look; Think; Act* stages associated with Action Research.

Carr and Kemmis describe action research as *"collective self-reflective enquiry undertaken by participants in collaborative situations in order to improve the effectiveness of their own practices, their understanding of these practices, and the situations in which the practices are carried out"* [24]. Its fundamental stages of *Look* (gather information); *Think* (interpret and explain); and *Act* (formulate solutions), as defined by Stringer [116], align quite closely with the *Ideation*; *Meditation* and *Translation* stages of the embosonic design approach.

In the Ideation stage we aim to *gather information*; and in the Translation stage we aim to *formulate solutions* however embosonic design diverges from action research in that intermediate stage: *Think*. In this transitional stage of embosonic design, *Meditation*, we do not look to *interpret and explain*, but instead focus on immersing ourselves in the medium (sound) and although there is a degree of interpretation involved, it is only to heighten our perceptive capabilities before we move into the Translation stage and make use of the medium to formulate solutions.

The three stages of embosonic design are described in detail in the sections that follow, but firstly, there are preliminary activities to carry out and concepts to establish at the start of an embosonic design session, which are described below.

At the beginning of the session, the facilitator must ensure participants understand that the workshop environment is a *'safe space'* and may find it helpful to explicitly set ground rules at the outset. See Figure 4 in the previous section (section 3.3) for a suggested set of ground rules.

An ice-breaker activity should be carried out before entering the ideation stage (section 3.4.1) in order to relax participants into the session and build confidence and trust between group

members. A suitable ice breaker would encourage participants to think quickly and imaginatively whilst working together, and ensure that everyone gets many opportunities to speak. See section 4.2.3 for a description of two ice breaker activities I employed in the workshop for the Her[sonifications] design project, which were a quick-fire *word association game* and a *round table story* game.

3.4.1 Ideation

The aim of the ideation stage is to create a *collection of feels*. This is a repository of data containing sensations, feelings, concepts and analogies that represent participants subjective impression of the characteristics of qualia associated with the theme of the workshop. Ideation must permit a fluidity of exchange between participants similar to that exhibited in normal conversation, allowing topics and descriptions to emerge naturally.

Data collection takes the form of written text (the words/phrases); and if applicable, diagrams and illustrations, where participants are invited to write each concept on a post-it note and place it on a whiteboard/flipchart. Concepts can be grouped appropriately, whether categories emerge during the activity or are determined beforehand *e.g., if we consider the theme of 'addiction', categories might form around feelings towards 'self', 'loved ones', 'dealers' or perhaps around the cycle of drug-taking itself, such as 'before', 'during' and 'after'*.

If categories are determined prior to the session and are deemed as beneficial to guiding conversation, they can be written on the whiteboard/flipchart and participants asked to place the concept or *feel* according to the category to which it associates, ensuring space is reserved for adding any further categories as they emerge.

When asking participants to share these words or analogies that encapsulate a particular effect or consequence of the theme being explored, it is important not to spend lots of time expanding on each one, but rather the idea is to generate and gather many concepts which will then be discussed in detail at a later stage. The collection of feels is subsequently used to inform the sound making activities in stage three, where each concept raised will be explored in detail. I

recommend that the facilitator photographs the collection of feels for potential use in further design activities that emerge as part of this process as it can generate a really rich set of data.

Figure 6 provides an overview of the method for the ideation stage and sections 4.2.4 and 5.3.2 gives detailed descriptions of how it was carried out in the Her[sonfications] project and the Emotional Machines project, respectively.

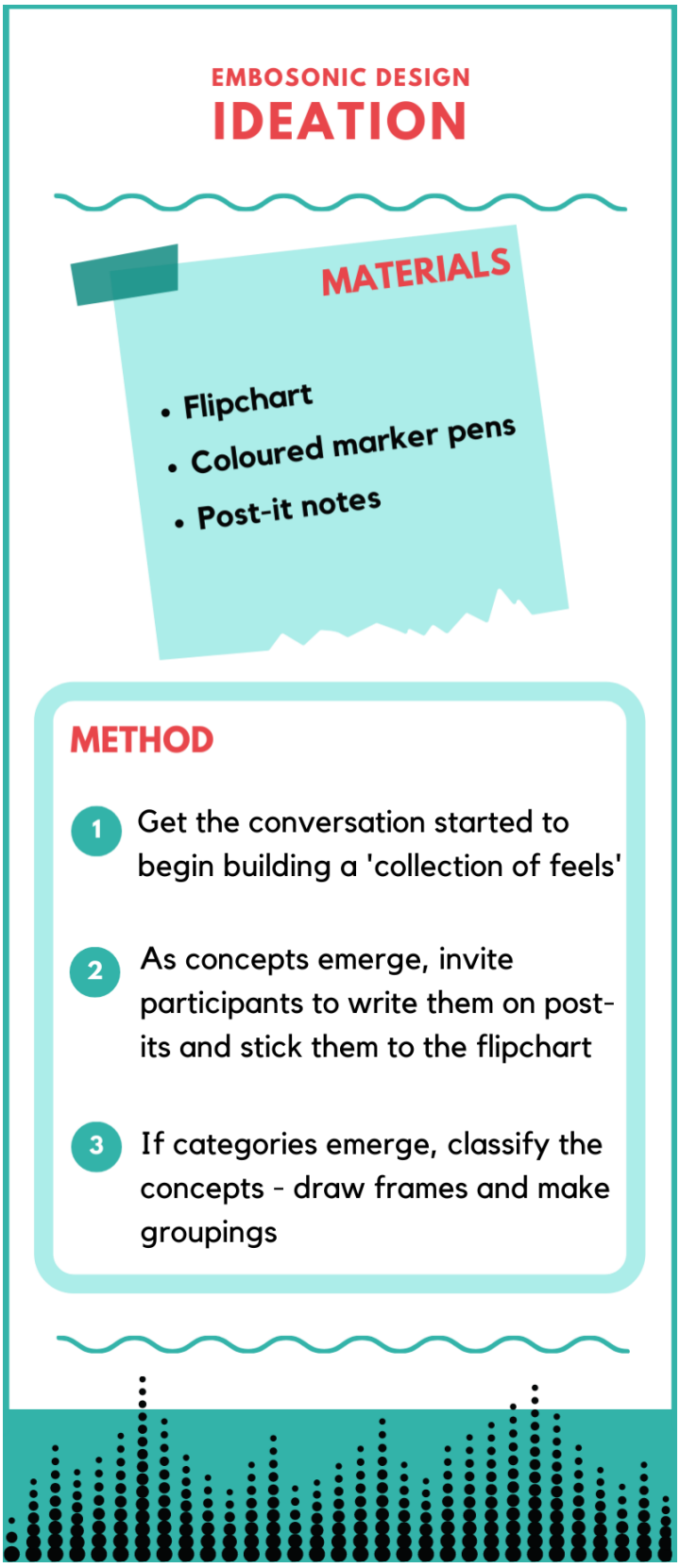

Figure 6: Overview of the Ideation method

3.4.2 Meditation

The meditation stage has been designed to prime participants for the sound making activities they will undertake in the final stage of the embosonic design process. The aim is to help participants start to focus on the intricacies of the sounds they hear, the materials and motion of sound sources and their spatial positioning. Spending at least fifteen minutes in this active listening mode, can result in people maintaining a heightened awareness and appreciation of sound for several hours, which is beneficial for participant immersion in the sound-making activities in stage three.

To carry out a simple deep listening exercise, participants are given a pen and paper and are asked to stay silent for a short period and listen to the ambient sounds in the environment. Ideally, this meditative practice will take place in a calm, sheltered area outdoors, providing a rich soundscape for participants to focus on.

If an outdoor setting with seating isn't practical, hosting this part of the workshop in a slightly busier and noisier space *e.g., near a thoroughfare in the building; close to a cafeteria or simply near an open window,* will suffice. If, for any reason, it is not practical to relocate participants for the middle stage of the workshop, a recording of an urban or similar environmental soundscape can be used, preferably containing only mundane, familiar sounds.

Before beginning the deep listening exercise, participants should be instructed to use their pen and paper to note down the sounds they hear and their perceptions of the different sound sources with respect to spatial positioning and motion. The facilitator should then bring participants together again to spend time reflecting on the sounds that were heard, with each participant sharing their impressions of the sounds they perceived.

See Figure 7 for an overview of the meditation activity and see section 5.3.3 for an account of how the meditation stage was implemented in the Emotional Machines design project.

Figure 7: Overview of the Meditation method

3.4.3 Translation

In the translation stage, participants are introduced to Foley-based sound sketching and are given access to the set of Foley tools that have been prepared for the session. This is the broad-spectrum palette of sounding objects described in section 3.3, which will allow participants to begin rapidly experimenting with sound. Refer back to Figure 5 for guidelines to help with the provision of suitable materials.

The facilitator should encourage participants to have fun and make lots of noise through manipulating the tools and exploring their sound-generating capabilities. Once the group has settled into making noise, the facilitator should start audio recording the session and informing participants of this (consent for audio recording should be elicited prior to the workshop taking place – see the Participant Information sheet and Participant Consent form for the Her[sonifications] project in appendices B1 and B2 for guidance).

The aim of the recording might be to specifically capture and preserve the resulting sound sketches or to capture qualitative data from the participants at work for subsequent analysis, in either case, a failure to record the session will result in valuable insights being missed.

Once recording is underway, the facilitator should ask a volunteer to refer to the collection of feels (which should still be displayed on the whiteboard/flipchart) and to choose one of the concepts they contributed during the ideation stage. The participant should then start experimenting with the Foley Tools in order to choose materials that might be helpful in starting to translate the concept to sound.

Translating these concepts into sound will not come naturally at first and much experimentation will be needed by the participants with encouragement from the facilitator to think about the processes that are going on – if it is a visceral concept, what does the sensation feel like? Is it heavy or light? Is the sensation of any motion, whether physical or mood-related, smooth or restricted? Is there tension or friction? If it was a physical entity that existed in space and time, what materials would be involved, how might it move and how might it sound?

I have found in my experimentations with translation, that it is often through hearing multiple *wrong* sounds that the closer participants get to sketching the *right* sound.

When participants have settled into the translation process and are sketching what they consider to be meaningful sonic representations, the aim is to work through the full collection of feels, if time permits.

An overview of the translation method is provided in Figure 8 and a full description of its use in the Her[sonifications] design project is provided in section 4.2.6.

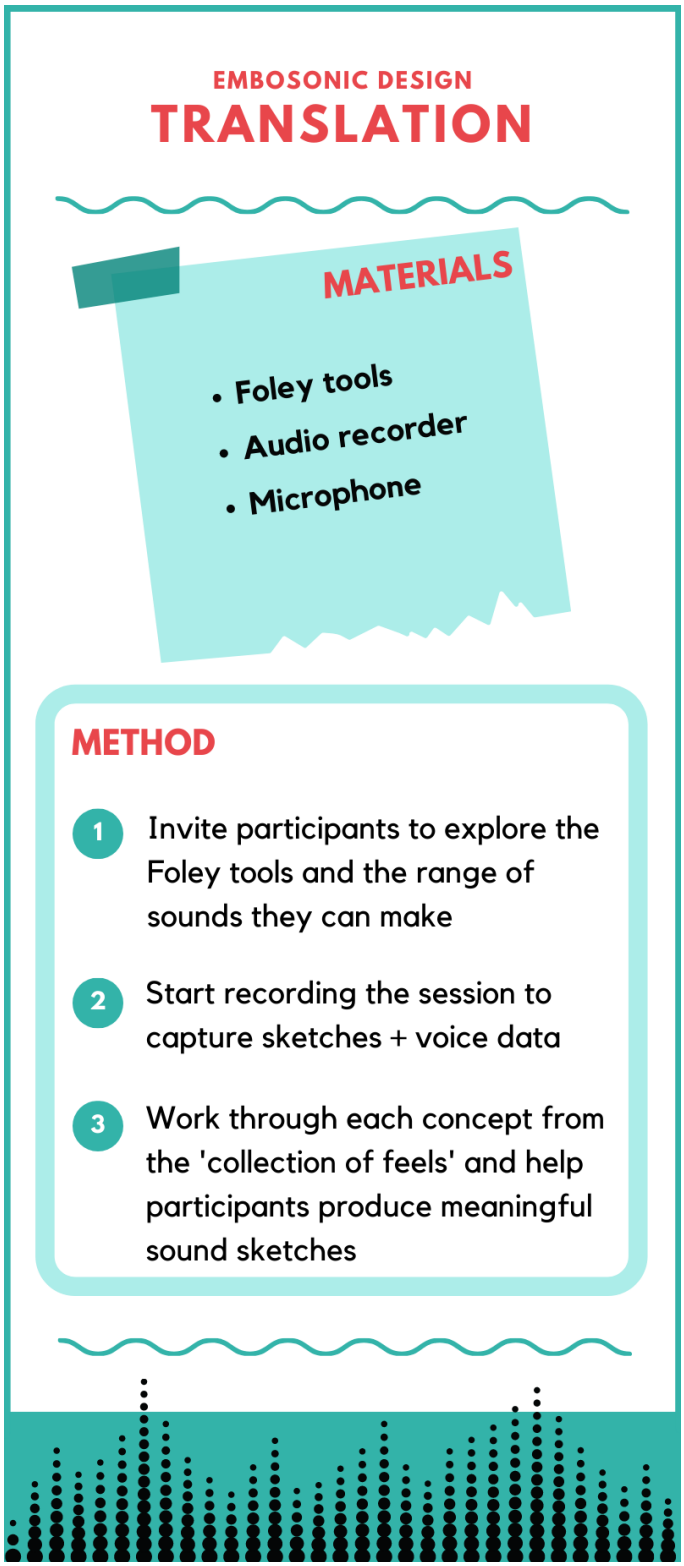

Figure 8: Overview of the Translation method

3.5 What to expect from Embosonic Design

The ideation, meditation and translation stages of the embosonic design method should be carried out sequentially during one single workshop session, as described in the previous sections and as shown in Figure 9.

Figure 9: The three stages of Embosonic Design

The film sound technique of Foley artistry as the primary sound design tool is playful and gives participants a feeling of presence through sound and physicality, which results in them having a sense of ownership over the sounds produced.

It also has a low barrier to entry, with no physical or digital interfaces to navigate and as all people (without hearing impairments) have ecological knowledge of how the world sounds, we can use that knowledge as representation for imagined or embodied sound.

Sharing deep stories through sound making, opens up narratives that go beyond the limits of description that language affords.

In this respect, the method generates *Tools for Reflection* which are useful for the communication and exchanging of ideas:

1 *Like this but more…* – where sound is the starting point and language is used to extend and refine ideas.

2 *Exactly like this* – where words fail and embodied phenomena and/or the sound to represent it cannot be articulated by language alone.

3 *Like this, then…* – where performativity through sound making brings focus to the form and structure of the experienced phenomena in pursuit of describing its temporal form in terms of beginning, middle and end.

The outcomes of the workshop will include:

- A set of textual data (collection of feels) generated in the ideation stage, which can feed into and inform further design activities
- A rich set of voice data captured during the translation stage, through which further insights can be gained about the phenomena discussed
- Audio recordings of the raw sound sketches produced by each participant

Materials may be suggested that are not present in the Foley Tools or directly accessible, for example, in the Her[sonifications] project a participant felt that the sound of glacial ice cracking would be the ideal sound to represent a particular aspect of their lived experience.

For this reason, it is beneficial to record the session even if you do not anticipate that the sound sketches produced in the workshop will be used directly in the design outcomes.

As facilitator, it is beneficial and highly recommended to document your immediate subjectivities and observations as soon as possible following the workshop. Immediately documenting your thoughts/feelings about the workshop process will be valuable for later reflection and as an exercise, will allow you to let go of any upsetting feelings you have after hearing stories from potentially vulnerable groups. It is advisable to write these thoughts down before leaving the venue and beginning your onward journey as a form of coping mechanism, even if you do not feel this is necessary, you should do it regardless.

In summary, embosonic design is proposed as a new method for participatory design that enables the sonification of qualitative data through the practice of Foley-based sound sketching. In this chapter I have introduced the method; described the inspiration behind it and its theoretical foundations; and have set out specifications for researchers and designers so that they can employ the method and approach in their own research and design practice.

In Chapters 4 and 5 I will describe how it was successfully employed in practice, in the Her[sonifications] project, for the participatory design of an interactive sound installation; and in the BBC R&D Emotional Machines project, for ideation support in design-led innovation work, respectively.

4 EMBOSONIC DESIGN IN PRACTICE 1: HER[SONIFICATIONS]

This chapter provides a demonstration of how embosonic design can be applied in practice, informed by the design guidelines and recommendations detailed in the Embosonic Design Method Specification in the previous chapter.

The following sections provide a comprehensive account of how the embosonic design method was employed in the design of the sound art installation 'Her[sonifications]'. Her[sonifications] is an interactive sound installation that allows the user to explore the embodied, visceral experience of womanhood through the reflexive act of guided walking. In this room-scale installation, while the user traverses a labyrinth of undulating crests and troughs their movement generates a sonic atmosphere that enables them to experience the different stages of the female menstrual cycle. The soundscape reveals a group of women's lived experiences of their menstrual cycles, where the soundscape elements are self-actualised sonifications of embodied experience, created by the women through the performative act of making sound as expressions of the embodied self.

Within this chapter, following a brief introduction to the background of the [Her]sonifications project, I provide a full account of the design process with specific detail of each stage organised into distinct sections.

Specifically, section 4.2.1 describes the workshop planning and participant recruitment process. Sections 4.2.4 and 4.2.6 provide an account of participant involvement with the 'Ideation' and 'Translation' workshop activities, respectively and section 4.10 is an evaluation of the workshop process with personal reflections. The chapter concludes with an analysis section and details of refinements to the embosonic design method that were made as a result of this work.

4.1 INTRODUCTION

The Her[sonifications] project formed when my HighWire colleague, Manu Brüggemann, wanted to submit a dual paper and installation proposal [21] for the 2017 Data Publics conference. I had recently shared with Manu the progress I was making in my experimentations with proximity-based audio triggering which made use of Bluetooth beacon technology. He was interested in the potential of the technology and asked if I would like to build a sound installation as a provocation for one of the topics of his paper: the female menstrual cycle.

Manu and I discussed possible forms the sound installation could take and these dialogues informed some aspects of the physical format of the installation, specifically that it would incorporate a walkable labyrinth of some sort, in order to encourage people to move around with the purpose of triggering audio for soundscape co-creation.

While Manu concentrated on writing the paper, I worked on the design, development, build and evaluation of the installation, working individually through the many stages involved in its evolution from the initial early concept we had discussed, to a fully functioning and aesthetically pleasing interactive sound installation, which was exhibited on two of the conference days[7].

With subject matter of an inherently embodied and subjective nature, along with the requirement of the work being of an appropriate standard for exhibition within an academic conference setting, I considered the project a valuable opportunity to employ the embosonic design method to explore its viability and assess its limitations in the design of an audience-ready installation. Furthermore, the context for the design project required delivering an effective product within an explicit timeframe, presenting an opportunity to test embosonic design as an in-the-wild approach as opposed to a lab-based experiment, in a similar manner to how creative practitioners operate within industry.

[7] 'Her[sonifications]' installation exhibited at Data Publics, Lancaster, United Kingdom, 1/04/17 - 2/04/17

The term ‘in the wild’ describes a range of approaches for carrying out research studies that examine user behaviour in natural, real-world contexts as opposed to lab-based studies.

Carrying out studies in-the-wild can help researchers understand how participants interact and engage with the technology, system, process or object of focus; and the insights that emerge are used to shape and optimise it to better fit the situations in which it will be used [25]. Beyond understanding how people react to novel design interventions and how these might integrate into everyday life, Crabtree, Chamberlain et al suggest that in-the-wild research can reshape design practice. They describe “a new way of doing innovation” with “an emphasis on a continuous community-oriented process of reflection, elaboration and modification, shaping the co-realisation of innovative systems” [30].

Having a similar perspective on the value of participatory design for innovation (section 3.1), I regarded the trialling of the embosonic design method in the wild as an important milestone and beneficial next step for the research.

4.2 Making Her[sonifications]: The Design Process

The prospect of building an interactive sound installation to convey notions of the embodied experience of womanhood is an interesting brief for any sound designer. It is also challenging, for example, how does one start to design sound to convey the turbulent effects of the female menstrual cycle as an individual who may have no direct experience of this bodily process?

And further, how does one decide which effects to incorporate into the design, if they have not themselves experienced the full range of effects commonly associated with the female menstrual cycle?

In order to minimise designer bias, one could potentially begin by exploring relevant information that is easily accessible, for example the information that is available online, including the myriad personal blogs devoted to female experience[8]; the informative guides compiled by health organisations such as the NHS[9]; and the relevant academic literature [123, 79]. A search such as this would serve to highlight the common effects experienced by woman during their menstrual cycle, including, for example, headaches; cramping; and changes in mood[10].

It is a great leap however, to start to translate these effects into a soundscape that could meaningfully reflect the related embodied phenomena that is by definition, tacit knowledge acquired through direct bodily experience, being that it is internal to the particular body experiencing the phenomena. Furthermore, where a particular effect may be cited as *common*, it is experienced subjectively by the individual and one woman's experience of said *common* effect could diverge wildly from another woman's subjective experience of it.

With the divergent nature of subjective experience in mind, it was deemed appropriate to design the installation to focus on the experiences of a sample group of women as opposed to creating a design that could be considered a false generalisation of female experience. It was envisaged that working with a sample group to explore subjective experience through sharing stories, might enable a design more meaningful and profound.

To this end, a participatory design workshop was conducted in order to work directly with a group of female participants, where the qualitative data generated by the women about their embodied experiences was sonified using the embosonic design method. The following sections provide a detailed account of the complete lifecycle of this design process.

[8] A personal blog example: https://www.bloodygoodperiod.com/blog
List of fifty popular blogs about menstruation in 2020: https://blog.feedspot.com/menstruation_blogs/

[9] NHS web article: https://www.nhs.uk/conditions/periods/

[10] Healthline web article: https://www.healthline.com/health/premenstrual-syndrome

4.2.1 Participant Recruitment

A poster campaign was launched at Lancaster University. The poster and accompanying Eventbrite page was aimed at all women, with no prerequisites stipulated with regard to having specialist experience in creative practice.

It was particularly important to convey to potential respondents that they would be able to fully engage with the process regardless of their backgrounds and skillsets. Sound design and audio engineering, like many STEM-oriented fields, is still male-dominated and this can have a negative impact on female take-up of associated practices, the reasons for this are not explored in this thesis, however to give a general indication of the problem space, reasons may include social conditioning during early childhood along with a perceived high barrier to entry, entailing steep learning curves and technological proficiency.

With this in mind, it was essential to make it clear that this type of workshop affords ease of participation and is accessible to all.

The campaign invited women to participate in a workshop titled *'Let's Talk about Periods… and Co-design a Soundscape'* and stated the purpose of the workshop as follows:

> "We are building an interactive sound installation that will allow people to experience the different stages of the female menstrual cycle. We invite women to share their experiences in a safe and open environment and have some fun participating in the sound design process. No sound design or creative experience necessary, just an open mind and a willingness to talk freely about 'girl stuff'."

As can be seen from the wording employed in the poster text, the purpose of the workshop as *creating a tangible artefact* was clearly communicated, as outlined in the Embosonic Design Principles in section 3.3.

In line with the method specification, the suggested number of participants for the workshop is between three and five participants. This guideline is informed by the approach undertaken in the Ideation activity in that there exists a requirement that conversation should flow easily whilst also reaching a depth that may generate a rich data set.

Based on the researcher's personal experience of running workshops in tandem with advice received from colleagues with workshop facilitation experience, these conditions can be naturally regulated when there are more than two but less than six people engaged in conversation, which is reflected in the suggested workshop size.

As a result of the poster campaign and in line with the specification outlined above, four female participants were recruited to take part in the workshop. All of the women were postgraduate students at Lancaster University and came from a range of backgrounds including Fine Art; Education; Computing; and Creative Writing. The four women were aged between 28 and 40 years old; two were UK nationals; one was from elsewhere in Europe and one was from North America. Three of the women spoke English as a first language and the forth woman was fluent in English as a second language and no issues relating to language barriers or cultural differences were anticipated.

All of the women who responded to the campaign were of 'mature student' status. This might suggest that older women are perhaps more open to discussing bodily experiences; or more willing to engage with new creative practices; or that a combination of both of these factors were at play.

4.2.2 Workshop Environment

The workshop took place in an Acoustic Room at Lancaster University. The Acoustic Room was selected as the venue for the workshop due to it being a completely private space with no view into the room from outside, with the aim of creating a safe space from the outset where participants could feel like no one was watching, listening or judging their participation in the workshop. The Acoustic Room is also a quiet and calm space with the additional benefit of

featuring a basic level of soundproofing (see Figure 10) which, in a building that can be a relatively noisy hive of activity at times, would help to minimise disruption to the workshop activities and provide a clean recording environment.

Similarly, the sound-proofing features in the room could help promote a sense that participants would be able to express themselves both vocally and sonically, through the sound making activities, without fear of creating a noisy environment for others working in the building.

Figure 10: The Her[sonifications] workshop environment

4.2.3 Eliciting Consent, Rule Setting and Breaking the Ice

On arrival, the prospective participants were given a Participant Information Sheet (see Appendix B.1) and were asked to take time to read it carefully. They were invited to express either privately or openly, any concerns or queries they had relating either to the workshop session they were about to take part in or to the research in general. They were then asked to sign a Consent Form (see Appendix B.2) to confirm their agreement to take part in the workshop, both of these documents had been reviewed as part of the Faculty of Science and Technology Ethical Approval process at Lancaster University and approval for the project was subsequently granted.

No concerns were raised and all four women gave their consent to participate in the research. The sole question put forward by one of the women related to a genuine interest in the research and in the authors background as a practicing sound designer. The women each disclosed that they had no previous experience of working with sound and all commented on being eager to immerse themselves in a process that was new to them.

The workshop began with welcoming the participants and thanking them for agreeing to take part. The venue was then designated as a *'safe space'* and this definition was reinforced through the setting of explicit ground rules.

Four ground rules were stipulated as follows:

A. **Be present in the room:**
   Leave outside stresses at the door as much as possible, clear your mind and as far as possible try to submit yourselves fully to the workshop processes.

B. **Care for each other:**
   Respect each other's contributions and insights. Immature ideas, gut feelings and raw impressions are valued here and will be constructively fostered.

C. **What is said in the room, stays in the room:**
   Everything shared here is strictly confidential. Please respect this.

D. **Be comfortable:**
   Try to relax and enjoy the experience of taking part. Don't feel pressured to contribute to the discussions and feel free to speak at will.

The participants indicated that they understood the ground rules and agreed to remain mindful of them throughout.

They were then guided through two short ice-breaker activities, with the aim of building confidence and trust between group members; strengthening communication; and fostering collaboration within the group. The first ice-breaker was delivered as a quick-fire word association game, of which a few rounds were played, then, using the first word and last word generated during the game, an introductory sentence for a round table story game was constructed by the facilitator (me). Two cycles of the round table story game were played as the second ice-breaker activity, where each participant took their turn to develop an unfolding story by appending a sentence to the previous sentence generated.

The second activity in particular created a light-hearted atmosphere in the room and participants were observed as becoming more relaxed and confident as the activity progressed, indicated both by a change on how they were sitting, adopting a more reclined position in their chairs; and also, through a marked change in the volume and the velocity of their speech. The activity was also punctuated with laughter, a further sign that the group had relaxed into their environment and were comfortable engaging with the process thus far.

The dynamic that had been created within the group during these ice-breaker activities shaped the environment as a forum for open communication. This was evident through some of the language and idioms that were being used to construct the developing story. There became a real sense that it was perfectly acceptable to say whatever came to mind, enabling the participants to introduce topics and use language that may be considered somewhat inappropriate in normal group exchanges *i.e., those exchanges that occur between people who*

do not know each other well enough to have established a customary linguistic style or vernacular. Words such as *sex* and various swear words were used a number of times by all of the women present (note: the facilitator refrained from mirroring the type of language used).

4.2.4 Ideation Activity

This activity was designed as a means of generating the concepts and themes upon which the sound making activities would be based. The qualitative data collected would inform the design of the installation, which had been stated as the purpose for and intended output from the workshop process, as previously described. The aim of the activity was to produce a *collection of feels*, the repository to which we would draw upon in later activities, as outlined in the embosonic design method specification (section 3.3).

The collection of feels for this particular workshop was the adjectives, verbs and analogies that participants would use to effectively convey the physical, emotional and visceral effects of menstruation. The Ideation activity is designed to be free-flowing and organic and as such there was no prescribed sequence employed during the process to control the flow of ideas. The women were invited to speak at will and no guidance was given with regards to a specific frequency or method of making contributions *i.e., at no point were specific requests made to the women to offer their thoughts or opinions*. As previously outlined in the embosonic design method specification, ideation must permit a fluidity of exchange between participants similar to that exhibited in normal conversation, in order to allow themes to emerge naturally.

As the first step in the ideation process, the participants were invited to start the conversation by describing an emotional, physical or other type of effect that they had previously experienced or that they regularly experience as either a direct or indirect result of their menstrual cycles. It was explained that throughout the process each effect would be discussed as a group in order to agree on meaningful words or phrases to encapsulate each effect and that these would be written on post-it notes and displayed on a *feels board*, where each effect would be grouped by type. Initial effect types of ‘Physical’ and ‘Emotional’ had been anticipated and were included on a tabular structure as column titles, however it was explained that other types

of effect may emerge during the discussion and that other columns could be added to the feels board to reflect this.

The conversation began with one of the woman describing the severe abdominal pain that she regularly experiences during her period, known as menstrual cramps. Menstrual cramping is one of the most common effects experienced by women during a period, it was therefore expected to emerge early on in the Ideation process. The other women appeared wholly comfortable with sharing their individual experiences of menstrual cramps, commenting on the type of pain they suffer, which in turn sparked the sharing of other types of physical symptoms experienced by the women.

The women seemed comfortable exploring the themes raised and changing the direction of the discussion when new or complementary themes were introduced. Throughout this process each effect was considered as a group and the women were encouraged to devise meaningful short phrases to effectively communicate the nature of the effect, based on the descriptions offered by the woman/women who had profound bodily experience of it.

4.2.4.1 Observations

A number of observations were made during the Ideation activity, some of which were evident during the course of the workshop and others which emerged following transcription and analysis of the audio data, specifically the dialogue that was recorded during the Ideation activity. These observations are described in the following sections.

4.2.4.2 Enhanced Participation: Similarity of Experience

A trend emerged where the women would take cues from each other in developing the themes that were raised, creating instances of *enhanced participation* of two distinct types. The first type of enhanced participation was driven by *similarity of experience* and was observed when two or more of the women found that they experience similar effects, which motivated the

women involved in the exchange to describe in greater detail their visceral perception of the effect and the sensations felt.

Participation was enhanced because the women were effectively inspiring each other to explore how deeply connected they were in terms of the exact nature of how they experience a particular effect *i.e., their experience may be similar, but to what extent is it similar and at which point do their visceral perceptions diverge?*

Instances of enhanced participation driven by similarity of experience occurred repeatedly during the ideation session. One example of this is when Participant 1 described the pain she experiences at the time of Ovulation, which inspired two of the other women to each describe their visceral perception of Ovulation and the nature of the sensations they feel, as can be seen in the following excerpt of dialogue (transcribed from the audio recorded during the Ideation activity and anonymised, as previously described):

> **Participant 2:** *"I have pain when I ovulate, every time and it's exactly on the side and I know when I ovulate! It's so funny and yeah, a lot of pain. It's not a horrible pain like a period pain but it's pain."*
>
> **Participant 3:** *"Ah yes - I used to get it and it felt like a pulling sensation."*
>
> **Participant 1:** *"Almost like a stabbing, I used to get it more before I had the coil."*

As can be seen in the exchange, participant 2 shares with the group that she has pain but does not clearly define the type of pain, only that it is not a horrible pain and that it is different to a period pain.

For clarity, the term 'period pain' or to use the medical term, Primary Dysmenorrhoea, generally presents as painful muscle cramps in the abdominal area, which may spread to the lower back and upper thighs and is caused by the muscular wall of the womb contracting to aid shedding of the womb lining[11].

For Participant 3, the suggestion of Ovulation pain triggered a memory that at some point in her life she too experienced pain and described it as a pulling sensation. Participant 1 then chose to contribute by reflecting on the sensation that she, at one time, regularly experienced during Ovulation and defined it more as a stabbing sensation.

The fact that Ovulation pain had been brought up inspired the other participants to reflect on their own experiences, to consider if they too had any prior conscious awareness of it and if so, they were able make contributions to the discussion.

Based on the observations made during the Ideation activity, it is proposed that such instances of enhanced participation driven by similarity of experience, promote *Recognition*, *Empathy* and *Insightfulness* amongst workshop participants.

4.2.4.3 Enhanced Participation: Uniqueness of Experience

The second type of enhanced participation was observed in instances where following a description of a particular effect, it was established to affect only one of the participants *i.e., three of the women had never experienced a similar effect.* Once determined, this *uniqueness of experience* fuelled curiosity and wonder amongst the women in that a desire for specificity was observed, where the women would probe the contributor by asking questions in order to gain a fuller understanding of an effect that was unfamiliar to them. One example of this is when Participant 1 disclosed that she experiences visual hallucinations along with migraines as a normal part of her menstrual cycle. As can be seen from the conversational exchange, as

[11] NHS web article: https://www.nhs.uk/conditions/period-pain/

quoted below, the other women became intrigued and were keen to gain a deeper understanding about the nature of the visual hallucinations.

> **Participant 1:** *"I get migraines as well and they're definitely linked to it always and like visual hallucinations, like aura."*
>
> **Participant 3:** *"Oh really?"*
>
> **Participant 2:** *"Oh wow! I mean, what kind of hallucinations?"*
>
> **Participant 4:** *"Yeah, what do you see?"*
>
> **Participant 1:** *"It's part of the migraine, it's kind of a visual hallucination thing so I see a hole in the world and I'll see a hole wherever I look and I see rainbows - it sounds more fun than it is."*

Through analysis of the data with respect to the quantity of instances where enhanced participation was observed, instances that were based on *similarity of experience,* were found to occur frequently throughout the Ideation session, whereas instances triggered by *uniqueness of experience* occurred considerably less often, specifically 14 times and 3 times respectively.

These observations might suggest that the women were more comfortable collaborating to determine specifics where an effect was found to be shared by others and less so, when the effect was limited to one individual.

4.2.5 Data Collection

Throughout the Ideation activity, the resulting words and phrases were written on post-it notes as they emerged and were classified through group discussion as being a 'physical', 'emotional' or 'behavioural' type of effect and were placed on a tabular structure which had been sketched on a whiteboard (see Figure 11).

These classifications emerged naturally and while it was anticipated that effects of a 'physical' and of an 'emotional' nature would arise; a third type of effect became prominent during the discussion, giving rise to the class 'behavioural'.

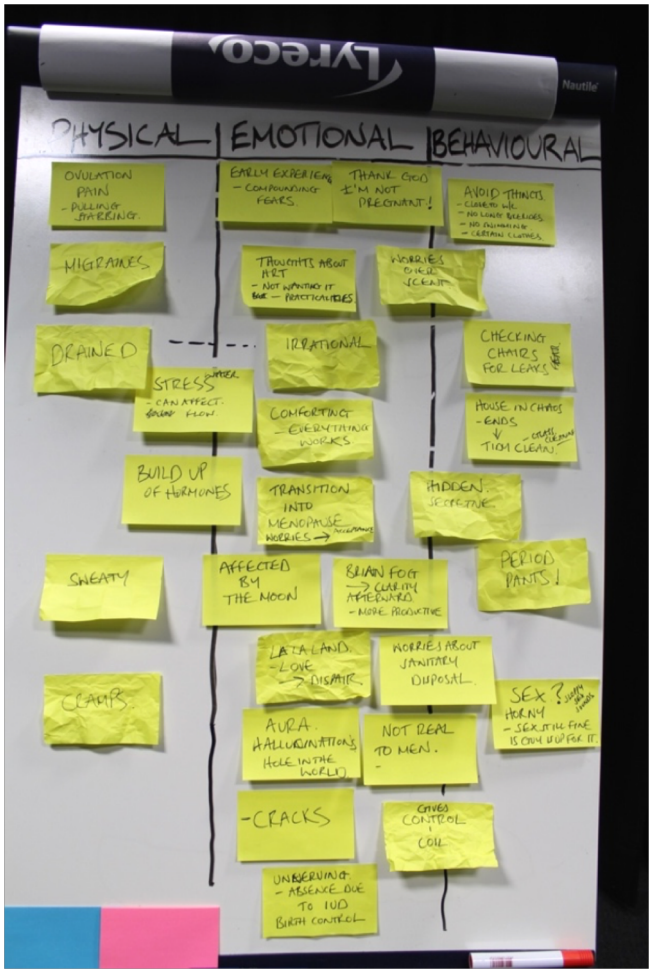

Figure 11: Data collection for the Her[sonifications] ideation stage

This third class of effect came into existence through discussions about how the women tend to either consciously or subconsciously adapt their behaviour and routine in response to their monthly cycles.

The first example of a conscious adaption of behaviour was raised by one of the women who described having a tendency to avoid taking part in physical activities that she regularly enjoys. She cited the reasons for this being a combination of two things: firstly, that she feels nervous about potential exposure *i.e., the leaking of menstrual blood brought about through the type of physical movement required to take part in the activity*, and secondly, she feels less energetic in general and thus less motivated to take part in *any* type of physical activity.

Another woman described how her monthly cycle affects the choices she makes about how to dress, in that around the time her period is due she starts to develop a preference for dark coloured, loose-fitting clothing, in attempt to divert attention away from her body and feeling a need to "hide under layers of loose clothing". Conversely, around the time of ovulation, she finds that her desire to look good increases and she dresses more confidently, chooses bolder colours and enjoys wearing make-up.

The conversation about subconscious behavioural effects started to deepen, when one of the women described how she finds herself cancelling social arrangements that she previously had been looking forward to, stating that she suddenly feels like she wants to "hide away". She also commented that she had only recently started to recognise this pattern of behaviour and suggested that it may be caused by a mild depression experienced around the time her period is due. She added that this particular feeling and associated trend of behaviour tends to last for several days and it is only afterwards, when she starts to feel better, that she is able to recognise that her malaise had been caused by her menstrual cycle.

There was much talk about how particular effects tend to appear and ebb away at specific points during the menstrual cycle and there were both similarities and differences between each woman's individual experience. The pattern and temporality of effects was discussed in detail and this was later found to be particularly valuable such that after subsequent transcription and coding of the audio captured during the discussion, the ability to map out the temporal aspects of each effect was enabled.

This is one major outcome of the Ideation activity that had not been anticipated at the workshop design stage, as such no mechanisms were in place for collecting temporal data in real time, the implications of this is described fully in section 4.10.

The Ideation activity had been projected to take one hour of the available time and if it had been established that additional time was needed to capture further data, the conversation would have been permitted to continue. At this point, the participants were asked if they felt anything was missing from the feels board that was integral to communicating the range of menstrual effects that they experience. No additional themes were suggested and with all of the women in agreement that they had together produced a rich collection of feels that had accurately captured their lived experiences of the female menstrual cycle, the Ideation activity was considered to have reached saturation and was brought to a close.

4.2.6 Translation Activity

The aim of the Translation activity was to translate the collection of feels produced during the Ideation activity into a number of raw sound objects. It was explained to the women that working through the collection of feels, for each post-it note on the feels board, where each contained a single effect, a sound sketch would be created. It was further explained that the resulting sound sketches would be incorporated into the sound installation.

The women were introduced to Foley Artistry, the sound design technique traditionally used in the Film industry, where the sound generating capabilities of everyday objects are exploited to create sounds for entirely different objects and interactions. A number of examples of Foley use in well-known films were described to illustrate the effectiveness and prevalence of the technique.

To provide an example, a description was given of the Foley created for a scene in the 1973 film ‘The Exorcist’, in which the possessed child’s head rotates 360 degrees, where the

macabre sound of cracking vertebrae and stretching skin was achieved by recording and processing the sound of a leather wallet full of credit cards being twisted and contorted.

It was explained that sound designers are often tasked with creating sounds to convey subjective notions, such as mood, and that we would now undertake a similar creative process to translate the collection of feels, the outcome of the Ideation activity, into a number of sound sketches, using the technique of Foley Artistry.

A range of everyday objects were placed on a table and were introduced as *Foley Tools (see example shown in Figure 12)*. The women were invited to handle the objects and explore the type of sounds that they could produce by using the objects as intended; using the objects in unusual ways and also by combining objects by manipulating them while in contact with each other.

The women were encouraged to consider the differences between the Foley Tools with regard to their constituent materials, surface characteristics, weights, malleability, and any mechanical features or moving parts. They were then invited to handle the tools and experiment with ways of manipulating them in order to explore the number of ways in which their different characteristics could be employed to produce interesting and varied sounds.

Figure 12: Example set of Foley Tools

As expected, the women were initially hesitant so the facilitator began by describing a situation in her early sound design career where part of the brief was to create the sound of 'happiness' for the atmosphere track in a film project. The women were asked to consider the task and to think about the kind of materials that might help to portray the notion of happiness.

One of the women suggested that metal and glass could be appropriate as wood might be too heavy and dull to be associated with happiness. Picking up two objects of the types suggested, the facilitator brought them together in a slow, arrhythmic pace and asked the group if it sounded like happiness. One of the women responded, "it needs to be faster as when you're happy, you're likely to move faster and with purpose". Another woman suggested that this might be achieved through introducing rhythm and picked up two other objects and started to bang them together rhythmically. The other women then joined in, picking up objects then bashing and rubbing them together in time with the beat.

Although there had been some hesitation initially, the women had quickly started engaging with the Translation process and appeared to be enjoying it, it was therefore considered appropriate to acknowledge their efforts and this was accomplished by informing them that they were *starting to think like a group of sound designers*. Their attention was brought back to the Feels Board and they were invited to select a post-it note from the board and consider how they might begin to translate the effect to sound.

As the group started working through the collection of feels, they appeared comfortable with the concept of expressing embodied phenomena with sound and as the activity progressed, were becoming increasingly creative in the way they were thinking about sound. As well as considering the physical properties of the Foley Tools, they began considering elements such as dynamics and resonance and how sounds should change over time to convey the characteristics of the effect as it develops and fades away, also making use of metaphors and analogies to describe the structure and form of the imagined sounds.

To provide an example, when sketching the sound of *Brain Fog*, one of the women who experiences this effect sonified the feeling she has of being unable to think clearly, by making use of an aerosol can which she sprayed in one long, continuous blast, resulting in a three second recording of what is essentially white noise.

It is interesting that she used this sound to represent her Brain Fog, for the white noise produced could be considered an elucidatory concept that is perhaps familiar enough for most listeners to understand and relate to. For information, white noise is an even distribution of all frequencies within the range of human hearing (20Hz – 20kHz), in the same way as white light is an even distribution of all wavelengths of light within the range of human vision. Note that although all audible frequencies are equally represented, we perceive white noise as a higher-pitched hissing sound, analogous to the familiar sound of static on a television or radio, this is because the human auditory system is more sensitive to higher frequencies and our perception of pitch is not linear.

As illustrated in Figure 13, the visual representation of a single frequency or *pure tone,* in both the frequency and time domain, is easily discernible. When multiple frequencies are present, and particularly in the case of white noise where all frequencies are present, as shown in the right-hand column, it becomes as impossible to isolate a particular frequency aurally, as it is

visually in the image below. If the embodied sensation of Brain Fog is sketched in sound as a period of penetrating cacophony of all frequencies, then it is rightly valid that one should be unable to distinguish a single frequency, analogous to the single object, thought or thing on which one wishes to focus, and so there would indeed exist "a lack of clarity".

To provide a familiar example of this masking effect in our environment, it is comparable to the way we struggle to hear another's voice when engulfed in a howling wind.

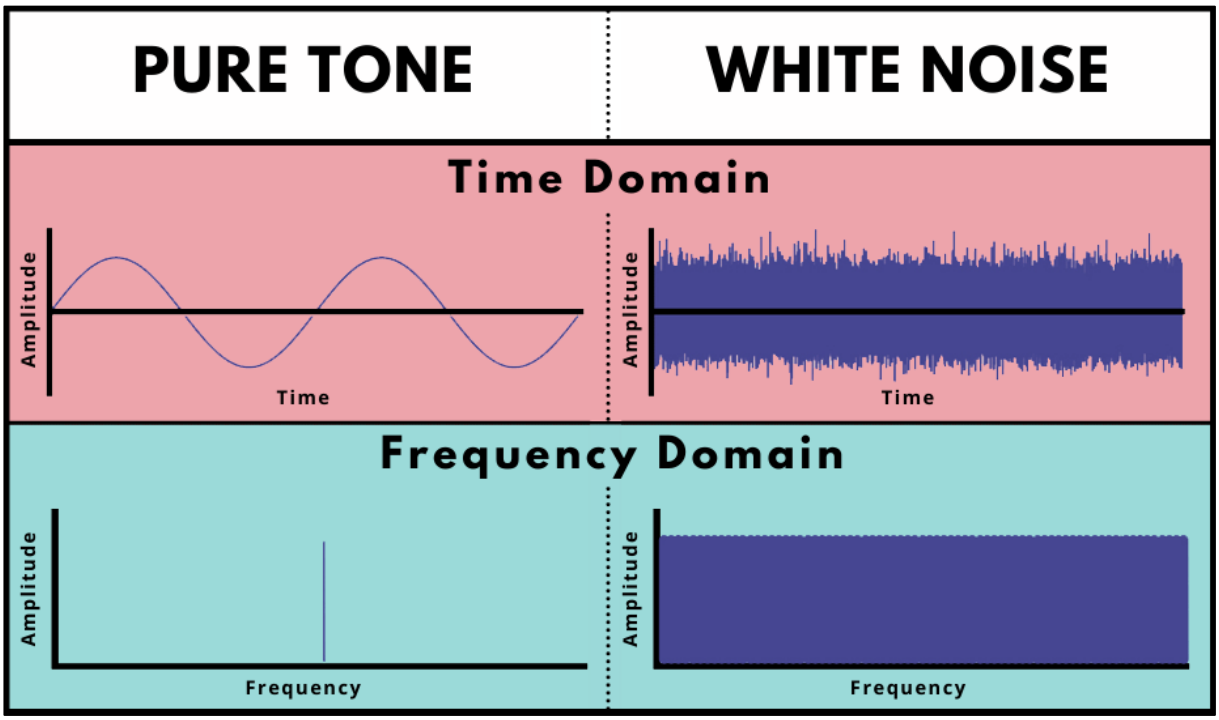

Figure 13: A visual representation of a pure tone and white noise in the time and frequency domains

Continuing with the sound sketching process, she said that to convey the change from Brain Fog to the feeling of *Clarity* that she experiences, the thick fog (white noise) should change to a "radio tuning sound" when things start to improve, then to "clear radio reception" to show that the brain fog has lifted and "everything is clear and back to normal again".

The radio analogy was useful in describing the brain fog effect to the group and it is considered to have been developed purely through exploring the available Foley Tools to find the starting point (white noise) before thinking about form or structure in any way.

4.2.7 Foley Tools for Reflection

Another observation made during the Translation Activity, and which was subsequently confirmed in the feedback received during follow-up discussions with each participant, was that sound sketching can inspire and support deeper descriptions of felt sensations, beyond that afforded by language alone.

When one sketches sound to describe embodied phenomena to another, the need for finding the appropriate vocabulary is lessened, which is particularly helpful in cases where lexical barriers exist in the ability to provide a full and accurate description.

The performative act of making sound encouraged self-reflection and made space for participants to develop a deeper understanding of the matters they had raised through their own refinement of the sounds and concepts used to convey and share their experiences.

Throughout the translation activity, previously shared stories were reflected upon and explored further in the pursuit of finding appropriate sounding materials to work with; rejecting certain sounds (physical materials) in favour of others; and suggesting materials which were not immediately available or that could not be directly manipulated, for example there was a suggestion that the cracking of glacial ice sheets would be an appropriate sound with which to sketch a particular effect.

To provide an example of how the sound sketching process provides tools for reflection, revisiting the dialogue from the Ideation Activity on ovulation, the woman who initially raised the notion of Ovulation Pain did not provide a clear description of the felt sensation:

> **Participant 2:** *"I have pain when I ovulate, every time and it's exactly on the side and I know when I ovulate! It's so funny and yeah, a lot of pain. It's not a horrible pain like a period pain but it's pain."*

When the same woman was invited to create a sound sketch of the type of pain she feels, she selected a metal rod and started exploring the different sounds she could achieve by striking it against various metallic objects before settling on a large, thin, metal bucket. She then spent time striking various areas of the bucket before stating "that's it – exactly like that but it needs to resonate more like this" and she vocalised a long *"oo"* sound. She then performed the action again with the vocalisation and considered it to be a highly accurate representation of what she feels at the exact moment of Ovulation.

Providing a verbal description of this visceral sensation would be challenging for anyone and describing a sound with which to represent it would be equally challenging, particularly to someone who is not well versed in the language of the audio professional, who might describe that particular sound in terms of attack, sustain and decay for example, however through the use of embosonic design, this woman was able to reflect on her lived experience and accurately share the nature of it with others.

4.3 Soundscape Structure Design

The workshop activities had produced a number of outputs that would inform the design of the soundscape that would feature in the Her[sonifications] installation, as well as shaping the design of the installation itself. As well as the recordings of the self-actualised sonifications of embodied experience performed by the women, there was a substantial amount of qualitative data to consider in order to guide the subsequent stages of the design process.

4.3.1 Data Coding

The ideation and translation activities stimulated insightful discussion and the sharing of highly descriptive experiential phenomena between participants, all of which had been captured through audio recording the workshop session. In order to access and to start to make sense of the qualitative data that had been generated, the dialogue captured during both activities was transcribed and coded using a thematic analysis approach [13] within the NVivo software package[12]. The verbal data was categorised with codes based on the experienced phenomena; the associated participant(s); whether the impact of the phenomena was of a physical, emotional or behavioural type; and whether it occurred before, during or after the period of menstruation.

The audio transcription and coding process was a substantial task for a single researcher however it became clear very early on in the process that a highly focussed and systematic approach was necessary for the volume and richness of the data captured. In addition to being able to reflect on the words spoken by the women during transcription, thematic coding enabled me to perform a thorough analysis of the data that would have been difficult if listening to the audio files alone. Linking the transcribed text to the associated audio excerpt was useful for occasions when I wanted to revisit the data, when for example repeat listenings were required in order to identify features such as tone of voice.

As a data collection method, audio recording followed by transcription and coding was vital as during the subsequent process of analysis it revealed new data about the concepts raised. If data collection during the ideation and translation activities had been carried out using a different method, *e.g., participant observation with note-taking,* a substantial amount of valuable qualitative data would have been lost.

Most significantly, the capacity for using the data to make strong inferences with regard to the temporal aspects of the experiential phenomena described by the women *i.e., how the women's experience of certain phenomena begins, ends and evolves over time,* would have been severely reduced, if not withdrawn completely.

[12] NVivo product page: https://www.qsrinternational.com/nvivo/nvivo-products

4.3.2 Data Mapping: Four Cycles of Temporality

Through analysis of the data, the approximate timing and duration of each of the effects experienced by the women could be contextualised within a typical 28-day menstrual cycle period. A systematic charting process was employed in order to reformulate the primary qualitative data from the stories shared by each participant as a method of narrative analysis.

To provide an example, Figure 14 shows the result of the charting process for the following quote:

> **Participant 3:** *"Around a week before my period, I start to feel anxious and it gets worse and worse. It lasts all the way through my period, then just stops and I feel good again".*

Participant	Effect	Days 1 -7 (Menstruation)	Days 8 - 14	Days 15 - 21	Days 22 - 28
3	**Anxiety**	Lasts throughout then stops	She feels good again		Starts and steadily worsens

Figure 14: Example of the charting of voice data for temporal analysis

This process was carried out for the verbal data captured during both the ideation and the translation (sound sketching) activities, with the translation activity providing a particularly rich source of temporal data. A possible reason for this richness is another example of the observation described in section 4.2.7, pertaining to embosonic design being a useful tool for reflection *i.e., sound sketching can inspire and support deeper descriptions of felt sensations.*

The temporal aspects of each effect were then mapped visually along a full 28-day cycle for each participant, which brought order to the myriad stories that were shared by the women and provided a narrative for each of them.

The resulting data map for one of the participants is shown in Figure 15 and the full set of data maps can be viewed in Appendix B.3. These data maps provide a visual representation that effectively demonstrates the unseen turbulence of a month in the life of each participant. Furthermore, the data maps presented a specification for the structure and flow of the comprising parts of the overall soundscape as well as heavily influencing the subsequent design of the physical installation.

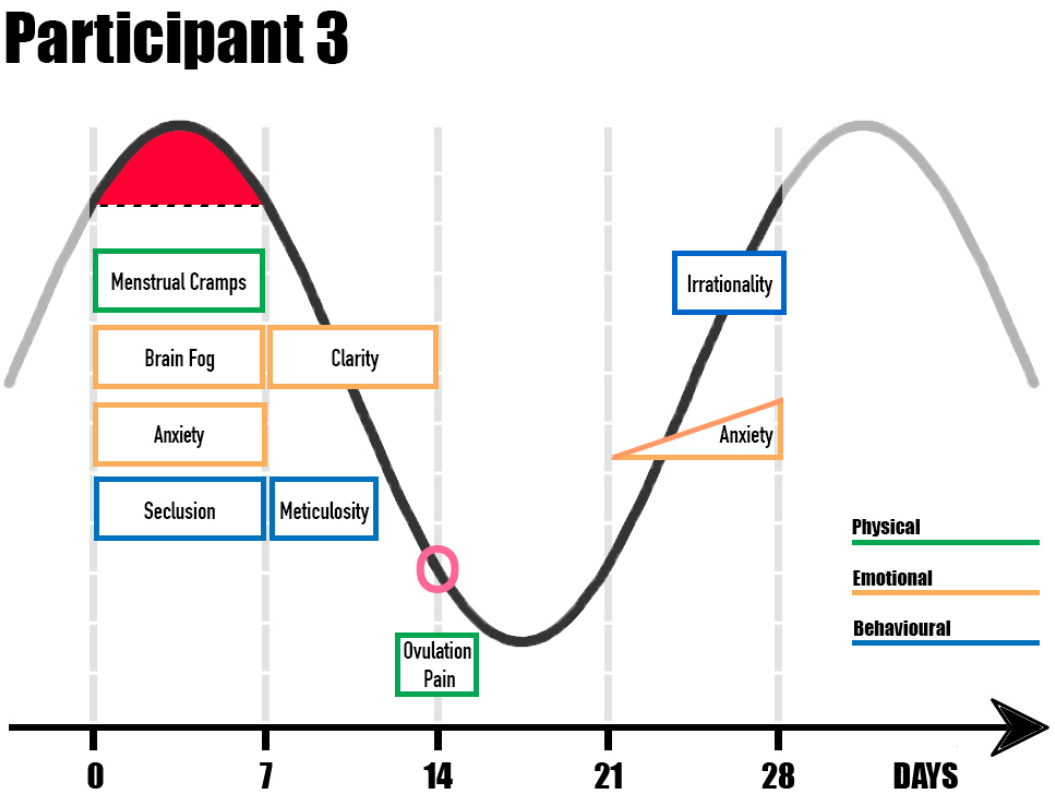

Figure 15: Example of a data map showing a visual representation of temporal data

4.4 Audio Post-Production: Raw Sketches to Sound Objects

One of the direct outputs from the embosonic sketching workshop was a set of close-mic'd recordings of the raw sound sketches that the women performed during the translation activity. These recordings captured the women's sonifications of embodied experience, which for some phenomena were complete and regarded by the women to be accurate sonic representations.

Some of the sound sketches however demonstrated only partial details of phenomena and others communicated ideas that were purely provisional. These sketches featured use of the available sounding materials in place of those considered as ideal but that were either not available or could not be manipulated or accessed directly.

The data coding process captured the spoken refinements and descriptions which accompanied these incomplete and provisional sound sketches and therefore were a vital component in the specification that informed the design of the soundscape.

Additionally, the process of coding and mapping the data brought insights that had not initially been accessible but that had emerged from having this holistic view of the qualitative data captured. With the data map providing narratives for the women's individual experiences of the physical, emotional and behavioural impacts of the menstrual cycle, they were a valuable component of the design specification required for designing the structure and flow of the future soundscape.

The sketched sounds, the coded verbal data and the data maps each contributed to the specification that would guide the design of the soundscape, as illustrated in Figure 16.

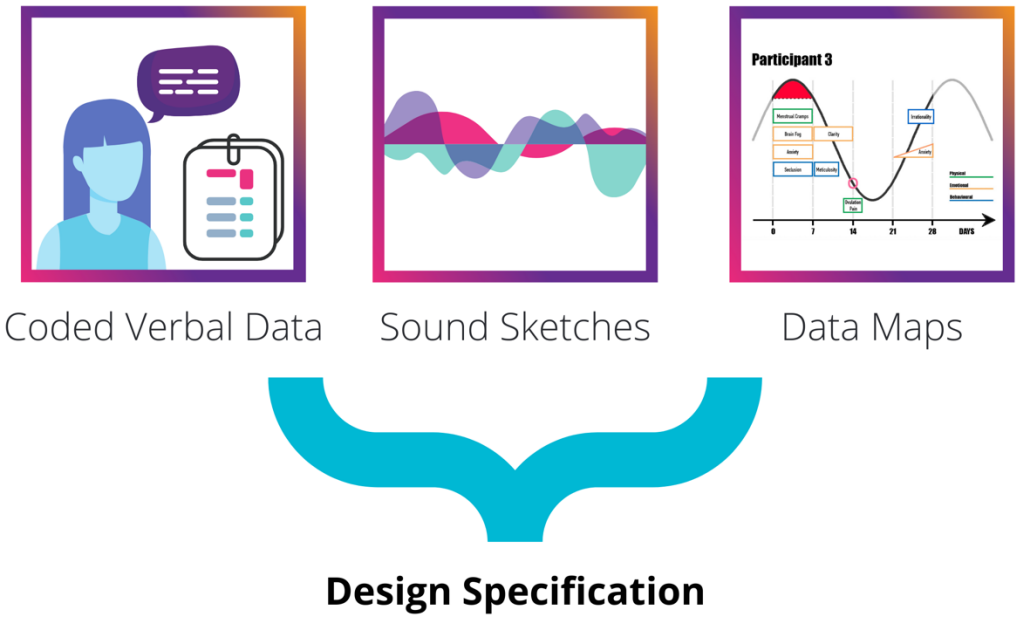

Figure 16: A model of the data types informing the design specification for the Her[sonifications] installation

With a detailed design specification in place, I was able to move from *researcher* mode into *sound designer* mode. Sound design was the field I worked in prior to studying for my undergraduate degree at Lancaster University, as mentioned previously, and never before had I had such a detailed brief for a sound design project.

I was able to use my audio skills and experience to effectively polish and build on what had already been created by the women through embosonic sketching. See Appendix B.4 for an example of some of my sound design notes that were informed by the voice data captured during the translation activity.

The raw sound sketches were brought into the Pro Tools DAW[13] (Digital Audio Workstation) where they were prepared for use, with trimming, equalisation, dynamics and effects processing applied where necessary, before being exported as mono WAV files for each individual sound object. Envelopes and fades were created according to the data maps for

[13] Avid product page for Pro Tools: https://www.avid.com/pro-tools

example, when an effect needed to build or subside over time, a fade was applied to produces a gradual increase or decrease in the audio signal level, which controls the perceived loudness of the sound over time.

For the incomplete and provisional sound sketches, I edited and layered further recorded and found sounds that had been suggested as most appropriate for conveying some of the concepts raised in the workshop session *e.g., the sound of a phone ringing and not being answered, to convey the feeling of seclusion and hiding oneself away from the world*.

Other sound sketches were layered with additional sounds to build texture and size including virtual synths and pads; additional recorded elements; and sound effects to represent phenomena which were not conveniently available for recording *e.g., glacial ice cracking and radio tuning sounds*.

4.5 Building a Labyrinth: Qualitative Data to Physical Space

As a direct output of the embosonic design method employed in the workshop session, there was a complete set of soundscape elements comprised of twenty separate sound objects, each representing a single experienced phenomenon linked to the menstrual cycle.

There was also a set of data maps, produced through analysis of the qualitative data generated and collected during the embosonic design process. These data maps contextualised each experienced phenomenon within a 28-day menstrual cycle period.

The next stage of the design process was to identify a creative way of transferring the knowledge gained to a tangible instantiation of female experience in the physical domain and positioning the data sonifications within.

With the data maps based on a monthly cycle, I found the cyclical representation brought focus upon the turbulent highs and lows that woman experience during the course of a month in

response to the biological rhythm of hormone regulation. Ovulation occurs roughly halfway through the cycle when oestrogen levels are at their peak, and this is where the participants in this study tend to experience a halting of effects; and as shown in the data maps in Appendix B.3, there are certainly fewer negative phenomena experienced around this time.

For this reason and with a cyclic, sinusoidal wave-like nature in mind, I had assigned the period of ovulation as the trough of a wave and the period of menstruation as the peak, where the incidence of experienced phenomena is at its highest.

I felt that if I could transfer that wave-type construct into physical space and effectively attempt to re-create the data maps in space and in time, it could allow others to move around and be present during a month of internalised womanhood, a month that is indifferent to all the external stressors and life events at play, an already turbulent month within which she must negotiate normalcy and the mundane.

In acknowledgment to the four women who participated in the design project, I felt that representing quadruplicity in the physical design was important and initially envisioned four cycles of a wave, as depicted in Figure 17 with ovulation (O) at the troughs and menstruation (M) at the peaks.

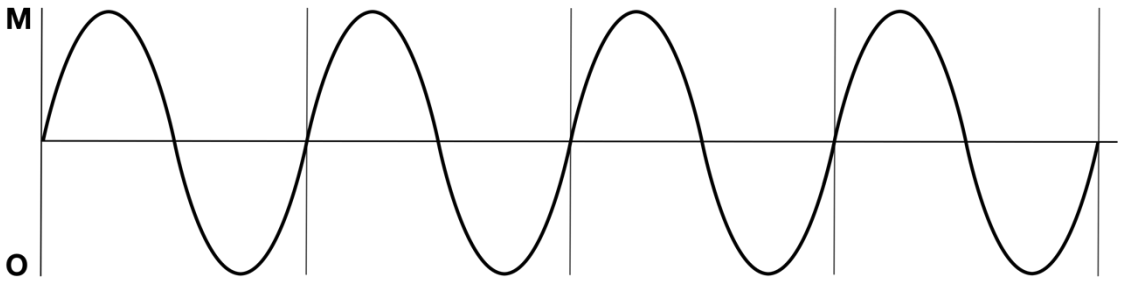

Figure 17: The cyclical wave concept that informed the physical design of the Her[sonifications] installation

Although the idea captured the essence of what I wanted to convey in physical space, i.e., the peaks and troughs, it did not express the notion of these cycles repeating endlessly. It needed to represent quadruplicity in a sine-wave type pattern but also convey there being no beginning or end, it needed to emphasise the nature of repetition through circularity.

In the second design, the four cycles were merged into a single, endless path which was essentially a circle deformed by four occurrences of the sine wave-type pattern, as shown in Figure 18.

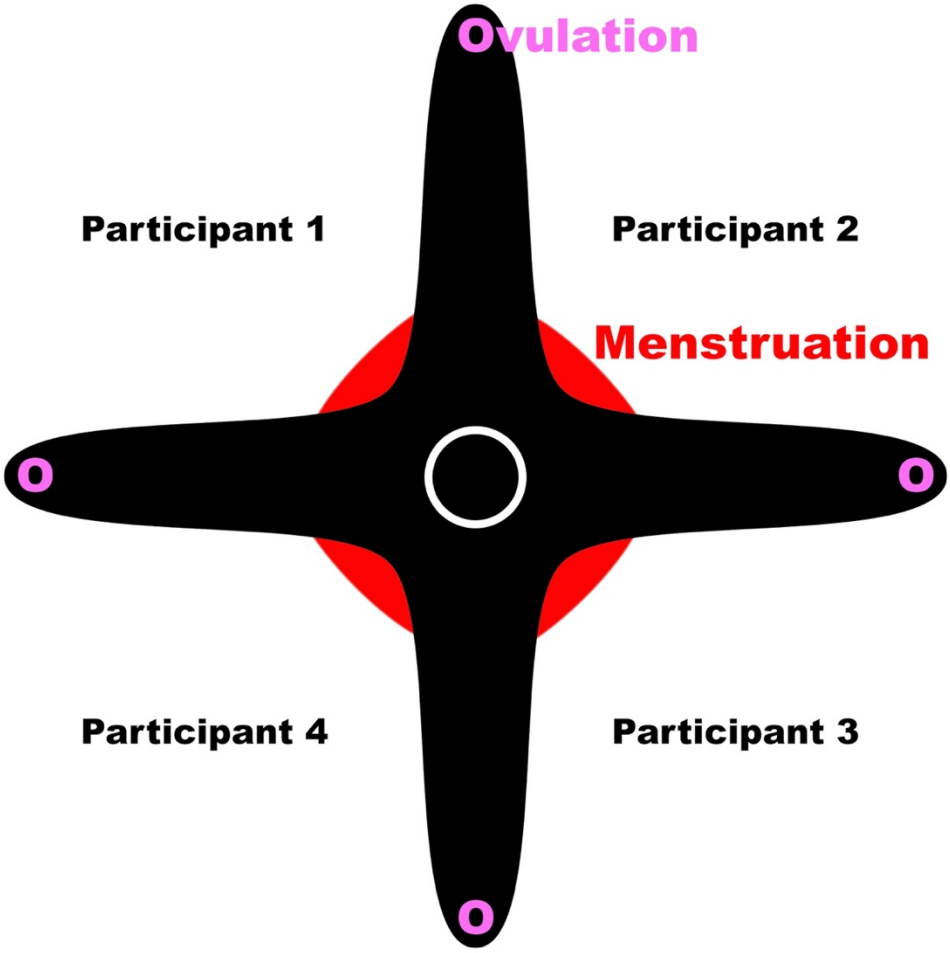

Figure 18: The final physical design of the floor-based walkable labyrinth in the Her[sonifications] installation

To encourage the reflexive act of guided walking, the aim was to physicalise and lay out the above design in the form of a walkable labyrinth.

Additionally, to promote immersion and awareness of sound, I wanted the installation to heighten the senses by allowing people to experience the soundscape in darkness.

I considered several options for creating a low-lit labyrinth that could be installed in a dark room. I firstly considered light projection, where an image of the labyrinth could be projected onto the floor and also looked into interactive floor projectors that you can use to detect user interaction, however to achieve a large enough size both options require situating the projector at a height that is not easily accessible in a conference exhibition setting. And although interactive floor projectors are becoming increasingly more affordable, the available options at the time were prohibitively expensive.

I then considered making laser-cut sections of wooden sheeting featuring the labyrinth marked out with inset low voltage LEDs (Light Emitting Diodes) but quickly rejected that idea due to weight and associated lack of portability. As a more light-weight option, I considered creating a large jig-saw based version from foam sheeting, again with embedded LEDs, however was not confident that it could achieve an atheistically pleasing look with the rough surface of the foam sheeting visible around every light and although lighter in comparison to wooden sheeting, the sections would still be cumbersome to carry and install in a conference exhibition space.

I elected instead to mark out the labyrinth directly on the floor using electro-luminescent (EL) wire. This removed the need for using a secondary solid material as a frame within which to install lights. EL wire is copper wire that has been coated in phosphor so that it produces light when an alternating current runs through it. It is lightweight, portable, reusable and easy to lay out and as it is encased in flexible tubing of thin diameter, it can be arranged into any shape and fixed in place.

The primary reason behind selecting this material however is that its luminescent properties are visually pleasing in dark spaces, producing a uniform, unbroken 360-degree line of light across its' length.

Figure 19 shows a 25-metre length of EL wire marking out the labyrinth on the floor of the installation space at LICA (Lancaster Institute of the Contemporary Arts), with the electricity supply coming from a mobile power bank in this practice set-up.

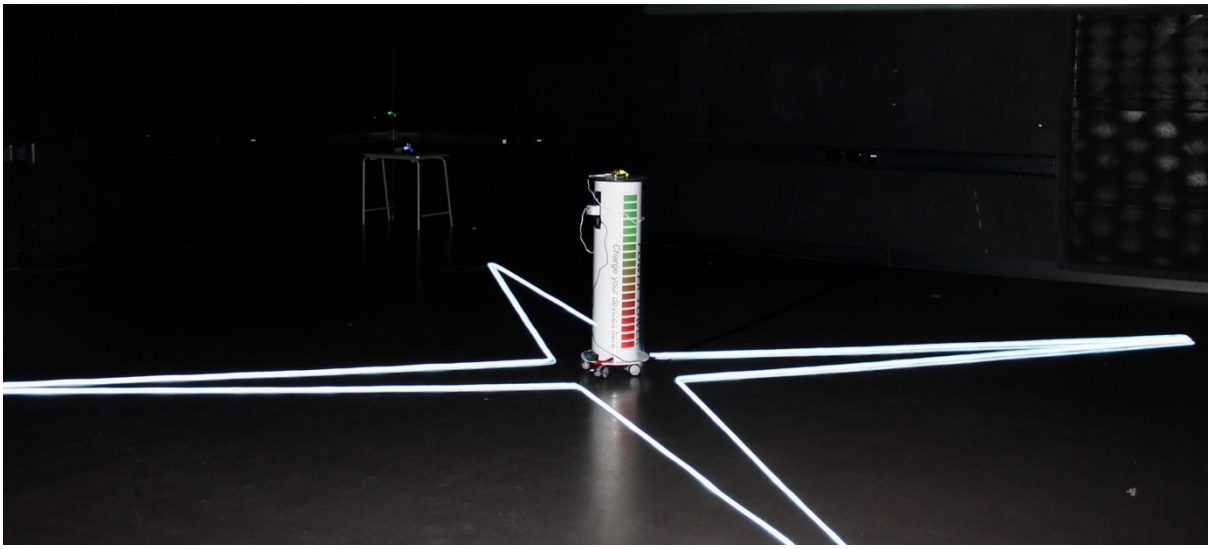

Figure 19: The floor-based labyrinth installed in electro-luminescent wire

4.6 Installation Technology: Making the Labyrinth Sense and Respond

With audio production complete and the physical layout of the labyrinth finalised, the next stage of the design process was developing a system that would sense a user's movement within the space and produce a dynamic, evolving soundscape in response.

The requirements of the system were as follows:

1. To detect a user's position on the labyrinth.
2. To determine the corresponding point in the conceptual monthly cycle.
3. To trigger the related audio files.

I was keen to develop an interactive solution that would not impact the aesthetic or the usability of the installation and would as far as possible, use technology that was as imperceptible to the

user as possible. I also wanted to deliver the experience via loudspeakers as opposed to headphones so that other people could enter the space, observe the user interacting with the installation and hear the soundscape produced.

Additionally, the system needed to be lightweight, portable and also quick and easy to set up and take down. I also required a development environment that was suited to rapid prototyping given the level of experimentation that would be involved.

To meet the stated requirements, I designed and developed a Bluetooth-based detection system which was built in the Python programming language and hosted on a Raspberry Pi microcomputer.

4.6.1 Location Detection

The system used Bluetooth technology to detect the presence of a user; approximate their distance; and respond to the sensed input by triggering audio at pre-determined distance levels. The use of Bluetooth enabled people to interact with the installation without the barrier of using a mobile application or handheld device.

A paired Bluetooth beacon was inserted into a lanyard so that it could be easily worn and passed between users, allowing people to participate without intervention and to move around freely within the installation space. Anyone wearing the lanyard containing the broadcasting beacon, and who was within range of the Bluetooth receiver placed at the centre of the installation, became detectable within the space.

The locative system was programmed to read the Received Signal Strength Indicator (RSSI) values from the Bluetooth signal broadcast from the beacon and approximate its distance from the receiving device. Figure 20 shows an early experimentation, with the console output showing the RSSI value and associated distance level when the BLE beacon is brought close to the Bluetooth receiver (the Python code is included in Appendix B.5).

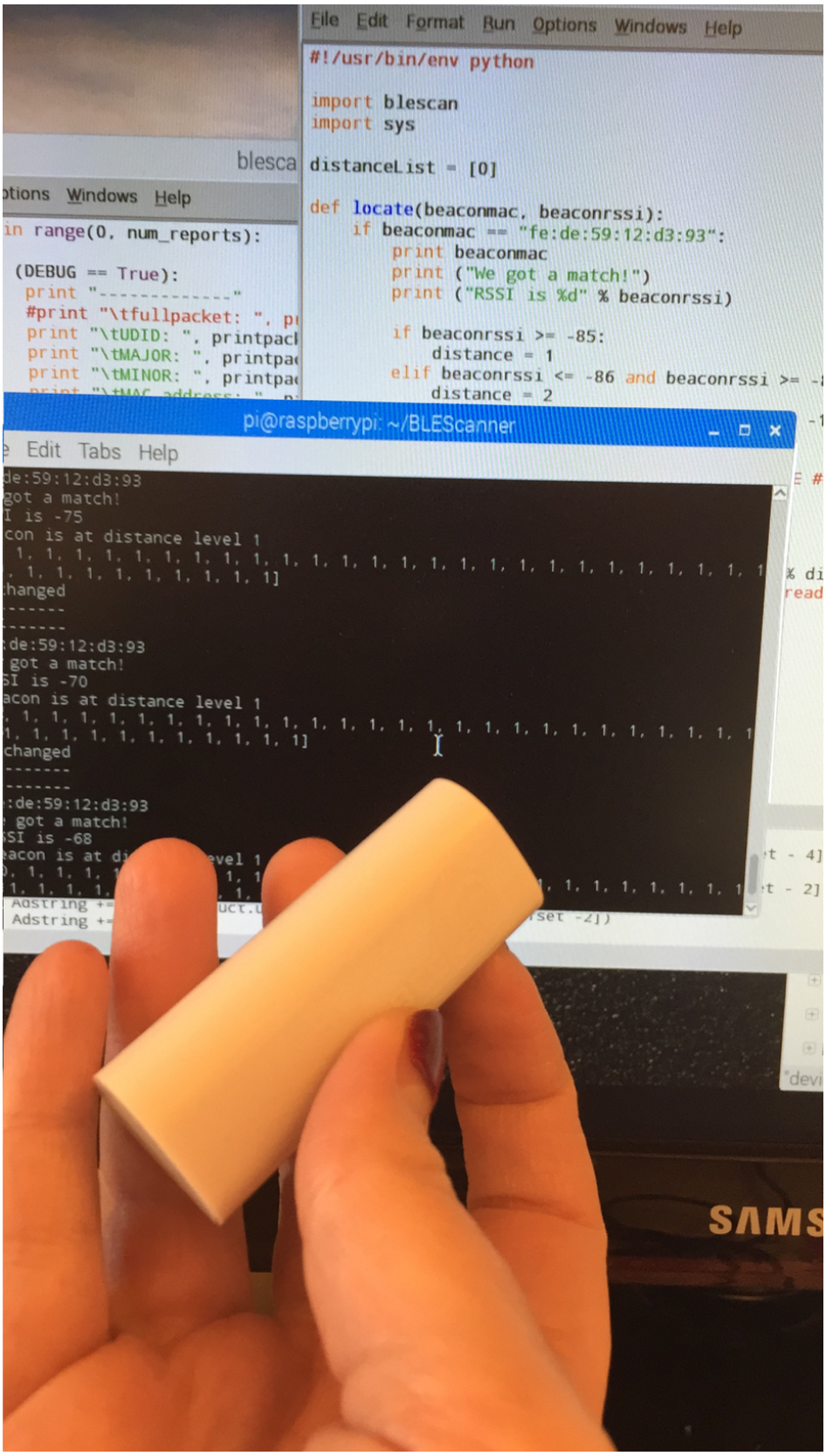

Figure 20: Early experimentation with reading RSSI values from a BLE beacon

A number of tests were carried out to determine signal strength ranges and corresponding distances for different transmission power settings. This process of calibration allowed me to establish an optimum configuration for the system which resulted in location accuracy of <0.8 metres.

I programmed the system to detect user movement by tracking changes in the RSSI values and determining relative location according to some pre-defined distance levels (defined as R1 to R5 as shown in Figure 21). By storing several consecutive distance levels in a Python List, the system could determine whether those changes indicated either movement towards the Bluetooth receiver or movement away from it.

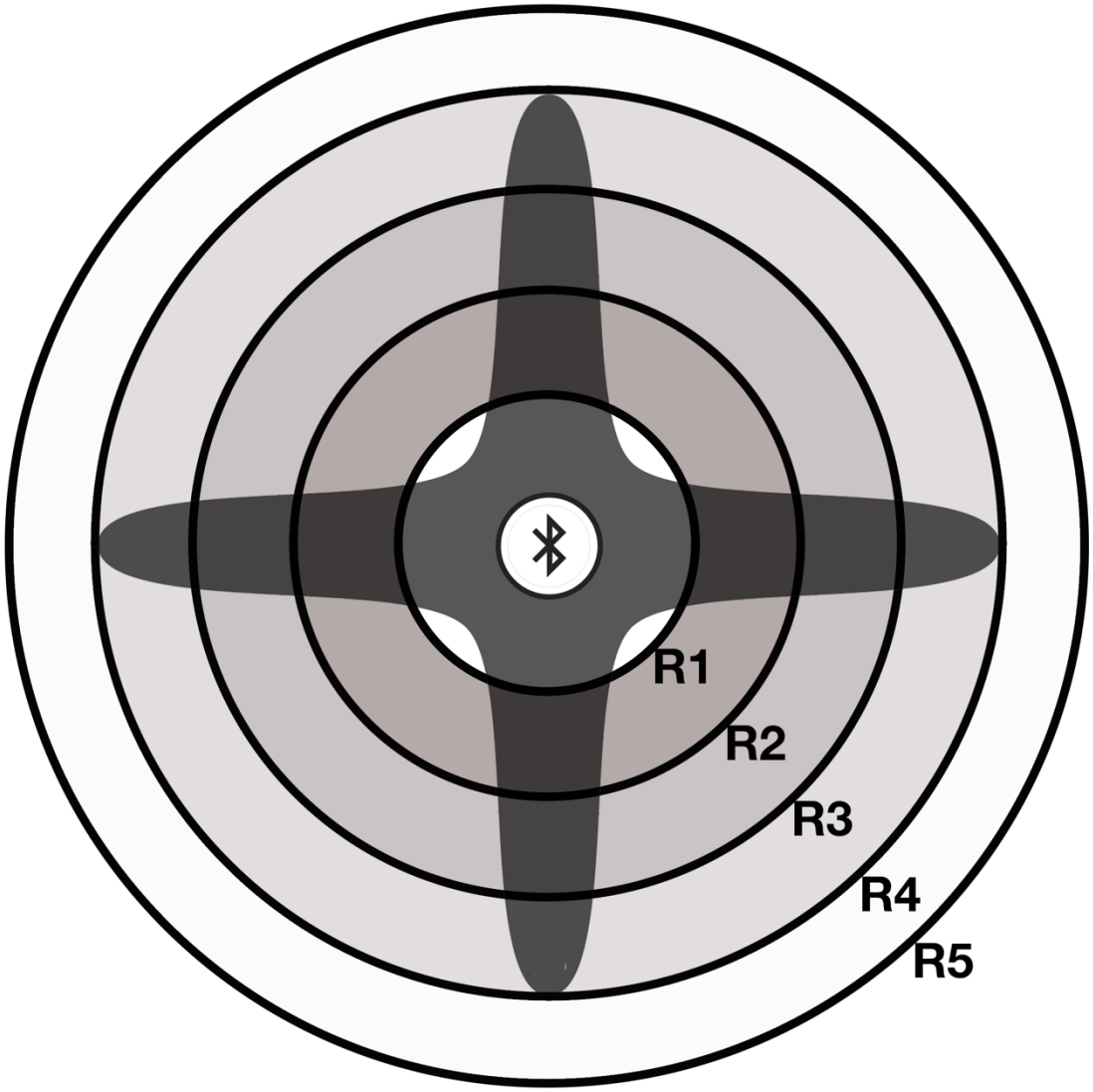

Figure 21: The model used to calibrate and determine direction and distance of beacon movement in space

The determined movement of the beacon in space triggered playback of certain audio files based on user location and effectively tracked user position along four pre-defined points on the labyrinth of menstrual cycles, namely 'pre-menstruation' *i.e., movement detected from R3 to R2*; 'during menstruation' *i.e., movement detected from R2 to R1*; 'pre-ovulation' *i.e., movement detected from R2 to R3*; and 'on-ovulation' *i.e., movement detected from R3 to R4*. A fifth point was defined to determine if a user moved out of range of the labyrinth and if so, a fade out was performed on all audio channels.

The build was tested with musical elements initially, to test system robustness *i.e., rather than placing a beacon and then physically returning to the console to view the output distance level, an ascending musical scale could be heard when moving towards the Bluetooth receiver and a descending scale heard when moving further away.*

The process of testing allowed me to identify issues with the code and to monitor hardware issues, primarily the handling of drop-outs and fluctuations in Bluetooth signal, which can be affected by the presence of obstacles and external interference. The Python code can be viewed in Appendix B.6.

4.6.2 Audio Triggering

The embosonic design method employed in the workshop session and the subsequent process of audio post-production produced a set of soundscape elements comprised of twenty separate sound objects.

The data maps produced as a result of the data coding process (section 4.3.1) were fundamental in determining which audio files should be triggered at each distance level (as shown in Figure 21).

The audio files were organised into four separate directories according to the timings at which they were experienced by the workshop participants during their monthly cycle i.e., there were four sets of audio files: ‘pre-menstruation’; ‘during menstruation’; ‘pre-ovulation’; and ‘on-ovulation’.

The installation technology was designed in such a way that when movement was detected and user location was determined, an audio file from the corresponding directory was selected at random for playout on the loudspeaker array. This meant that as a user traversed each point in the lit labyrinth, they would hear the sonification of one women’s experiential phenomena at the appropriate point on the monthly cycle.

This was a design decision that was taken to provide both a sense of anonymity for the women and to achieve a more generalised view of the group’s qualitative data as a representation of female experience opposed to a detailed representation of an individual’s data.

The manner in which a user moved along the labyrinth affected how the soundscape was generated. For example, a user that moved slowly or chose to stop at various points along the labyrinth would hear each sound object in isolation and could listen to the detail of the sound envelope *i.e., how the sound starts, builds, changes over time and fades away,* whereas a user who moved quickly along the labyrinth (through the month) would hear the sounds merge into one another and play over each other to produce a cacophony of sound during their tumultuous, whirlwind tour of the female monthly cycle.

The user could effectively control the depth and detail of the sonified data based on how they interacted with the installation at any given time, with differing levels of interaction over time producing an evolving and dynamic soundscape. By varying one’s distance to the host device, albeit unwittingly due to the invisibility of the installation technology, users would take an active and playful role in sound generation, becoming co-creators in the performative piece.

4.7 INSTALLATION LAUNCH AND RECEPTION

Her[sonifications] was exhibited at the Data Publics conference at Lancaster University in April 2017, having been accepted along with a full paper contribution titled 'Publics, Pluralism, Protests, Periods.' and was open to visitors throughout the duration of the conference.

It was situated in the Installation Space at the Lancaster Institute of Contemporary Arts, which is a room with black-coloured walls and floors and no windows, making the space ideal for light installations. An array of four loudspeakers are suspended from a very high ceiling and are directed towards the centre of the space.

The Electroluminescent wire was laid out, fixed to the floor and powered by a mobile power bank; and the Raspberry Pi that was responsible for the processing of location data and the triggering of sounds, was installed at the centre of the lit labyrinth (Figures 22 and 23).

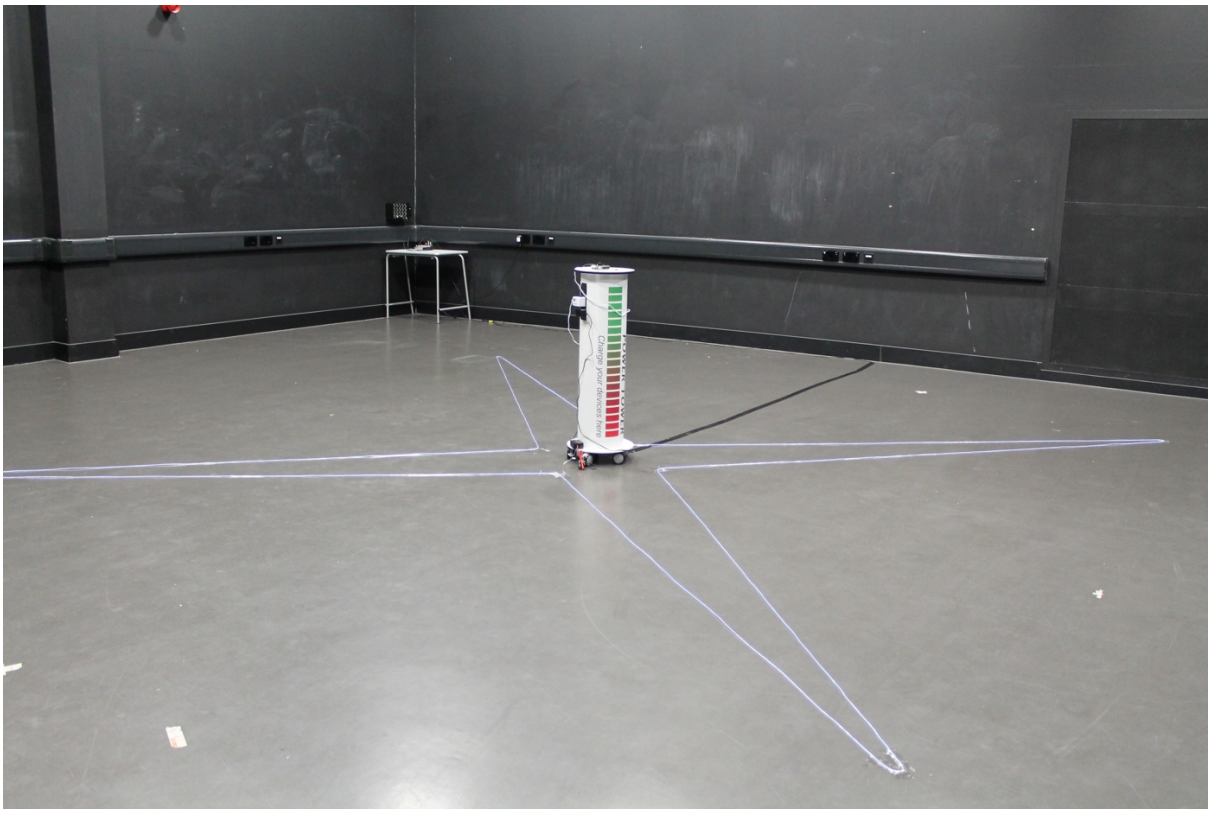

Figure 22: The floor-based labyrinth set up in the installation space before launch

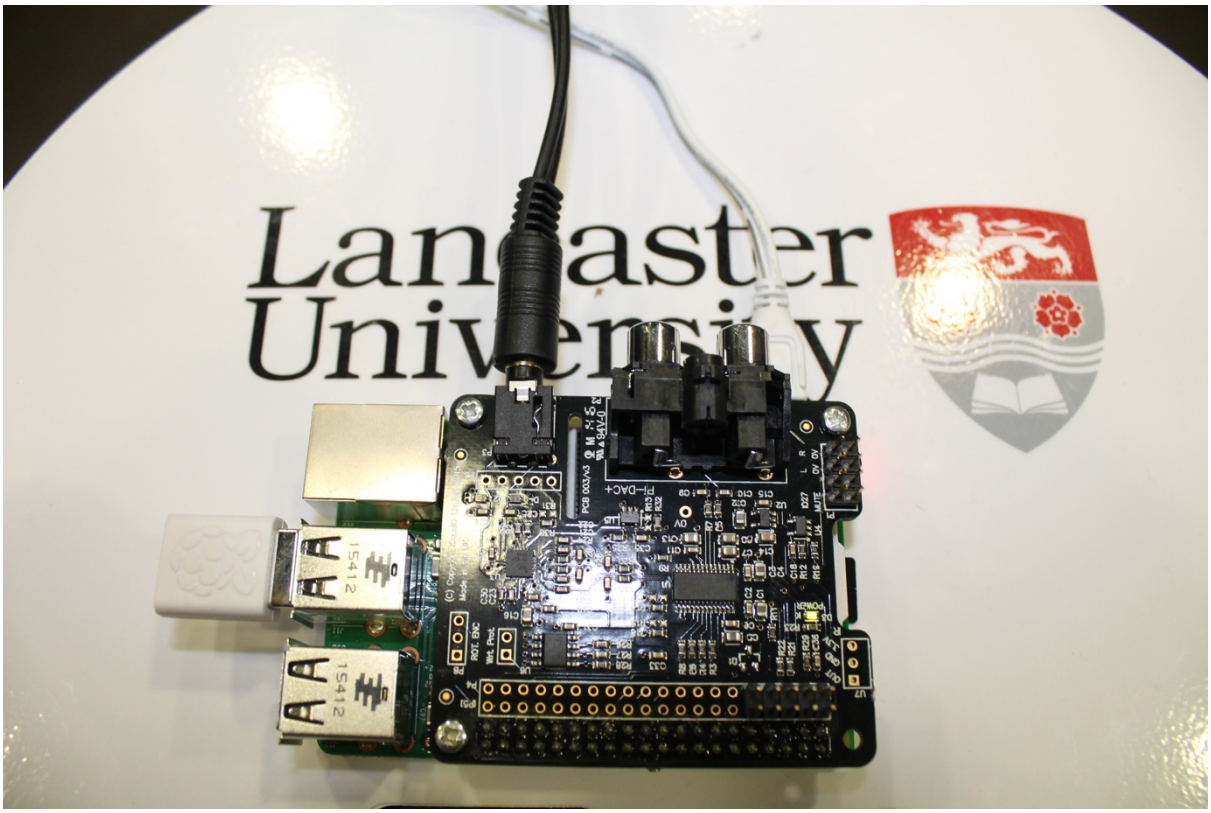

Figure 23: The Raspberry Pi hosting the installation technology

A projector and laptop were placed at the back of the room with a video I had produced[14] to complement the installation, set to loop, providing a large wall projection at the back of the space (Figure 24).

[14] Video showing the complete wall projection that was exhibited as part of the Her[sonifications] installation: https://youtu.be/MlHDZNx_RLk

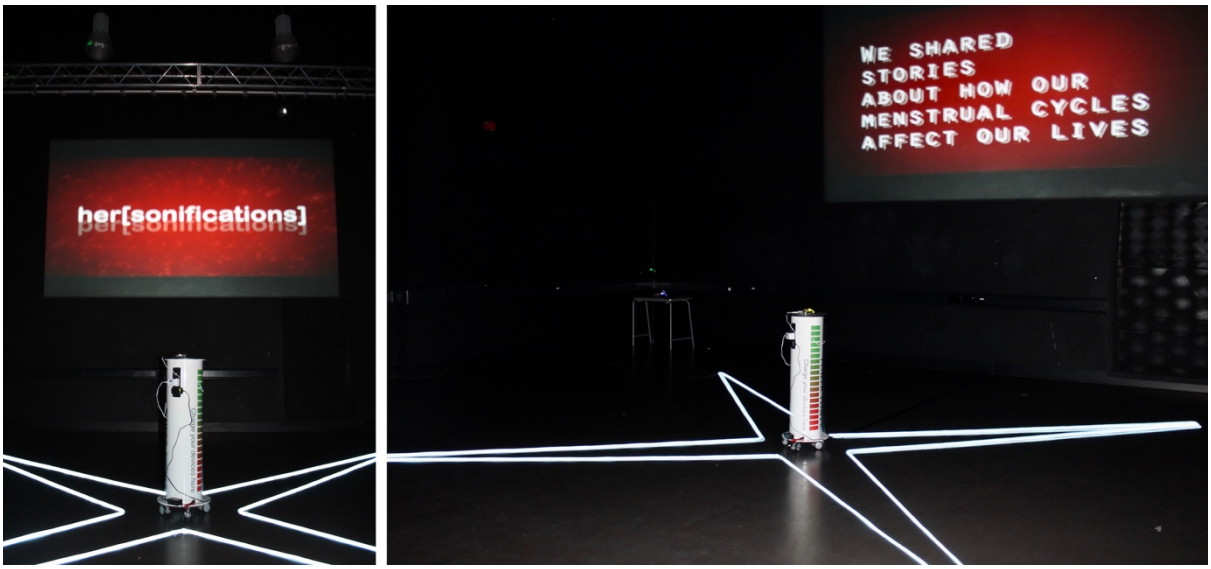

Figure 24: The Her[sonifications] installation during exhibition (camera's flash exposes the mobile power bank)

At the entrance to the room, the lanyard containing the paired Bluetooth beacon was hung on the outside of the door along with some promotional materials (Figure 25) and a description of the installation (see Appendix B.7).

Figure 25: The lanyard containing the BLE beacon that visitors wore to interact with the installation

Over the course of the two days, around forty people interacted directly with the installation[15] (Figures 26 and 27) with a number of others only observing from the perimeter of the space. Several of the people who observed others interacting with the installation then went on to take the lanyard in order to generate the sounds themselves.

A few visitors stayed within the installation space for an extended period of time, in one case the visit time was observed as being in excess of fifteen minutes, which was unusually long compared with the average visit, noted at the time to be around six minutes. Interestingly, most of the visitors who interacted directly with the installation were male however there was fairly even split of men and women who approached me to discuss the installation after they had experienced it.

Figure 26: Visitors to the Data Publics exhibition reading about the Her[sonifications] installation

[15] Video showing a user interacting with the Her[sonifications] installation: https://youtu.be/jWQ_juIWwa0

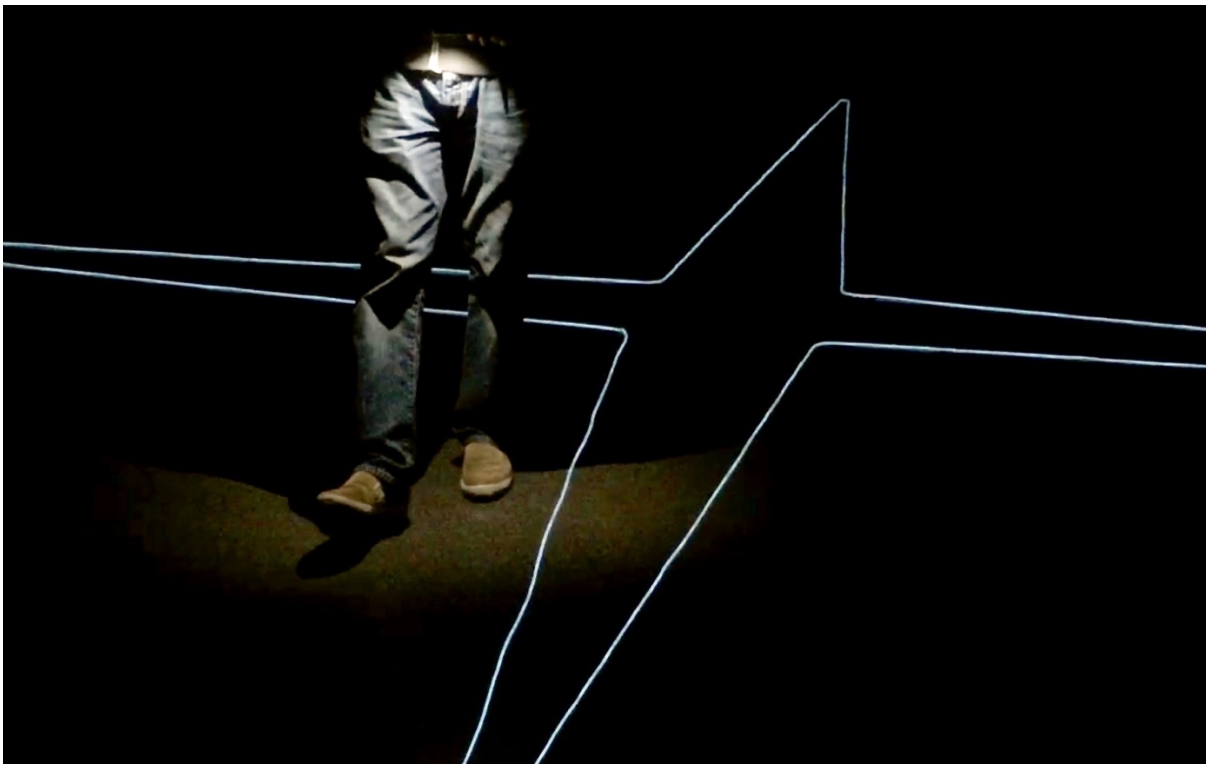

Figure 27: A visitor interacting with the Her[sonifications] installation

Of the feedback I received, the majority were wholly positive and I was pleased that the installation had generated much interest from the conference attendees. A few men commented that the installation had opened their eyes to the sorts of effects that women regularly deal with and talked about the level of disruption that is hidden and never openly acknowledged in the working environment or during social interaction with women.

Some of the women that I spoke to commented on how interacting with the installation made them reflect on their own experiences and how they could recognise some of the effects. A couple of the women told me that after observing the installation, they discussed over lunch how they both wished to remain actively mindful going forward in order to understand when "biology is in control" and to "cut themselves some slack" during their low points.

Interaction styles differed greatly with some people stopping after every small step along the labyrinth, which is something that I had not anticipated but that the system handled well. In this case each small step triggered a sound object randomly from the appropriate directory while the user stood at that particular point in the cycle and while there were not significant cases of a sound object repeating, there were some repetitions, however this did not sound out

of place and would have been perceived as a loop for those unfamiliar with the sounds. In hindsight, I could have added functionality to track each sound file that had been triggered and ensure that any subsequent file played from the same directory was different to the previous one.

At the opposite end of the range of interaction styles, there were a few users that as soon as they realised their movement controlled the soundscape, began to run along the lit track and even jump over the labyrinth to see what effect it had. As expected, this resulted in a cacophony of sound which was hugely immersive but that was not closely representative of female experience but was more analogous to the concept of a montage in a film, where drama from an extended period of time is condensed into a short and action-packed highlights reel, which some visitors took great delight in!

Some visitors gave feedback that the wall projection was striking and valuable in providing some additional context and background to the piece but that it distracted them slightly and they would have preferred to view it in isolation and been able to experience just the sound and the lit labyrinth. If I chose to exhibit the installation again, I would ideally allocate a separate darkened room as a holding area, where visitors could view the projection with a soundtrack of spill from the installation space and then enter the main space for a first look at the labyrinth.

The installation functioned well for the duration of the exhibition however one issue was identified with the use of Bluetooth technology. The Bluetooth signal broadcast from the beacon, like all Bluetooth signals, is a radio frequency and as such, is omnidirectional and therefore should be easily received from any angle. With the relatively low power used to transmit the signal for optimal granularity of location detection, as determined during my calibration tests, reception of the Bluetooth signal suffered from shadowing at times, this is when a direct line-of-sight signal path between transmitter and receiver is obstructed such that the signal suffers drop-outs.

The shadowing in this case was caused by the torso of some users, while they were facing away from the Bluetooth receiver, with the lanyard containing the broadcasting beacon located at their fronts, their torso caused shadowing of the direct line-of-sight signal path, likely due to the very low transmission power that I had selected. This happened only intermittently and I could not pin down the exact conditions that caused it, but fortunately this issue would not have

been overly apparent to the user, if at all, however I found it noticeable given that I was continually anticipating sounds to be triggered at certain user locations. To overcome the issue of potential body shadowing in any future applications that required low-powered transmission, I would mount the beacon on a headband or hair clip so that it was positioned on top of a user's head, to ensure an unobstructed line of sight to the centre of the installation, from all bodily angles and orientations.

4.8 PROJECT SUMMARY

How does one begin to design sound to convey phenomena, where one's personal experience of said phenomena is narrow, little or non-existent? How can we know the turbulent effects of the female menstrual cycle as an individual who may have no direct experience of this bodily process? And how does one decide which effects to incorporate into the design, if they have not themselves experienced the full range of effects?

It was the divergent nature of subjective experience and the desire to accurately represent lived experience with sound in the Her[sonifications] project that sparked the need for the new design method, Embosonic Design.

A group of women were brought together in a workshop environment and through a number of planned activities, we gathered a broad range of insights into the various effects of the female menstrual cycle. The ideation activity drew on participants' personal experience to gather a 'collection of feels', a common language for describing some of the more visceral aspects of female experience. The women were then introduced to the concept of embosonic sketching and were able to translate these insights into meaningful sonic representations. The women naturally began considering elements such as dynamics, duration, resonance and decay, with regard to how sounds should change over time to convey the characteristics of the effect as it develops and fades away, also making use of metaphors and analogies to describe the structure and form of imagined sound.

The intrinsic value in Embosonic Sketching became clear in terms of how it strips out the terminology that sound designers use when they describe sounds and makes the exchange of ideas about the form and characteristics of sound, more accessible.

The women were able to self-sonify their lived experiences with just their hands and the sounding objects. The development of ideas that were initially difficult to describe were made possible through the women exploring the sounding objects and making reference to the characteristics of different sounds. Exploring the sounds provided the women with opportunities to further reflect upon and refine descriptions of embodied phenomena enabling them to more accurately share the nature of it with the rest of the group.

With the ideation and translation sessions audio recorded for data collection and close-mic'd recordings made of the raw sound sketches as the women performed them, I was able to perform a thorough analysis of the data collected, which led to the unearthing of temporal aspects of the concepts raised. This allowed me to contextualise each effect within a typical 28-day menstrual cycle period and produce data maps for each of the women.

The data maps produced a cyclical representation that played a significant part in informing the design and layout of a physical floor-based, walkable labyrinth. The data maps were also fundamental in determining the locations on the labyrinth where the sound files would be triggered and heavily informed the audio-post production process and additional sound design that was carried out.

In this chapter I have provided a detailed description of the design process undertaken to create the interactive sound installation Her[sonifications]. A significant part of that design process was enabled by embosonic sketching, the new participatory design method for sonifying qualitative data developed specifically for this project and shaped further as a result.

I have described how it was applied in practice and have reflected deeply on the new knowledge and extended opportunities that emerged through its application in a real-world project. The new knowledge gained throughout the design process informed the set of design guidelines outlined in Chapter 3.

I have described the workshop planning and participant recruitment process and have provided an account of participant involvement with both the 'Ideation' and 'Translation' workshop activities. While describing in detail each stage of the design process, I have shared my insights and observations and have been explicit about the decisions that were informed by tacit knowledge and my experience as a designer, creative technologist, researcher and sound engineer.

This project enabled me to actively evaluate the potential of embosonic design and I have attempted to describe all of my personal reflections and observations in the context of how and when they were formed. The rest of this chapter is dedicated to my analysis and overall evaluation of the design project, with details of further work that was identified in order to improve the method.

4.9 Analysis

This design project not only provided the inspiration for the development of the embosonic design method, but it provided a suitable environment for testing its use in real-world design practice, given that the design goal and artefact was a public-facing installation due for exhibition at an academic conference.

The first application of embosonic sketching suggests that it is a useful tool for enhanced qualitative data collection in that it can inspire and support deeper descriptions of felt sensations, beyond that afforded by language alone. Through the observations I made during the workshop session, I found that when one sketches sound to describe embodied phenomena to another, the need for finding the appropriate vocabulary is lessened, which is particularly helpful in cases where lexical barriers exist in the ability to provide a full and accurate description.

Furthermore, the performative act of making sound encourages self-reflection and makes space for participants to develop a deeper understanding of embodied experience through their own

refinement of the sounds and concepts used to convey and share their experiences with others. Sketching sound in this way encourages reflection upon previously shared stories and promotes further exploration for finding appropriate sounding materials to work with; rejecting certain sounds (physical materials) in favour of others; and suggesting materials which are not immediately available or that cannot be directly manipulated.

The four women who took part in the project were invited to experience the Her[sonifications] installation for themselves and take part in a subsequent focus group session, where they were asked to reflect on their participation in the project and the resulting artwork produced. The focus group was intentionally informal, providing a space for open discussion rather than employing a structured interview approach.

The feedback indicated that all of the women found that their participation in the project provided considerably therapeutic benefits. They each described how they enjoyed talking in detail about a taboo subject openly in a group but that in particular, they found engaging in a creative process to create the sounds together brought light-heartedness and joy to the session, one participant commented that they came out feeling revitalised and felt that they wanted to call a particular friend to tell them about the experience.

The women indicated that it was the creative element that encouraged such deep self-reflection, that it made space for them to each develop a deeper understanding of the individual matters they had raised through their own refinement of the sounds, the language and the concepts used to convey their lived experiences.

The women also spoke about a sense of empathy and connectedness that they felt with the other women and how the creation of sounds gave a sense of ownership and materiality, that these effects were now more than a feeling experienced alone, they were now externalized, made real, identifiable and visible to others.

The feedback from the women show that embosonic sketching affords a sense of embodiment while producing sound; and ownership of the sounds produced, which is natural, accessible and empowering for those taking part. Presence through sound and physicality, and oneself becoming a sounding object, encourages playfulness and enhanced engagement in participatory design settings.

4.10 Evaluation

The successful use of embosonic design methods in this project shows that embosonic sketching is a useful and accessible tool for exchanging ideas about sound and can promote heightened participant engagement with participatory design processes. In particular, it can: enrich the process of qualitative data collection in group-based settings; produce sound sketches to inform the sound design process; and enable the creation of self-actualised sonifications of visceral and experiential phenomena [129].

In terms of trialling the embosonic design method in practice, it is important to contextualise the research and consider the limitations and nuances of working in the wild, for example working with a different set of participants would have brought different views and perspectives, which would've resulted in different outcomes.

In terms of doing participatory design in the wild, we must take an experience-based approach to methodological understanding for example, participants on another occasion may be less engaged; preoccupied by external factors or personal circumstances; or have personal characteristics or experiences that might inhibit full participation with the workshop activities. In practical terms, there was a degree of selection bias in relation to the participant group that took part in Her[sonifications] due to how the workshop was pitched and advertised (section 4.2.1), resulting in a participant group made up of female students with mostly creative backgrounds.

I am aware that if I had recruited volunteers from the general population with no creative experience, this may have had an impact upon the success of the method and the quality of the design outcomes. I acknowledge that it would have been beneficial to have trialled the method in a wider range of arts-based design situations and with a broader range of participant groups.

I did plan for one more arts-based design project, both to trial the method with non-creatives and to investigate potential use for creative arts therapy, in order to further explore insights gained from the Her[sonifications] workshop. I had been liaising with a local support group, getting to the stage of preparing an ethics application and designing materials for participant

recruitment but unfortunately, for reasons beyond my control (a change in their management), it could not go ahead. Regrettably, my impending move to full time employment left me with little time to build a solid enough relationship with another support group to initiate a further large design project in that space.

Given that I did not trial the method in a wider range of arts-based design situations, and with a broader range of participant groups, I cannot make broad generalisations from the results of this research project. I see the potential impact of these factors as relatively low however, given that I experienced high engagement and positive results with the sound-making activities during initial trials with friends and family, who have little to no artistic experience or interest.

Looking forward, in order to mitigate against the potential impact of the selection bias associated with this research, I would recommend that if an individual or group wishes to employ the method as an arts-based approach, that they ensure an experienced workshop facilitator is present. Effective facilitation, where participants are engaged and fully supported through the activities, will ensure they have a positive experience, which is essential for achieving good design outcomes.

In terms of using embosonic sketching as a design practitioner, never before had I had such a detailed brief for a sound design project. I was able to use my audio skills and experience to essentially polish and build on the sounds already been created by the women and the deep descriptions they had shared. In this regard, the design process felt truly collaborative and I feel confident that the installation presented a more accurate representation of female experience, than would have been possible, through traditional sound design practice.

With respect to the significance that the temporality of effects had on the functional and aesthetic design of the final sound artwork, there were implications brought about through a failure to actively capture this temporal data. These implications had not been anticipated and only became evident after the ideation activity was well underway.

If these implications had been anticipated at the outset, I may have been able to devise a suitable method for capturing temporal data. This may have enabled earlier identification of patterns and lessened the need for the intensive, manual data analysis required in producing the data maps. A suitable method may also have enabled the participants to be actively involved with

plotting the data, which may have led to further description and refinement of the temporal aspects of the stories shared. In conclusion, there was a need for further work to explore methods for real-time collection of temporal qualitative data in order to improve the embosonic design method.

5 EMBOSONIC DESIGN IN PRACTICE 2: EMOTIONAL MACHINES

In this chapter I will describe how embosonic design was employed in industry to help inform and facilitate work exploring how smart speakers and other voice-activated devices might exist and function in our daily lives in the future. I will firstly provide some context about how the opportunity arose that allowed me to continue my research on this new design method, by employing it in a broadcast and media industry-based research and development setting as part of a mixed-modal interaction design study.

While I was still a full-time HighWire PhD student, I completed an application for a full-time position with BBC Research and Development (BBC R&D) on their Graduate Scheme. The prestigious and highly sought-after Graduate Scheme at BBC R&D offers exceptional training and development opportunities as well as permanent employment with the public-service broadcaster. As working at BBC R&D was my ultimate career goal following completion of the HighWire Digital Innovation programme, I completed the application as a practice-run, knowing that it was open for only a small window each year, hoping to familiarise myself with the application process in preparation for applying for real further down the line. A few months later, I was invited for interview and shortly after attending, was offered a place on the 2018 intake of the BBC R&D Graduate Scheme. After seeking advice from my PhD supervisors Alan and Paul, I made the decision to accept the offer of employment from the BBC and to continue working on my research in my spare time.

With the context of how embosonic design (and me as a researcher) came to be transferred from academia to industry now clarified, I will now describe how this new method was used to inform and facilitate the research carried out during my first project as a trainee Research and Development Engineer with BBC R&D.

The Emotional Machines project explored the concept of a future smart speaker that could express emotion and internal state. I defined the modalities of gesture, sound and light/colour as suitable communication channels through which a device could express emotion and then explored each modality through a series of workshops. Three prototypes were built and tested

with users to probe the efficacy of the three modalities for emotional expression in relation to human understanding. The insights gained through the workshops and the findings from the user tests led to the development of an emotional voice robot prototype. The following sections will describe how embosonic design was employed to inform and facilitate this exploratory work as well as how it fed into the development of design resources for future work in this area.

5.1 Introduction

The Emotional Machines project was my first graduate research project where I was supervised by Libby Miller, a Lead Producer working in the London-based Internet Research and Future Services section of BBC R&D. The project, proposed by Libby, was inspired by the fact that machines could, in theory, use Machine Learning to at least partially understand peoples' emotional states, and could use tools to convey emotional states too. The aim of the research was to explore the over-arching research question *how might machines show us how they feel*?

Machines do not have affective states like humans, but they can be uncertain or confident about something, based on the probabilities issued from their machine learning models. Machines can know the condition of their surroundings through either onboard sensors or via the Internet of Things in a smart home environment. They can also know their exact location in the world as well as the state of the wider world. The potential benefits of machines expressing simulated emotions include social bonding, user empathy towards machine internal state, directing user flows and enabling new forms of value.

At the time the research was carried out in late 2018 and early 2019, voice technologies were of particular interest to the BBC as the scale of audiences regularly interacting with BBC audio content on smart-speakers was seeing significant growth. Early ideas about creating the World's first public service voice assistant were also starting to form (the BBC Voice and AI team later released the beta version of 'Beeb', the BBC voice assistant, in early 2020).

BBC R&D conducts research with a longer-term view, experimenting with ideas for how media might be produced, delivered and consumed in five to ten years into the future. In the context of smart speakers, I was exploring a future where voice-assistants could show simulated emotions of their own. For example, what if a voice-assistant could show embarrassment when they do not know something or could exhibit exhaustion after a day of continuous use? What if Amazon's Alexa could be saddened by bad news and excited (or not) about the arrival of visitors. What if Google Home could express its comfort with the temperature and noise in the room or offended by our tone of voice when we issue commands?

Machines can also obtain sentiment data, where Machine Learning models are used to approximate the emotional state of a user so I wanted to explore a future where voice assistants can use this data to communicate with users more effectively. I considered what a future might be like if voice assistants could detect how we were feeling and change their behaviour, tone of voice and functionality to better suit our mood. For example, what if Siri could give us fast, to-the-point answers when we are in a rush? What if Alexa could be cheerful and playful when we are feeling upbeat; and be soothing, restrained and low-key when we are tired?

During the eight-month project, I aimed to generate ideas for, research, build, and evaluate a physical robot / smart speaker that uses appropriate mechanisms *e.g., movement, lights, sounds,* to express emotion and behaviour *e.g., listening, agreeing, offended, embarrassed, friendly*, in response to voice commands.

In the following sections, I will describe my approach to the research activities undertaken that were informed and facilitated by embosonic design, which included a sound ideation workshop, the production of the sounds used in the experiment and the design of hardware prototypes for user testing. I will also share some of the key findings that emerged through the use of embosonic design, specifically the new knowledge that was produced from transferring concepts from the sound domain to the domains of gesture and light and a design tool that was produced to help people design multimodal expressions of simulated emotion for non-anthropomorphic machines.

5.2 User Research

The results of some user research I carried out at the start of this project fed into the subsequent activities where embosonic design was employed. I will provide a brief summary of how the user research was carried out and will share the results that informed the design activities and therefore relevant to this particular use case.

Should the reader be interested in the user experience of smart speakers and the emotions that people experience when interacting with them, all results and key findings from the user research is detailed in the publication 'Smart Speaker UX and User Emotion' by Young and Miller, which is available on the BBC R&D website[16].

The aim of the Emotional Machines project was to explore the possible future evolution of voice assistants possessing more human-like behaviours such as expressing internal state and being responsive to user mood. I designed and carried out some user research in the form of an online survey, in order to understand the user experience of current voice products *(e.g., Google, Alexa and Siri)* and to determine the range of emotions that users of these products experience.

I wanted to inspire people to think speculatively about future smart speakers by offering relatable scenarios within the survey questions, in order to gain insight into the values, desires and concerns people have for a next-generation voice assistant.

The survey was advertised on the BBC R&D website within a blog post that discusses the role of emotion in future voice assistants[17]. I collected and analysed statistical and qualitative data from 330 participants, who had completed the survey in full.

[16] BBC R&D publication 'Smart Speaker UX and User Emotion': https://www.bbc.co.uk/rd/publications/voice-assistant-interface-emotion-research

[17] BBC R&D blog post: https://www.bbc.co.uk/rd/blog/2019-01-voice-interface-emotion

People of all age groups took part although distribution was uneven, with higher numbers of people aged between 25 and 54 and a slightly unequal gender split of 46% female and 54% male. The sample population contained representation from all UK nations and regions, with predominance in both North West England and London, likely due to a large number of BBC staff taking part and the largest BBC working sites being located in these areas.

Analysis of the survey data led to a number of key findings, which allowed me to make a number of useful recommendations for the improvement of existing voice products and for shaping future work.

The results that are relevant to this thesis however are those that informed the activities where the embosonic design method was employed. These are the most prevalent emotions that users reported to have experienced while interacting with a smart speaker, which are: *anticipation, curiosity, interest, frustration, hesitancy, surprise, excitement and joy*, as shown in Figure 28.

These six emotions were selected as the key emotions to explore in a series of workshop sessions that were designed to investigate the modalities of sound, gesture and light/colour as communicative channels for emotional expression.

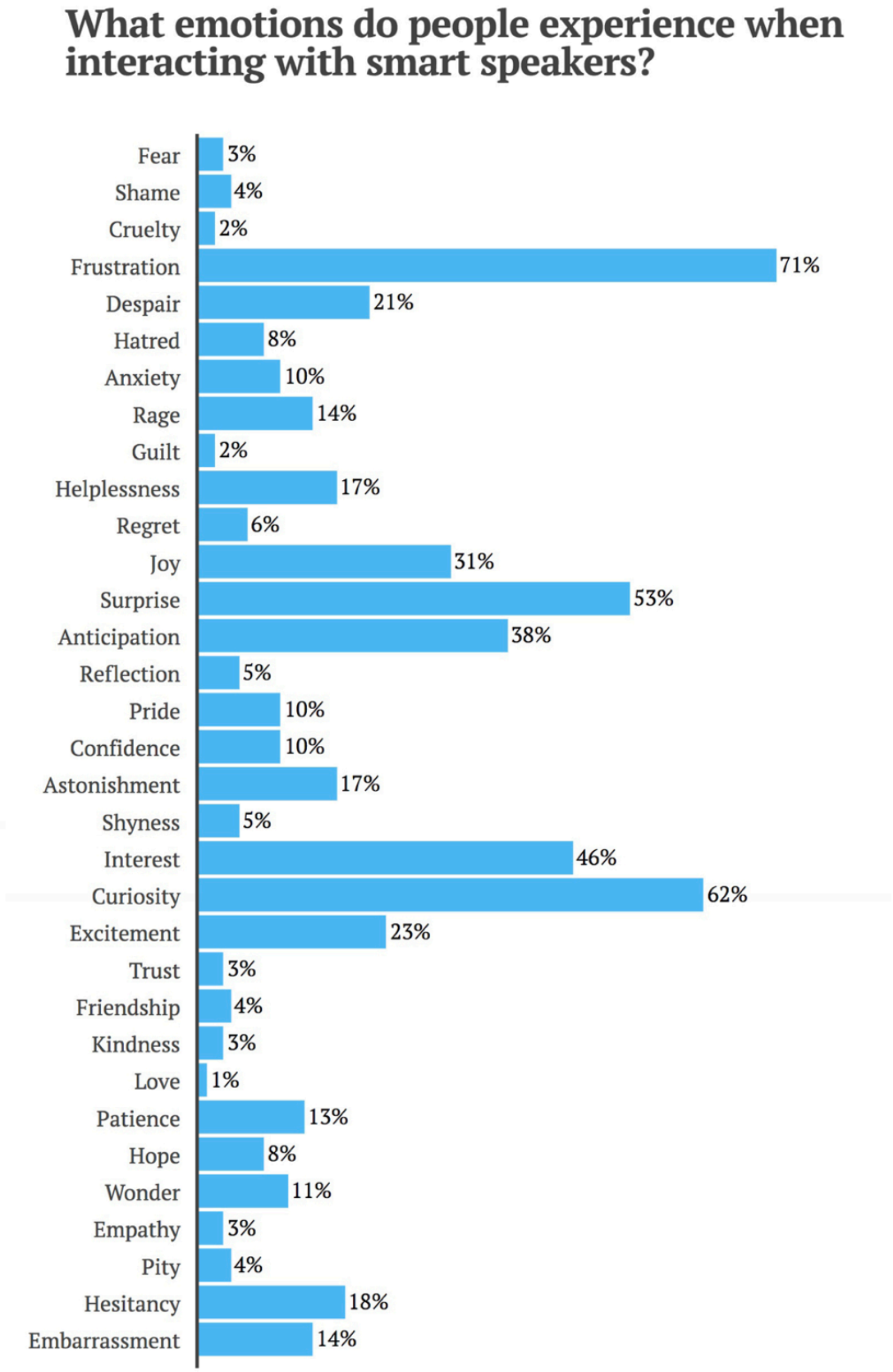

Figure 28: Graph showing the distribution of emotions experienced by smart speaker users based on survey data

5.3 Doing Embosonic Design at BBC Maida Vale Studios

In order to explore the three modalities selected as emotion communication channels *i.e., gesture, light and sound*, I organised a series of workshops, bringing in facilitators with expertise in each area to work with me and some of the designers and engineers from BBC R&D.

I explored gesture in two workshops led by an expert in robotic design, where I learned about the first principles of animation and the fundamentals of puppetry, where participants were shown how enacting changes in speed, tension, rhythm and focus can convey a puppets intention, emotion and its response to stimulus, in even the simplest of puppets *e.g., a piece of fabric*. I then explored how sentiment can be conveyed with light and colour with the help of a cinematic photographer, who introduced participants to colour theory and emotion perception; and the role of colour in visual storytelling. And finally, I explored how sound can convey emotion in a workshop I designed and led, and it was during this workshop that I introduced participants to embosonic design.

As described in the conclusion of the previous chapter of this thesis, the Her[sonifications] project revealed the need for further work to explore how the temporal aspects of the qualitative data and the sonifications could be captured in order to reduce reliance on transcribing and analysing workshop dialogue and doing extra sound design around (and post-production processing of) the short raw sound sketches produced. I had taken this into consideration when designing the sound workshop.

5.3.1 Workshop Environment

The workshop took place in the Radio Drama Studio (Studio MV6) at BBC Maida Vale. For readers that are not familiar with Maida Vale studios, I will provide a bit of background: the complex of seven studios and performance spaces is the BBC's earliest premises and it has been used to record music and drama sessions for BBC radio since 1946.

It hosted BBC News operations during World War II and the BBC Symphony Orchestra has been based there since 1934.

It was also home to the BBC's Radiophonic Workshop from 1958 to 1998, where producers and engineers experimented with electronic music and sound, developing tape manipulation techniques for producing unusual sounds and effects in the days before synthesisers were available. Many notable television themes and sound effects were created there, including the original 'Doctor Who' theme and the sound of the 'sonic screwdriver', a fictional tool that appears in the television series. Some of the tape effects developed at the Radiophonic Workshop made their way into mainstream studios and onto major artist's records, including Pink Floyd's first album 'The Piper at the Gates of Dawn'.

The Radio Drama studio is made up of multiple spaces with differing levels of deadness, *i.e., a range of absorptive materials line the walls and floors which alter the sonic reflectiveness of the space,* to suit the needs of any production. There is a kitchen area that is fully mic'd up for capturing any kitchen-based drama scenes and a staircase with three different surface materials per step (wood, concrete and carpet), allowing producers to capture footsteps according to their needs.

Similarly, there is a full range of internal and external doors to capture the perfect door slam and buckets of different materials for stepping in, including reams of scrap magnetic tape that emulate the soft crunchiness of footsteps on snow. There is even a corridor to nowhere, that spirals in on itself and becomes ever narrower until you reach its dead end which, as the Studio Manager demonstrated to everyone's delight, creates the perfect sound of somebody running off into the distance.

Aside from all the fascinating quirks of MV6, the primary reason for choosing this studio in particular is that it includes a comprehensive props store with an abundance of sounding objects that are used to create spot effects for most of the BBC's radio content, this not only gave convenient access to a sound palette for the translation activity, but was in effect, the greatest and most varied sound palette you could possibly imagine (see the images in Figure 29 for context).

Figure 29: The props store of sounding objects attached to the Radio Drama studio at BBC Maida Vale

The workshop was attended by eight BBC R&D colleagues, composed of a mix of engineers, producers and user experience designers. Three of the attendees have significant experience in audio production and I was therefore interested to see how they would respond to the activities and to the overall concept of embosonic design.

5.3.2 Ideation Activity

I had initially planned to run the first of the three activities in the studio, before walking to a nearby green space for the second activity, however given that it was a beautifully warm and sunny day in London, I decided to take the group to the outdoor setting straight away and save the fun of the Radio Drama studio for the final sound making activity.

I began the workshop with a facilitated process of ideation in order to bring focus to the emotions that we would be attempting to translate to sound. These were the principal emotions that were identified in the user research described previously, that the survey respondents had experienced when interacting with voice user interfaces: *anticipation, curiosity, interest, frustration, hesitancy, surprise, excitement and joy.*

I had prepared and laid out large sheets of paper, each with one of the aforementioned emotions written on. I gave my colleagues post-it notes and pens and encouraged them to think about one emotion at a time; to draw upon their own experiences of the particular emotion and to think about the different things they feel when they are actively experiencing it. They were asked to assign meaningful words and conceptual metaphors to convey mental models and any physical manifestations they experience *e.g., changes in behaviour, posture and tone of voice.*

Each person contributed well to the activity and did not hesitate to begin attaching their ideas to the associated emotions. There was a good mix of physical and visceral descriptions, but much less awareness of behavioural consequences than I had seen during the ideation session for Her[sonifications]. I had not used prescribed headings for which to guide contributions, as I had done previously, but instead had purposefully avoided setting any form of classifications or delineations between the different manifestations of phenomena.

The reason for this decision was that some of the attendees of this sound workshop had also recently taken part in the robotic animation workshop and had spent two days immersed in thinking about emotion with respect to movement and gesture. Additionally, my colleagues were aware that the reason for running these workshops, was to inform the design of a physical voice robot prototype. I hoped that by not guiding people to specifically share behavioural

manifestations, I might improve the chance of them becoming immersed in and thinking about sound.

Figure 30 shows the group taking part in the ideation activity, building the ‘collection of feels’ for the eight key emotions identified in the user research.

Figure 30: The Ideation stage of the embosonic design workshop for Emotional Machines

5.3.3 Deep Listening

Following on from the ideation activity, I guided the attendees through a deep listening exercise where they were encouraged to stay silent for a short period, actively listen to the ambient sounds in the environment and to plot on paper their perceptions of the different sound sources they heard with respect to both spatial positioning and movement.

This activity aimed to get participants into active listening mode bringing focus to sound, space and silence, and to heighten awareness of the materials and motion of things we hear in the world. The outdoor environment in the residential neighbourhood of Maida Vale provided a rich soundscape for the attendees to focus on, from sounds from the nearby canal and the adjacent play park with its tall trees providing sanctuary for the birds, to the rumble of traffic and overhead planes, to passing phone conversations and the mish mash of radios and televisions through open windows on a hot day.

The images in Figure 31 show the attendees listening for the different sounds in the environment and recording the position and any motion of the sound sources they heard.

After approximately fifteen mins of sitting in silence, I invited each person to share some of the things they heard, with each person having picked up some subtle sounds that some of the others had not heard. We talked about the different approaches to recording what was heard, with most of the attendees favouring a graphical method of documenting the motion of sound sources whereas some favoured writing a list of sounds with textual motion descriptions.

Figure 31: The Meditation stage of the embosonic design workshop for Emotional Machines

Moving into the Radio Drama studio at BBC Maida Vale, I gave a short introduction to the concept of embosonic sketching, and spoke about how my process was inspired by the art of Foley sound design for film, I shared some examples of Foley and spot effects production that demonstrates how various materials can be used creatively to produce new sounds which complement the onscreen action in a scene.

I wanted to spend some time talking about these things as firstly, as creative beings, I knew my colleagues would be interested and secondly, the iconic location we were occupying warranted a bit of reflection and context on the techniques we were about to employ.

I fixed the sheets of paper with the data we had generated for each emotion during the ideation activity, onto one of the walls. With there being nine of us taking part in the session, I instructed the attendees to organise themselves into three groups of three people and I joined the group that was one person short. I then instructed each group to discuss and choose one of the emotions with the requirement that they did not share their choice with the other groups.

I explained that we would then, in our groups, attempt to create sound sketches for the selected emotion, prompting them to consider each phenomenon associated with the emotion and discuss the sonic qualities that they would imagine the phenomenon to exhibit if it could produce sound.

The Studio Manager who was working with us that day, then invited us to start exploring the extensive props store, which was a just short walk along the corridor, and I must say it really is a feast for the eyes. The range and quantity of different objects, covering the spectrum from the mundane to the completely obscure, is a sight that surprised us all. He shared some stories about a few of the items and demonstrated some of the strange and surprising sounds that can be generated by manipulating objects in different ways, as we listened intently.

I encouraged the attendees to investigate the objects, to detach them from their intended purpose and/or operational use, and to instead consider their physical qualities; the different materials they are made of; their surfaces; and their moving parts, and to consider each object as nothing more than a sounding material.

I instructed them to select objects based on their potential for sonifiying the phenomena associated with the emotion they were focussing on. I then encouraged them to return to the Radio Drama studio when they were ready, bringing with them a potentially suitable and appropriate selection of objects and in their groups to describe their choices and demonstrate the sounds they could generate. I suggested that they then try working together to collectively translate the collection of metaphorical concepts gathered previously, into meaningful sonic representations of their respective emotion.

Back in the studio, having given the groups approximately twenty minutes to work on their sound sketch, I announced that they would be invited to perform their sound sketch for the rest of the attendees and that we would record the sounds as they were being performed.

Our Studio Manager had set up a table and a microphone, which would act as both the performance and recording area and I invited each group in turn to perform their sound sketch (see Figures 32 – 34).

After each performance, I invited the remaining two groups that were observing to guess the emotion that was being conveyed. A high success rate was achieved, with observers perceiving the performed emotions correctly in all except once case, where *hesitancy* and *curiosity* were mistaken for each other.

After all the groups had performed their sound sketches I asked the attendees if they would like to try repeating the process and sketching the sound of a different emotion. All were keen to try another and one group managed to fit in a third round. Again, a very high success rate was achieved, with all sketches being linked correctly to the emotion they were attempting to express, except in one case, where the sketch for 'curiosity' was interpreted as 'hesitancy'.

Before we left Maida Vale studios, our Studio Manager who had been recording the session, made a copy of the recording for me to take away for further use. Every attendee gave feedback that they enjoyed the session and had found it a really useful design method for collaborative sound design that was completely different to anything they had engaged in before.

One colleague commented that they had always felt that they could not play much of a role in designing sounds for digital products and had trouble defining sound design briefs when engaging external audio producers. They said that this method could potentially give them the ability to express ideas and explore different options with their collaborators.

A couple of my colleagues told me the following day, that they had continued to experience a heightened awareness of sound during their commute home from Maida Vale, which demonstrates the effectiveness of the activities for encouraging people to more deeply engage with sound.

Figure 32: Group 1 performing sound sketches with a range of sounding objects

Figure 33: Group 2 and Group 3 performing sound sketches with a range of sounding objects

Figure 34: The Studio Manager at BBC Maida Vale recording the performed sound sketches

5.4 Cross-modal Insights

In the workshop, the attendees approached the ideation activity with substantial use of conceptual metaphors when contributing ideas about the physical and visceral manifestations of the emotions *e.g., anticipation is a racing heart*. While reflecting on the workshop process and the output, it was clear how these conceptual metaphors were useful for translating emotions into physical parameters.

In this case, those physical parameters *e.g., an accelerating heartbeat,* were conveyed with sound, however they could similarly be conveyed with the other modalities I was considering for a machine to express emotion (light and gesture).

I wondered if equivalent gesture and light-based expressions could be intuitively understood by a user if they incorporated the same mental models and emotional manifestations described by the workshop attendees. In essence, could the ideation and translation activities used in embosonic design be useful in helping to inform the successful design of lighting effects and gesture simulations.

Reflecting on the sound workshop, I compared my observations with what I had learned from taking part in the gesture workshops with the robotics expert, which focussed on the fundamentals of puppetry *e.g., speed, tension and stimulus response,* along with the fundamentals of animation *e.g., squash and stretch, slow in and slow out, and solidity.*

Through my reflections, I established that those concepts could be transferred to the domains of sound and light, and could be applied to the physical parameters of all three target modalities, being that although the modality's features diverge taxonomically, there are similarities with respect to the transformations of a medium in space and in time.

Drawing from the literature, Knight and Simmonds [80] produced a set of motion features based on the theatrical method of the Laban Effort System [83], an ontology for how we enact motion and a widely-used system used in drama training. The Laban Effort System defines the basic components of physical movement and their associated state possibilities. Through a combination of these efforts, an actor is able to indicate their character's inner state through four basic components of physical movement and their associated state possibilities:

1. **Direction** (attitude toward target)
   - ***Direct*** *(single-focus) or* ***Indirect*** *(multi-focus)*

2. **Speed** (attitude toward time)
   - ***Quick*** *(abrupt) or* ***Sustained*** *(gradual)*

3. **Weight** (force or apparent inertia)
   - ***Heavy*** *(powerful) or* ***Light*** *(delicate)*

4. **Flow** (sense of restriction)
   - ***Bound*** *(constrained) or* ***Free***

Knight and Simmonds operationalised the Laban Effort System to create motion vectors for mobile robots with only position (x, y) and orientation/angle (theta) available, with a view to being able to use only these features to generate expressive motion.

Applied to a mobile robot with omnidirectional base, they attempted to express oppositional pairs of emotions relative to their robot's task scenarios *e.g., Happy vs Sad in response to their success or failure of a task*. They found that the Laban effort system is useful for expressive motion and suggest principles connecting Laban efforts to robot state, for example to clearly communicate 'shy', direct paths with hesitations are appropriate and that timing elements are fundamental for distinguishing between manners.

I propose that these concepts from the Laban Effort System can be meaningfully transposed to the mediums of sound and light, in order to understand common affordances inherent in each modality.

These insights and learnings led to the development of the Modality Parameter Matrix shown in Figure 35, in which I have mapped the corresponding physical parameters of gesture, informed by the Laban Effort System, for sound and light and have defined equivalent state possibilities for each.

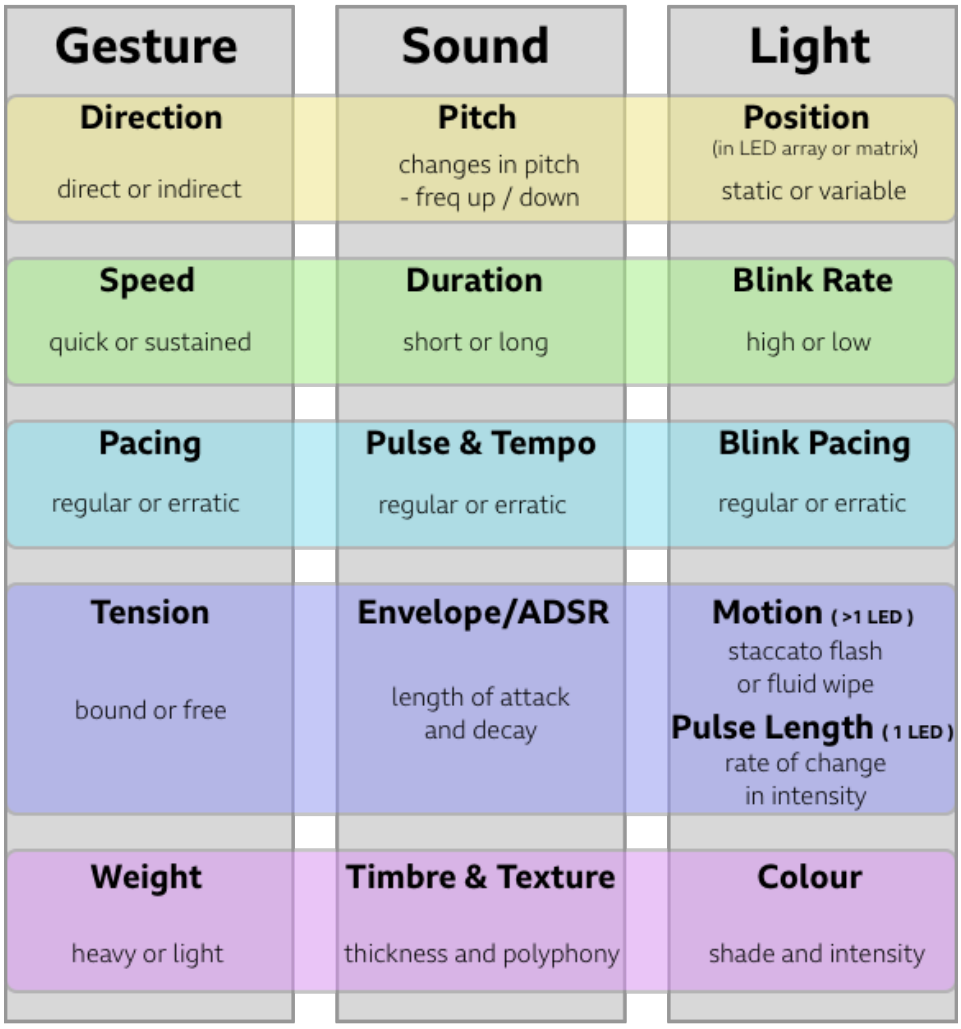

Figure 35:Modality Parameter Matrix showing affordances and state possibilities for gesture, sound and light

I wanted to test the theory and investigate whether the matrix could be a useful design tool for emotion expression, I therefore employed it in the design of a set of emotion sequences for gesture and light in order to test their effectiveness alongside the sound sketches created by the workshop attendees. The emotion sequence design was informed by the outcomes of the ideation activity employed in the sound workshop. I will describe this process in the following section as I see it as being relevant and useful for readers who may want to extend the outcomes of the embosonic design method for multi-modal design tasks.

5.5 MULTI-MODAL EMOTION DESIGN

A number of emotion sequences were designed using the Modality Parameter Matrix that was developed based on the insights and learnings from the workshop series, with the gesture parameters inspired by Knight and Simmonds operationalisation of the Laban Effort system [80]. This matrix shows the physical parameters of gesture, sound and light and their state possibilities, revealing common affordances between modalities.

In order to demonstrate how the matrix can be employed as a useful design tool for emotion expression, I will describe how it was used in the design of gesture and light sequences to convey the emotion of 'anticipation'.

The 'collection of feels' shared by the participants during the ideation phase of the sound workshop (see Figure 36) were used in the design process. These were the fundamental concepts and metaphors that the workshop attendees attempted to sonify as part of an overall sound sketch for each emotion.

Figure 36: Ideation data and performance of the associated sound sketch

Taking this data into account, decisions can be made on appropriate state possibilities for each physical parameter per modality.

For example, if we consider some of the reported effects associated with 'anticipation' such as *experiencing nervous energy* and *feeling tense* and we consider the physical parameters of gesture, with reference to Figure 37: it feels appropriate that any motion would be *direct* and not wavering, *bound, stiff and heavy* rather than relaxed, free and light. These ideas can then be transferred to the associated physical parameters of the other two modalities.

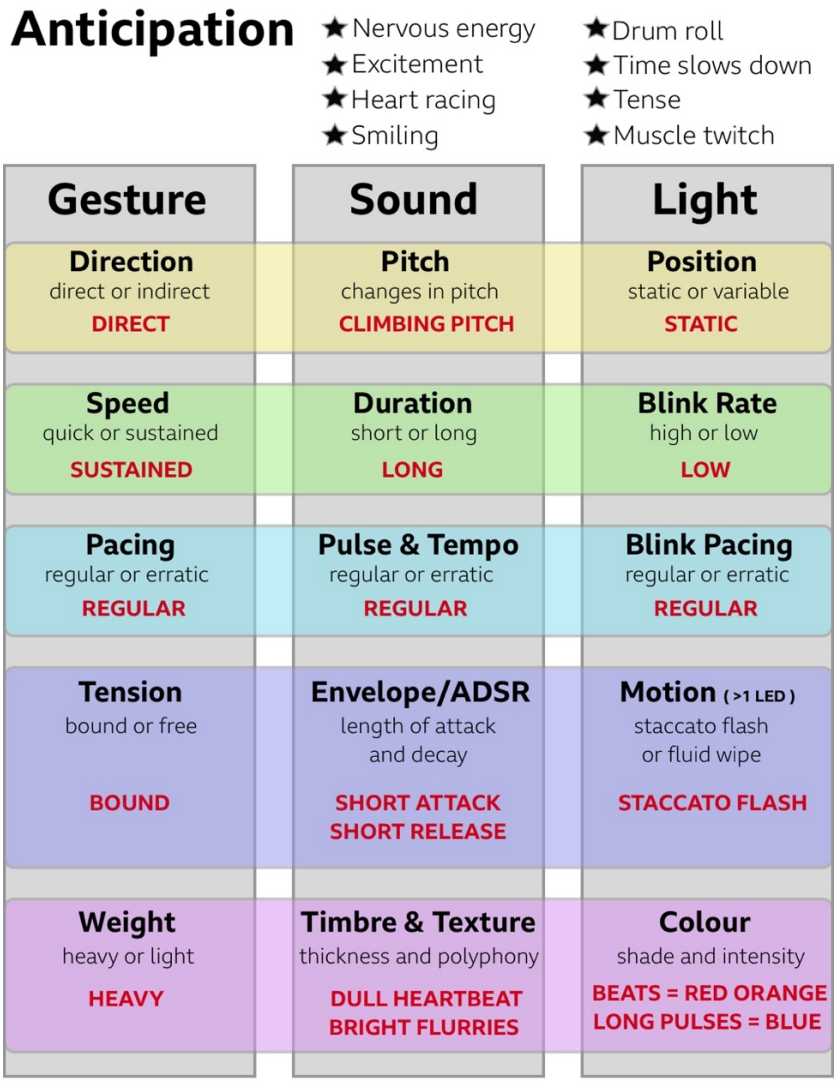

Figure 37:Mapping anticipation metaphors to the Modality Parameter Matrix

Working through the data, we can consider the qualities of each conceptual metaphor or idea shared by the workshop attendees, just as they did in their selection of sounding objects and in their sketching performance, and we can note the appropriate state possibility until the matrix is fully populated.

When considering each available parameter individually in this way, we are essentially creating a design brief where the properties of any gestures, sounds and lights should fulfil each state possibility for their respective physical parameter, as far as is possible.

I employed this method in the design of six lighting sequences and six gesture sequences, each representing one of the top five emotions identified in the user research as the most common emotions that people have experienced while interacting with voice user interfaces.

In the following section I will describe how I tested the effectiveness of the gesture and lighting sequences and the sound sketches created by the workshop attendees, with real users.

5.6 User Testing Design

In order to test the efficacy of the three modalities for emotional expression in relation to human understanding, I designed and built three prototypes that would each test a specific modality *i.e., gesture, sound and light*. Each prototype featured a button interface with five arcade-style buttons so that the separate emotion sequences and sound sketches could be easily triggered individually by a user in a test environment.

The sounds used for the user tests were shortened versions of the sound sketches recorded by the attendees of the sound workshop at BBC Maida Vale and the lighting and gesture sequences had been designed using the Modality Parameter Matrix as previously described. In the following subsections, I will describe how these prototypes were built and will provide links

to working code which is publicly available on GitHub for anyone seeking to work with gesture and light actuation in the Arduino development environment.

5.6.1 Gesture Trigger Prototype

The gesture trigger was built with an Arduino Nano, which was used to drive three servo motors, with five sequences for each servo motor coded within a single sketch, using the Arduino IDE (integrated development environment).

Four parts were 3D printed and attached to the servos: a base mount, a yaw mount, a double joint and a head (see Figures 38 and 39), which were designed to work together to allow three degrees of freedom. In terms of motion, there was a rotational base, forwards and backwards motion in the middle part and side to side motion at the head.

The code I wrote for the Arduino sketch is available on GitHub[18], points to note are that the Arduino's Digital IO pins to which the servos are connected need to be defined correctly, to match the pins used in the physical set-up via the breadboard and also that the inbuilt pull-up resistors should be enabled for those pins.

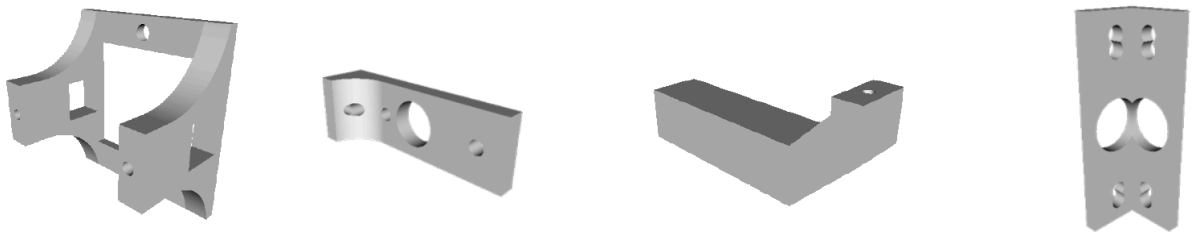

Figure 38: CAD drawings of the base mount, yaw mount, head component and the double joint

[18] https://github.com/bbc/irfs-emotional-machines/blob/master/EM_gesture_fx_trigger.ino

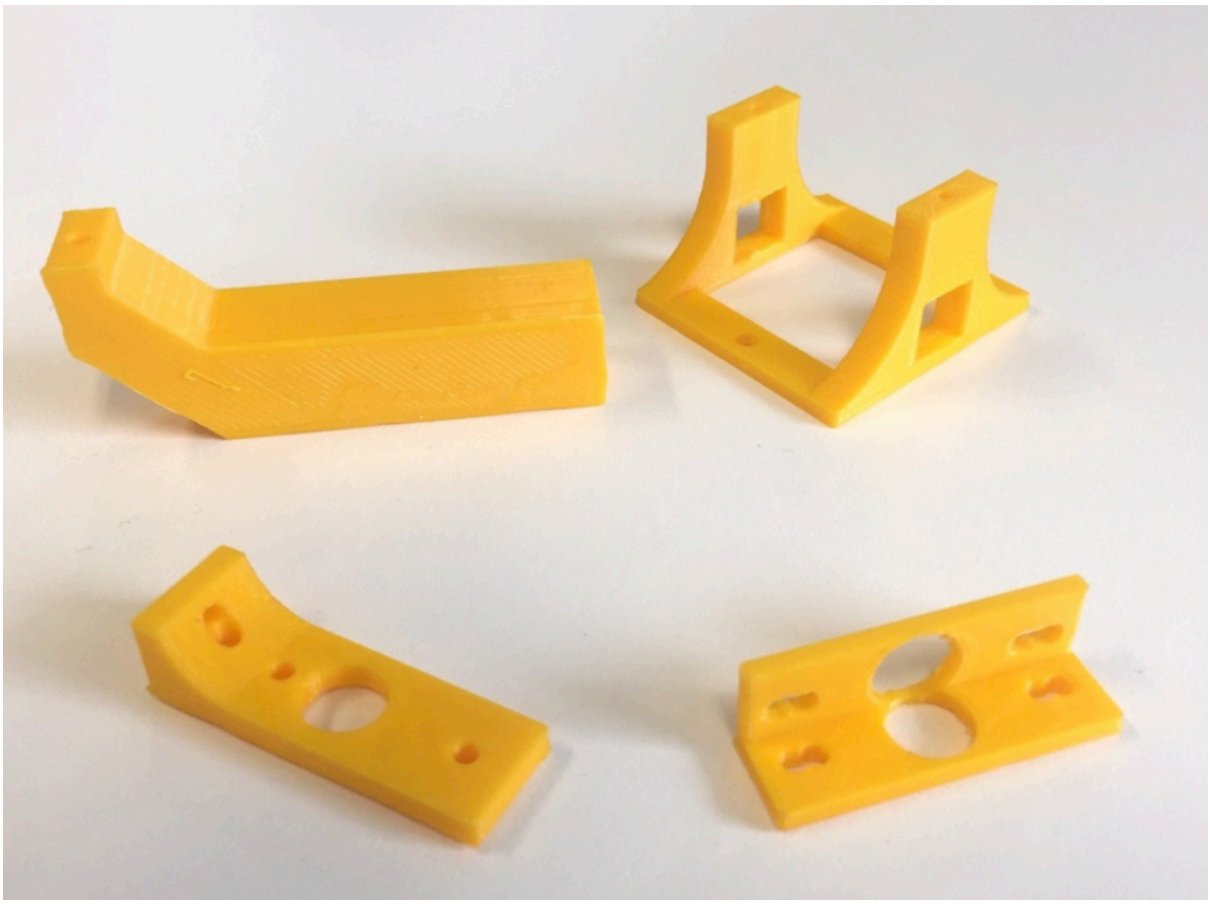

Figure 39: The 3D printed parts for the Emotional Machines gesture prototype

A plastic container was used as a body for the prototype, with the Arduino Nano mounted on a breadboard along with a battery pack, stored inside.

Five arcade-style buttons were mounted on the lid with jumper wires soldered to the arcade button pins to ensure a stable connection and the other connections made via the breadboard.

The components were wired up as shown in Figure 40 and the resulting prototype is shown in Figure 41.

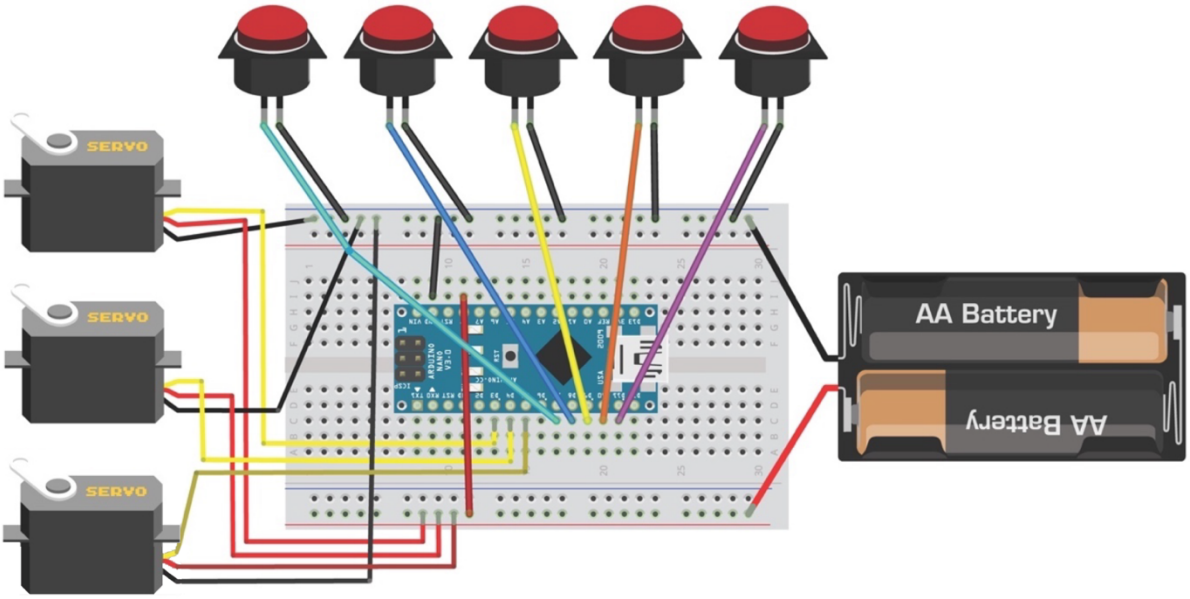

Figure 40: Circuit diagram for Emotional Machines gesture trigger prototype

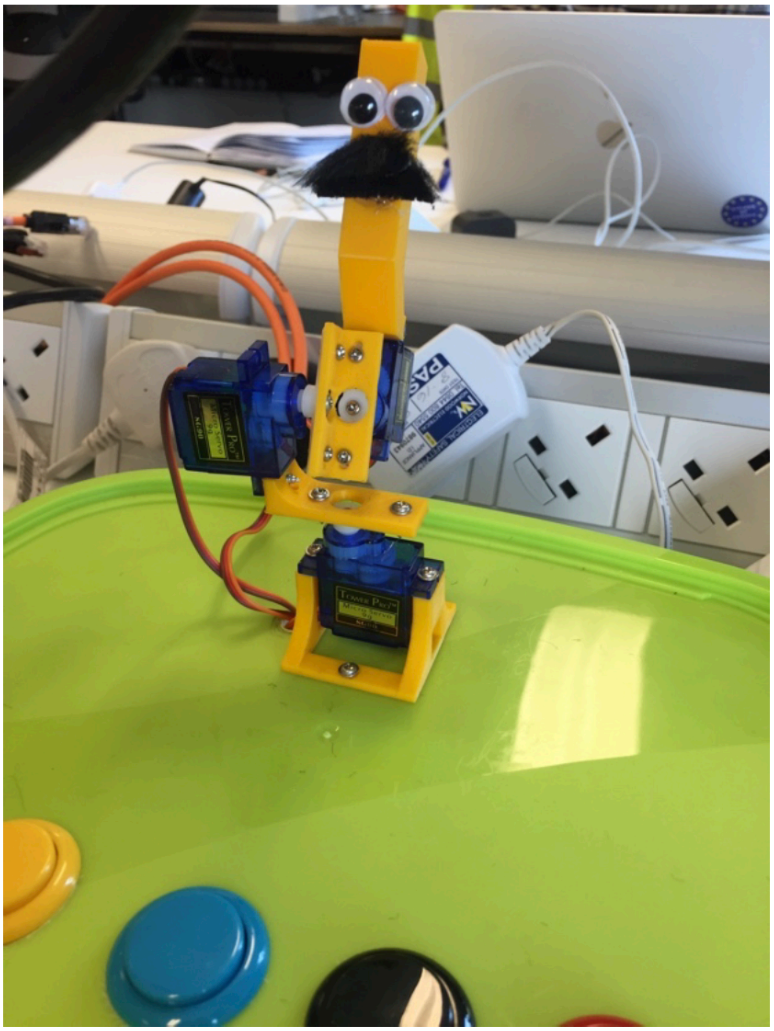

Figure 41: Gesture prototype for Emotional Machines user testing

5.6.2 Light Trigger Prototype

A second Arduino Nano was used to drive a NeoPixel strip containing eight individually addressable LEDs. The five lighting sequences that were designed using the Modality Parameter Matrix, as described previously, were programmed into a single Arduino sketch (code available on GitHub[19]), with each emotion associated to one of the five buttons, in a different order to both the sound and gesture triggers. The components were connected as per the diagram shown in Figure 42.

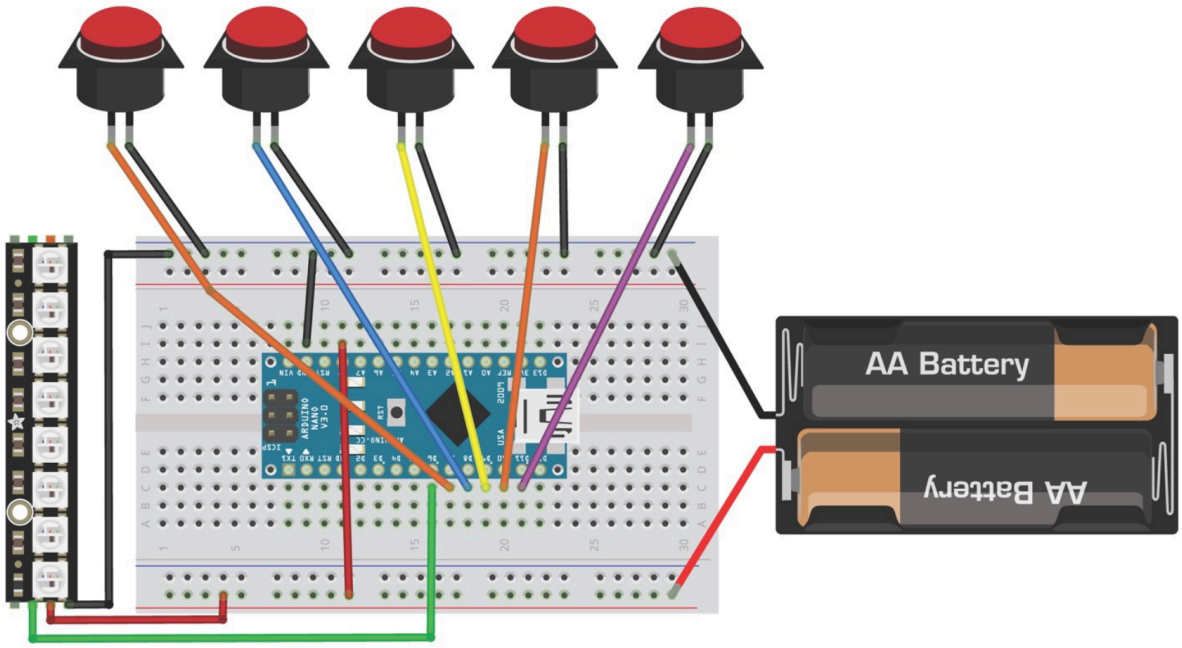

Figure 42: Circuit diagram for Emotional Machines light trigger prototype

Again, a plastic container was used to house the components and arcade buttons were mounted in the lid. A range of materials were tested for use in diffusing the light emitted from the LEDs (see Figure 43), with frosted film chosen for its uniform smoothing effect as well as being most effective at transmitting light at low intensities and when only a single LED was lit.

[19] https://github.com/bbc/irfs-emotional-machines/blob/master/EM_lighting_fx_trigger.ino

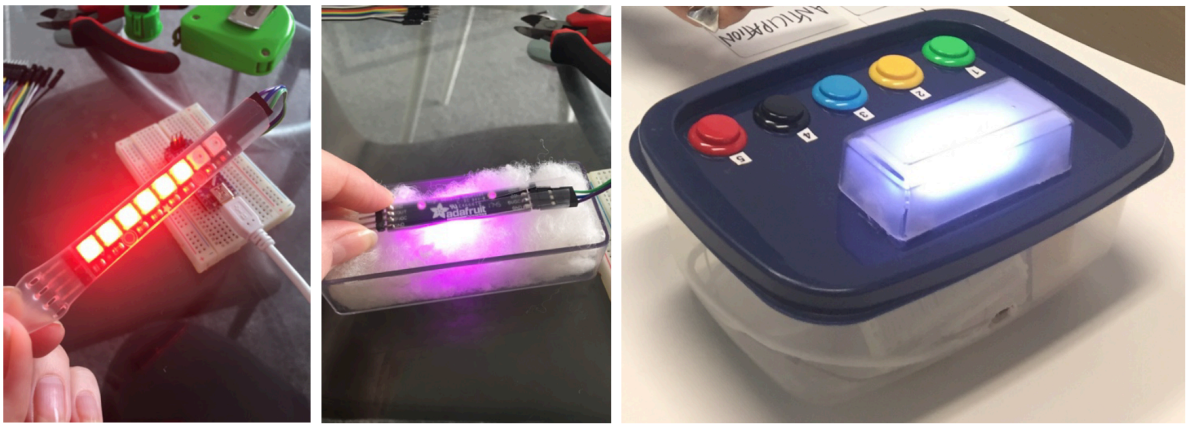

Figure 43: NeoPixel strip; experimenting with light diffusion; light trigger prototype for user testing

5.6.3 Sound Trigger Prototype

For the sound trigger prototype, a Raspberry Pi 3 Model B was used to store sound files, handle the button logic and drive a loudspeaker. The Linux-based operating system, Raspbian, was installed via boot image on a microSD card and connection to the Pi was over SSH using the command line interface (Terminal on Mac OS). The loudspeaker was recessed into a plastic container with the speaker grill mounted flush with the lid. See Figure 44 for a diagram showing the connections between the Raspberry Pi and the arcade buttons.

A USB loudspeaker was used, connected directly to the USB port of the Raspberry Pi, which meant that a separate audio DAC (digital to analogue converter) and amplifier hat was not required. The Raspberry Pi was powered via mains adapter, which was connected through a hole drilled into the back of the container.

The sound trigger logic was scripted in Python, where each arcade button input was linked to a specific sound file and the PyGame[20] module was used to load and play each sound file. The resulting prototype is shown in Figure 45.

[20] PyGame Mixer documentation: https://www.pygame.org/docs/ref/mixer.html

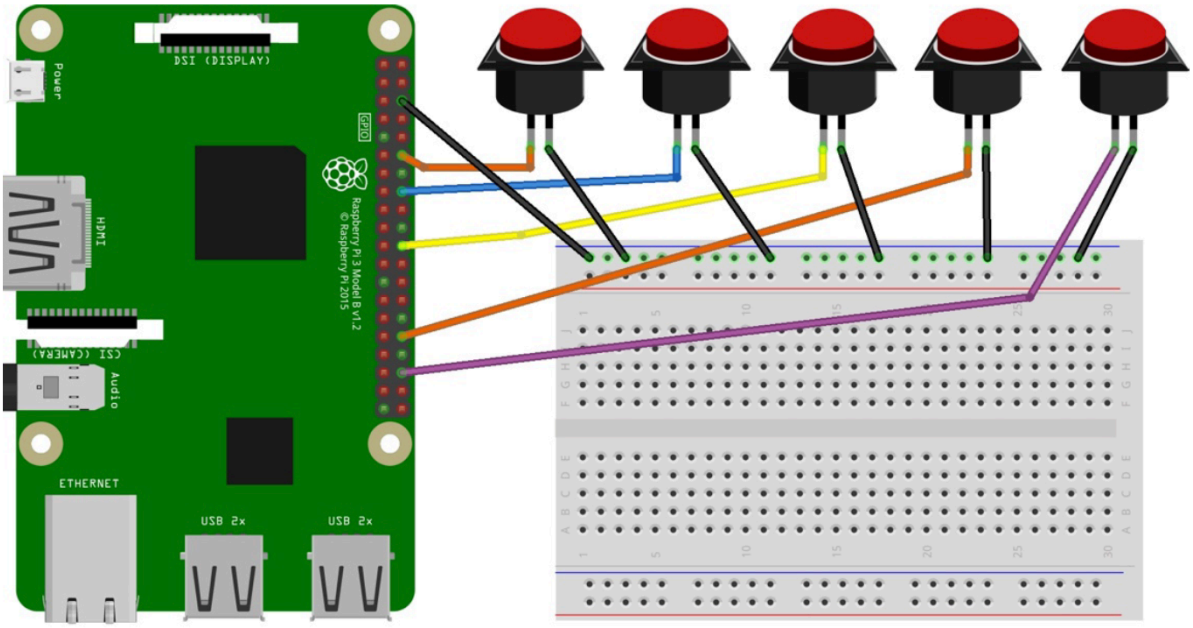

Figure 44: Diagram showing connections between Raspberry Pi 3 (model B) and arcade buttons

Figure 45: Sound trigger prototype for Emotional Machines user testing

5.7 User Testing Implementation and Results

Twenty people took part in an open user testing session that ran over the course of a day, and each person tested all three prototypes. Users were instructed to use the buttons to trigger a sequence, to let the sequence play out and then to match an emotion card to the button number that they though most closely represented the emotion perceived.

Tags labelled with the numbers one to five were laid out on the table and users were given five emotion cards with the emotions *joy*, *frustration*, *hesitancy*, *anticipation* and *curiosity*. To explore whether the eyes and moustache attached to the gesture prototype affected users' perceptions *e.g., through potential anthropomorphosis,* these facial elements were removed for half of the users. Figure 46 shows a user taking part in the user testing session.

Figure 46: User testing emotion perception with the sound, gesture and light prototypes

Following the user tests, the results were collated and analysed. In order to quantify the success of each modality in conveying a particular emotion, each correctly matched emotion was assigned a value of 1. The percentage of users that correctly identified each emotion was calculated and noted in a table (see Appendix XX) with the resulting data presented in the chart in Figure 47.

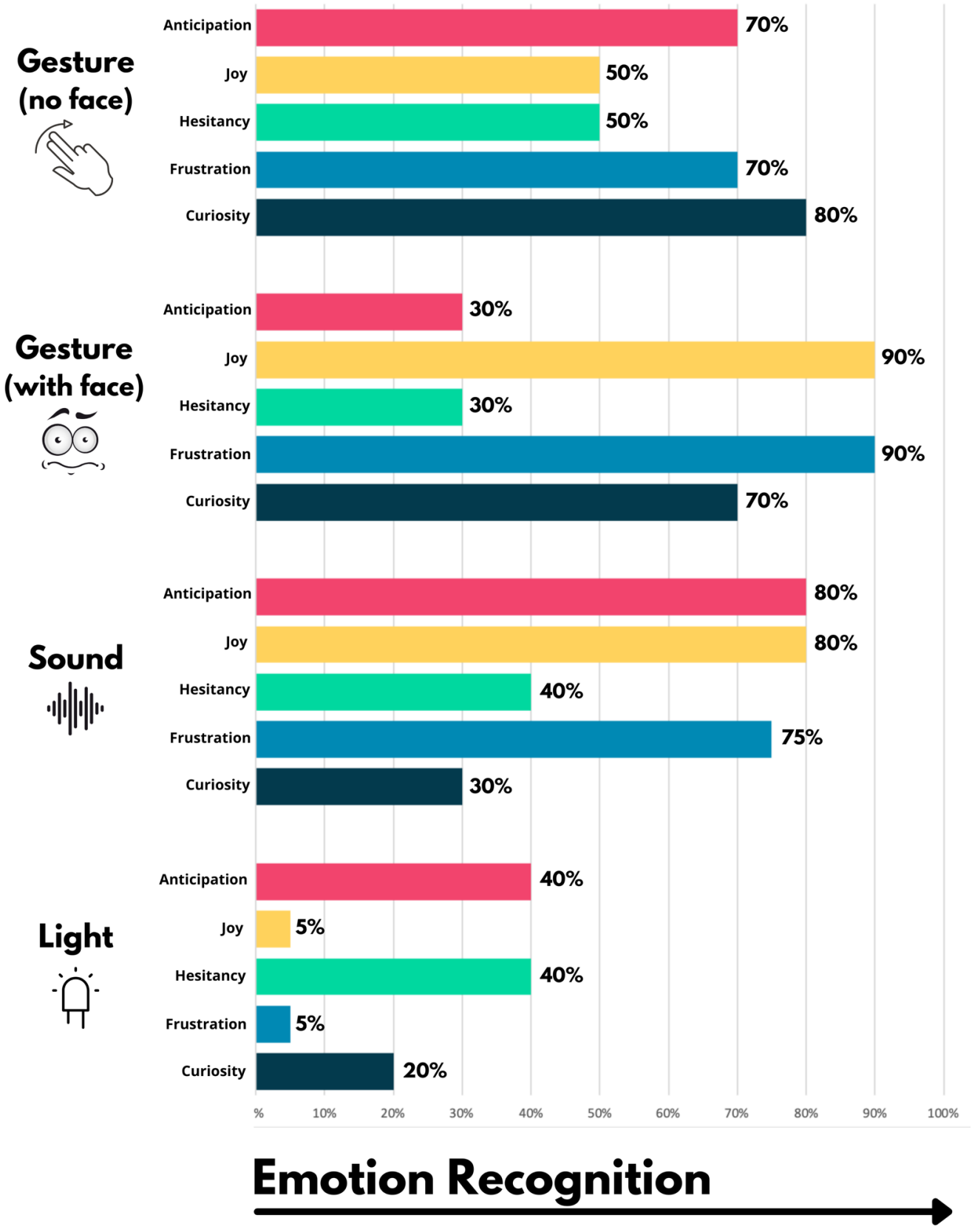

Figure 47: Chart showing the results of the Emotional Machines user testing sessions

As shown Figure 47, the sound sketches created by the workshop attendees were effective in conveying *anticipation, joy* and *frustration* with these emotions scoring recognition rates of 80%, 80% and 75% respectively.

We can also see that *hesitancy* and *curiosity* were mistaken for each other almost half of the time. Interestingly, this same error occurred in the sound workshop, with observers perceiving *hesitancy* as *curiosity* and vice versa, when hearing the live performance of these embosonic sketches.

For gesture, there was a high recognition rate for *curiosity* and *frustration*, both with and without the facial features (eyes and moustache). Interestingly, the gesture sequence for *joy* was highly effective, with a 90% recognition rate, when the facial features were present but was considerably less effective when those facial features were removed.

With the facial features in place, some users commented that the "robot" appeared to dance and be jolly, whereas during the user tests where the facial features were not present, there was still a tendency for anthropomorphising the motion with some users commented that they viewed the robot as "possibly a finger".

Light was the least successful modality with no lighting sequence achieving more than a 40% emotion recognition rate, which is unfortunate as lighting is perhaps one of the easier and most cost effective of the modalities to incorporate in new smart speaker designs.

Users commented that they found sound easiest to read, followed by gesture then light, apart from one user who felt they understood the lighting sequences more than the others. All users felt that lights are a nice feature and although they found it more difficult to attribute meaning to the lighting sequences, they felt that lights would add ambience in a darkened room but could also be distracting depending on the context *e.g., if watching TV or trying to sleep.*

Some users also suggested that light would be less intrusive than sound and that sound might lead to annoyance as it is always perceived *i.e., you can turn away from a light but you cannot easily stop hearing unwanted sounds*.

Others said that for this same reason, they think sound would be most useful as they might not notice the other modalities in action if they were not looking directly at the device. One user commented that they would prefer a single base sound with different treatments applied to indicate emotion whereas other users felt this would be too repetitive.

Most of the users that took part in the user testing session felt that they would like to live with a moving voice device and would welcome feedback through smooth and quiet motion, but would find jerky and noisy motion of servo motors unsettling. Others commented that they would like a robot's gaze to follow them around the room and would welcome a robot that could move between rooms.

Many users felt that gesture is the most entertaining of the three modalities and that it would be great if a robot could "whizz around in joy when you return home". Some users commented that they felt an attachment to the gesture prototype, this was mostly reported by users who had interacted with the robot with facial features.

5.8 Summary and Evaluation

In this chapter I have described how the embosonic design method was employed in industry to help inform and facilitate exploratory innovation work, investigating how future smart speakers and other voice-activated devices might exist and function in our daily lives. I have described how the ideation and sound sketching activities in synthesis with reflection on insights gained from design thinking in and around the areas of movement and light informed major elements of this research and design project. Significantly, this synthesis with inspiration stemming from the concept of the Laban Effort System, in conjunction with the insights gained from actively participating in and engaging with the workshops on gesture, sound and light, led to the development of a Modality Parameter Matrix, which has been demonstrated as a useful tool for emotion sequence design across modalities.

The embosonic design method produced sound sketches that were highly effective in conveying simulated emotions. This is confirmed through my evaluation of the live sketches that were performed by the groups at BBC Maida Vale studios, where the observers perceived the performed emotions correctly in all except once case.

Similarly, in the user testing session in a lab-based environment, where users listened to the sketches reproduced on a physical sound player prototype, there was at least a 75% recognition rate for three out of the five emotions and the emotions that achieved a lower recognition rate (hesitancy and curiosity) were equally less successful in the other modalities of light and gesture.

The sound sketches produced in this application of the embosonic design method were of longer duration than those produced in the Her[sonifications] project, which is as I had expected and likely due to them being performed in front of a small audience, as opposed to the short sketches of visceral phenomena that the women had performed during ongoing discussions and explorations.

In terms of temporal aspects of the emotions conveyed, the groups had considered how they would begin, change over time and dissipate, and due to them being able to sketch the sounds as a performance with multiple contributors, they could perform the emotion in its entirety, lessening and in this case, removing the need for extra sound design and post-production processing.

We must consider the limitations and nuances of working in the wild in order to contextualise the research, for example working with a different set of participants would have brought different views and perspectives, which would've resulted in different outcomes.

In practical terms, there was a degree of selection bias in relation to the participant group that took part in the Emotional Machines project, with the participants being colleagues from BBC Research and Development and while not all of them work in design-related roles (see section 5.3.1), their projects in general are highly experimental and the culture and working environment at BBC R&D is effective in fostering creativity.

If I had recruited volunteers from the general population with no creative experience, this may have had an impact upon the success of the method and the quality of the design outcomes. I acknowledge that it would have been beneficial to have trialled the method in a wider range of industry-based design and innovation contexts and with a broader range of participant groups.

I conclude that embosonic design, although initially devised as an arts-based approach for sound-focussed design projects, has value when applied more generally as part of overall interaction design in industry-based innovation contexts.

Through trialling its application in the industry-based use case described in this chapter, a mixed-modal interaction study in the BBC's Research and Development lab (BBC R&D), embosonic design has been shown to be a valuable method for interaction design in creative and exploratory innovation projects.

The method has been shown to be flexible enough to successfully support design activities in this space, when working with groups with diverse experience and skills.

Furthermore, the Modality Parameter Matrix that was produced as a result of this work and that enabled the design of the lighting and gesture sequences that were programmed into the user testing prototypes, contributes new knowledge to the field and is a useful tool for cross-modal actuation design.

6 DISCUSSION AND CONCLUSION

This research was triggered by a motivation to produce an artistic sound artwork that could communicate a person's authentic lived experience to another. If understanding the emotion of others entails experiencing the emotion observed [18], sound is an emotive and viable experiential medium for a number of reasons.

Sound is intuitive: acoustic ecology renders us experts in listening, we have inherent capabilities to produce sound through voice, body and gesture. Secondly, sound is not bounded by limitations of language. Thirdly, sound is largely universal, although cultural differences do exist.

When one experiences the embodied sonification of another's lived experience, it can stimulate forms of intersubjectivity. Embodied sonification and consumption can facilitate what Vittorio Gallese terms as Embodied Simulation [56], building on Merleau-Ponty's theory of Intercorporeality [90], *i.e., intuitive recognition of another based on embodied interaction, to help one understand and relate to the experience of another.*

I had a distinct awareness from the outset that an artwork such as this could only be achieved from truth and it was this awareness that sparked the need for providing people with accessible, easy to use tools, with which to express their experiences and their ideas with sound.

There has been a lack of focus on sound design techniques and approaches that relate to improving design outcomes, especially in designing sound for events and processes without an attached sonic convention. Similarly, there is a distinct lack of research that specifically examines the early conceptualisation stages of the sound design process.

In my sound design practice, I regularly used Foley techniques for creating sound to accompany and complement visual action and wanted to explore the technique to support the sonification

of non-physical phenomena and subjective notions. The overarching goal was to enable non-sound designers to sketch and exchange ideas about sound.

Sketching in visual design is a quick, accessible technique for externalising and communicating ideas with others but there were no comparable techniques for sound design with a similarly low barrier to entry.

A design stakeholder does not need to be skilled in art practice to produce meaningful hand-drawn sketches to communicate an idea. Sound design is far less accessible and there has been great need for a 'pen and paper' equivalent. I wanted to explore whether Foley-based techniques could support ideation at the early conceptual and exploratory stages in the design of new systems and interfaces, as well as for collaborative sound design projects.

This research was not undertaken with a clear route or intention to produce specific knowledge and as such, no hypotheses were declared at the outset. I explored concepts through design practice, employing a Research *through* Design approach which has resulted in the production of knowledge and a recoverable design process [60, 131].

Through deep reflections upon, and rigorous documentation of, all the observations, tacit knowledge, decisions and actions associated with the design processes involved in this work, I make a number of research contributions that I consider to be valid and useful for the design community.

My theoretical contributions are in the form of conceptual frameworks and guiding philosophies for design, and the specification of design methods that support them. Transferring this knowledge to the design community has been the principal purpose of this thesis.

Through the conceptualisation and articulation of these aspects of the research and from subsequent testing of the design methods, the produced theory is shown to hold in two specific instances, as described in the two chapters dedicated to *embosonic design in practice* (which describe the Her[sonifications] and Emotional Machines projects, Chapters 4 and 5).

The principles and concepts I have developed can be abstracted from these ultimate particulars and therefore be considered a valuable contribution to knowledge.

This thesis responds to calls for "designing through sound making to be advocated" in order to establish the approach as legitimate methods [96]. I have demonstrated the use of Foley-based techniques in mitigating against the inherent technical biases that are associated with the sound sketching tools described in the sonic interaction design literature.

Foley sound design relies on the embodied knowledge of the sketcher to bring about bodily action upon the sounding materials in hand and I have demonstrated how these techniques can support the sharing of sound-based ideas that remove the need for specific descriptive language about the characteristics of sound.

Furthermore, I have shown how this type of sound sketching can support collaborative design processes and knowledge sharing between participants from multiple backgrounds and disciplines.

In design and innovation, highly subjective insights and tacit knowledge are extremely valuable but notoriously difficult to capture and share. The action of the body *in producing sound* can not only play a role in the development of thought and ideas, but can bring what is known, through first-person subjective experience, out in to the physical world.

In my research I have shown how sound sketches produced through Foley artistry become boundary objects that can support the communication and sharing of ideas, not only about sound but of the visceral phenomena and lived experience that a person might like to share with another. Embodied sound sketches carry meaning for the performer and similarly, the listener can ascribe meaning to the sound heard, leading to shared empathic understanding.

In terms of what has been covered within these thesis' chapters, I have described the background and context for this interdisciplinary work, integrating concepts from cognitive science, design and HCI. I have discussed how this work is situated in relation to relevant literature in these diverse fields and have discussed the integrating concepts and resulting implications for design and sound design practice.

I have introduced the new participatory design method, Embosonic Design and have described the need for such a method and my approach to its development, detailing its benefits and implications of use.

I have provided a method specification in line with the recommendations for participatory design method definition as specified in the literature (see section 3.1), detailing application area (section 3.5); perspective (section 3.3); and providing a detailed set of guidelines (section 3.4) to enable other designers and researchers to employ the method in their own design and innovation work.

I have provided comprehensive accounts of how embosonic design was employed in practice, describing rich insights I gained from its use in group-based design tasks for two very different design goals. I have described how it was employed in the design and development of an interactive sound art installation and subsequently, how it was employed in a mixed-modal interaction design and innovation project in industry.

6.1 Revisiting Aims and Objectives

This research explored the concept of designing through sound making in order to establish whether Foley-based sketching can benefit participatory design processes. Through examining the type and extent of the concept's value, the aim was to establish group-based methods to help other researchers and designers employ the thinking in their design-led innovation work and in participatory design practice.

I defined five primary objectives for this research and will now describe how I approached each objective with a brief overview of my key findings and/or results:

1. **Determine suitable group-based activities to support non-sound experts to start thinking about and experimenting with sound.**

   To support initial explorations at the start of this research, I organised a workshop on sound expression, which was designed and led by Chanel Summers, a leading sound design expert and director of the Experimental Audio Design Lab at the University of Southern California's School of Cinematic Arts.

   The two-day workshop was designed to help attendees explore the nature of sound through listening exercises as well as learning techniques for vocalisation and experimenting with sound simulation and design using only cardboard as a sounding material (photos from the workshop are included in Appendix B.8). I also took part in the workshop as an attendee, along with a small number of my HighWire colleagues and a few people who were working in the creative industries in North West England.

   Taking part in the workshop inspired some ideas for potential group-based activities. I then spent time developing these ideas, specifically around the use of group-based Foley techniques and subsequently engaged in trialling the activities with family, friends and some of my HighWire colleagues.

   Throughout the trials, I developed and refined the activities based on feedback and my observations of engagement level and initial inhibitions *e.g., devising an initial fun activity to serve as an ice-breaker before moving on to the ideation and translation (sound making) activities*.

   This work led to the production of a detailed workshop plan and Foley palette, comprising a collection of sounding objects which I developed in response to the needs that emerged during the activity trials, in order establish a broad-spectrum range of sounds (see Chapter 3).

2. **Examine engagement with group-based sound making activities in arts-based workshop and industry-based workshop settings.**

I approached objectives 2 and 3 (see below) by trialling embosonic design in two significant design projects that centred around the Foley-based sound making activities that I had developed and trialled in objective 1.

The Her[sonifications] project, described in detail in Chapter 4, was formed to design an interactive sound installation that would enable a user to explore the embodied, visceral experience of womanhood through the reflexive act of guided walking. The soundscape that featured in this room-scale installation revealed a group of women's lived experiences, where the soundscape elements were self-actualised sonifications of embodied experience, created by the women through the performative act of making sound.

The group of women took part in multiple rounds of the sound making activities and I analysed and reflected upon their level of engagement using three methods: 1) **Direct observation** - as workshop leader and also taking on the role of a co-participant, I was able to closely observe the workshop participants during the sound making activities. 2) **Data collection** – the workshop session was audio recorded and during transcription, a rich set of insights were gathered, capturing details that were missed during the sound making activities via direct observation. 3) **Post-workshop focus group** – through discussion I was able to hear directly from the women about their experience of, and attitude towards, the sound making activities.

In the second design project, Emotional Machines, which was industry-based, I directly observed participant engagement with sound making activities for a mixed-modal interaction design study that I carried out as part of my previous role as a trainee Research and Development Engineer with BBC R&D. The sound making activities informed and facilitated interaction design research exploring how smart speakers and other voice-activated devices might exist and function in our daily lives in the future, as detailed in Chapter 5.

Through examining participant engagement with group-based sound making activities in the two workshop settings described above, the findings are that embosonic sketching affords a sense of embodiment while producing sound; and ownership of the sounds produced, which is natural, accessible and empowering for those taking part. Presence through sound and physicality, and oneself becoming a sounding object, encourages playfulness and enhanced engagement in participatory design settings. Furthermore, embosonic design is not only useful in arts-based settings focusing on sound, but is shown to have value when applied more generally as part of overall interaction design in industry-based contexts.

3. **Assess the effectiveness of Foley-based sound sketching in enabling people to express mental models; qualities and characteristics of lived experience; and imagined sound.**

Using the same approach as described above, I worked towards this objective through a combination of direct observation, data collection and post-workshop discussion in the workshops held as part of the Her[sonifications] and Emotional Machines projects. Through this approach I was able to gather a number of insights that support the idea that Foley-based sound sketching is an effective method for expression of these highly subjective phenomena.

The findings, which are described fully in sections 4.10 and 5.8, show that Foley-based sound sketching is not only a highly accessible tool for rapid experimentation with sound, but it is a useful and valuable method for externalising ideas and subjective notions that are inherently difficult to describe.

It supports deeper descriptions of felt sensations, beyond that afforded by language alone, as it encourages a high degree of continuous self-reflection during active refinement of the sounds and concepts used. These findings support Rocchesso and Monache's idea of sketching-in-action (see section 2.2), which describes the dialectic relationship between sketcher and sketch as "a continuous feedback loop of new knowledge creation and form production" [92].

Furthermore, I found that sound sketches produced through embosonic design are boundary objects (see section 2.5). The insights gained from the Her[sonifications] workshop (described in section 5.3.4), show that sound sketches can function as anchor points in conversational ideation. The process of sketching sounds as boundary objects facilitates the externalisation of highly subjective insights into objective, transferrable knowledge that people can share and understand.

4. **Evaluate the effectiveness of sound sketches produced using Foley-based techniques.**

I took a mixed-method approach to evaluating the sound sketches that were produced as part of this research project:

a) During the workshops: for the Emotional Machines project, I probed efficacy by making use of theatrical techniques to explore whether observers could identify performed sketches; and in the Her[sonifications] project, I used direct observation to establish how meaningful the sketches were to the other participants.

b) In post-workshop discussions and focus groups: I hosted discussions with participants to discover how they perceived the sound sketches they had produced.

c) I tested a number of Foley-based sketches that were produced as part of the Emotional Machines project, where participant groups worked together to sonify a set of simulated emotions. Carrying out the user testing process described in sections 5.6 and 5.7, I examined whether the emotions conveyed in the sonifications could be accurately perceived by a separate group of volunteers. In the same test session, I also examined how the sonifications performed against light and motion sketches for emotional expression.

d) While the Her[sonifications] installation was running as a conference exhibit, I interacted with visitors to informally assess their perception of the soundscape produced.

My findings indicate that the Foley-based techniques used in these design projects produced sound sketches that were highly effective in conveying simulated emotions (see section 5.7 for a breakdown of the results relating to the Emotional Machines project). In terms of visceral phenomena, I was able to establish that the participants themselves found their sound sketches to be accurate and meaningful sonic representations of their lived experience.

5. Identify ways in which sound making can support design-led innovation work and participatory design practice in industry.

This objective was approached with active mindfulness along with thorough documentation and analysis of design decisions and data in order to uncover and reflect on how the sound making activities yielded new discoveries, inspired subsequent processes, informed design decisions and impacted design outcomes.

The Research *through* Design methodology employed in this research and in particular, sustained use of the process Schön terms *reflection in action* [106] (see section 1.3.6), was crucial to unearthing a number of interesting insights during both the arts-based and industry-based design and innovation projects.

I was able to develop these insights into conceptual frameworks, practical tools and guiding philosophies for design-led innovation and participatory design practice, as well as the specification of methods that support them (described in the Contributions section below).

6.2 CONTRIBUTIONS TO KNOWLEDGE

As a result of working towards and achieving the objectives as outlined above, this research shows that embosonic design is not only applicable as an arts-based approach for enhanced participatory sound design but is a valuable method that can be applied more generally as part of overall interaction design and design-led innovation in industry-based contexts.

Its use in a mixed-modal interaction study in the BBC's Research and Development lab (BBC R&D), shows that the method is flexible enough to support complex design tasks and enhance idea generation in groups with diverse experience and skills.

Specifically, this research has produced the following contributions:

1. **The proposal of the novel concept of *Qualitative Data Sonification*:**

    a. A theoretical definition of a process where sound is used to represent non-numerical data that is specifically associated with lived human experience (section 3.2)
    b. Demonstrated to be a useful and feasible concept for the communication and interpretation of qualitative data (sections 4.10 and 5.8) which led to the development of new methods

2. **A new participatory design method (*Embosonic Design*) for generative ideation through group-based sound sketching and guidelines for designers looking to employ the method (section 3.3):**

    a. Uses sound-making as inquiry to enhance qualitative data collection in group-based settings

b. Enables the creation of self-actualised sonifications of experiential phenomena
c. Minimises designer bias and supports the exchange of ideas in both arts-based and industry-based settings
d. Is accessible and useful to non-sound experts
e. Encourages playfulness and promotes heightened participant engagement
f. Informs and facilitates exploratory innovation work
g. Supports mixed-modal interaction design

3. **A demonstration of how Embosonic Design has been applied in practice for two distinct use cases:**

    a. As an arts-based approach: for the participatory design of an interactive sound artwork that represents the lived experience of a sample group (project: 'Her[sonifications]', Lancaster University) (chapter 4)
    b. As an applied design approach in industry: for mixed-modal interaction design in a public service media research and development setting (project: 'Emotional Machines', BBC R&D) (chapter 5)

4. **Design patterns, models and guiding philosophies:**

    a. In-depth accounts of design processes provide means for replication of the design projects described in this thesis (section 2.2.4 – 4.6.2 and section 5.3.1 – 5.6.3)
    b. Rich insights from observations and reflections on the making of artefacts gained from a Research *through* Design approach, are articulated and accessible (section 4.2.7, 4.9, 4.10 and 5.8)
    c. Guidelines for a Foley Palette to help designers and workshop leaders prepare for employing the method's sound making activities (Figure 5)
    d. A model for cross-modal interaction design and a demonstration of its use as a design tool for extending embosonic design ideation outcomes across the modalities of sound, light and gesture (section 5.4)

5. Knowledge dissemination to the academic community where material from this thesis was peer-reviewed and published:

> Emma Young, Alan Marsden, and Paul Coulton. (2019). **Making the Invisible Audible: Sonifying Qualitative Data.** In Proceedings of the 14th International Audio Mostly Conference: A Journey in Sound (AM '19). Association for Computing Machinery, New York, NY, USA, pp. 124–130.

6.3 FUTURE WORK

A possible extension of the presented work could be the real-time collection of temporal qualitative data in order to improve the embosonic design method. It would be useful to investigate ways to actively capture the time-based descriptions that people often generate vocally during sound-sketching activities, given the impact this rich data had on the functional and aesthetic design of the Her[sonifications] installation.

An effective method would reduce the need for transcription of audio recordings to enable earlier identification of patterns. One possibility may include participants being actively involved with plotting the data, perhaps encouraging further description and refinement of the temporal aspects of the stories shared.

In addition, if future research looks to develop the method, I would suggest that in order to combat the limitation of selection bias associated with this work (described in the previous section), it would be useful to test its use in participatory design trials with sample groups of people who consider themselves as having no creative interest, skill or experience.

A possible direction for new research would be to investigate the method as a potential tool for creative arts therapy. My findings suggest there is scope for Foley-based sound-making being useful in the design of methods to support practitioners working with vulnerable groups.

Where music therapy is widely accepted as being highly useful for building confidence and allowing people to express themselves, a method such as this could provide an avenue for communication that gives people a sense of ownership over the sounds produced that are attached to their lived experience and the stories they share.

Finally, this work has raised a number of new questions for future research:

Firstly, what are the affordances of sound with respect to the expression of embodied phenomena and sense-making? Can these change in different places, contexts, whether we are alone or with others?

And in what ways could sonifications of experiential phenomena inspire different levels of immersion and engagement for the listener *e.g., could it be upsetting or cathartic to hear certain sound art, could we identify with it?*

Can an experience expressed with sound affect us more or less than the story narrated?

And when interacting with such works, can listeners become more introspective or more social, more playful or deeply focused and which are preferable for the type of experiences and artefacts we want to build?

6.4 CONCLUSION

This thesis explored the concept of designing through sound making in order to establish whether Foley-based sketching can benefit participatory design processes. The trialling of accessible group-based activities to support rapid experimentation with sound led to the formulation and development of a new method, Embosonic Design.

The method was employed in participatory design workshops for two significant design projects, where its effectiveness was tested and evaluated. Although initially devised as an arts-based method focusing on sound, embosonic design is shown to have value when applied more generally as part of overall interaction design.

The findings confirm that Foley-based sketching and embosonic design are effective methods that can improve design outcomes and enhance idea generation in both creative arts-based applications and in industry-based innovation contexts.

Sound sketches produced with these methods are boundary objects that can support knowledge exchange between people from different backgrounds and disciplines. Its use in a mixed modality interaction study in the BBC's Research and Development lab (BBC R&D), shows that the method is flexible enough to support complex design tasks in groups with diverse experience and skills.

Furthermore, Foley-based sound sketching affords a sense of embodiment while producing sound which can lead to meaningful sonic representations of direct experience. Evaluation of the design outcomes, both through industry-based user testing and deployment in an interactive sound artwork, show that listeners with no knowledge of the underlying data and sonification processes, can perceive the desired information and can emotionally connect to the sounds.

Sound elicits emotion. Emotion elicits sound.

New knowledge produced as a result of this thesis underwent peer review and was subsequently published in the Proceedings of the 2019 Audio Mostly conference: A Journey with Sound [129], with the work receiving positive feedback from the academic community.

The conceptual frameworks, practical tools and guiding philosophies contained in this thesis, as well as the methods that support them, will help researchers and designers employ the thinking and methods in their participatory design practice, whether sonification is the design goal (see Her[sonifications], Chapter 4) or the means to achieving the goal (see Emotional Machines, Chapter 5).

Could Foley-based sketching be the accessible 'pen and paper' equivalent for sound design? Could it support ideation and UX design in new system and interface development? And will it inspire new collaborative sound projects and artistic works?

If ***you*** *are* inspired and you make something – please let me know…[21]

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APPENDIX A: PUBLICATIONS AND OUTPUTS

Emma Young, Alan Marsden, and Paul Coulton. (2019). **Making the Invisible Audible: Sonifying Qualitative Data**. In *Proceedings of the 14th International Audio Mostly Conference: A Journey in Sound (AM '19)*. Association for Computing Machinery, New York, NY, USA, 124–130. DOI:https://doi.org/10.1145/3356590.3356610

Manu Brüggemann and Emma Young. 2017. **Publics, pluralism, protest, periods**. Paper presented at Data Publics conference, Lancaster University.

Emma Young and Manu Brüggemann. 2017. **Her[sonifications]**. Installation exhibited at the Data Publics conference, Lancaster University.

APPENDIX B: SUPPLEMENTARY MATERIALS

B.1 PARTICIPANT INFORMATION SHEET

Participant Information Sheet

I am a PhD student at Lancaster University and I would like to invite you to take part in the research study ***'Connecting with Sound: Making the Invisible, Audible'***.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

What is the study about?

The study aims to explore how sound making can be used as a tool to support open discussion between people who face similar issues in their lives and/or have had similar lived experiences, specifically relating to those which are unseen i.e. they are not immediately apparent or perceived by others; and hidden i.e. they are not generally exposed in conversation with others because dialogue is inhibited by stigma or social taboo. And secondly, to explore, through the creation and delivery of collaborative sound artworks, how these issues and experiences can be conveyed and brought to light through the affective medium of sound, to create space for recognition, reflection and empathy and be a catalyst for dialogue around invisible issues.

Why have I been invited?

I have invited you to participate in this study because I am interested in understanding how people in a group environment might benefit from taking part in facilitated sound making activities. I'm also trying to understand whether bringing invisible issues to light through sound art is useful for helping people who have never had similar experiences to understand and appreciate the complex issues with which other people live.

I would be very grateful if you would agree to take part in this study.

What will I be asked to do if I take part?
If you decided to take part, this would involve participating in a **workshop** session where you would, as part of a group:

- Take part in two short icebreaker activities.
- Take part in a sharing activity where you can choose to share any aspect of your life, for example this might be insights you would like to share; issues or concerns you have; difficulties that you face and wish to discuss with the group; or stories that you would like to share. We will then collectively find meaningful words, phrases or analogies to effectively convey the essence of each shared story, thought and insight and use these to inform the design of an artistic work.
- Take part in a deep listening exercise, during which you will be asked to stay silent for a short period and listen to the ambient sounds around you. We will then spend time reflecting on the sounds we have heard.
- Take part in a translation activity where you will be introduced to a range of sound sketching techniques including Vocalisation and Foley Artistry. We will work together to explore these tools and their sound-generating capabilities. We will then explore how we can use these tools to start to translate the collection of words, phrases and analogies into meaningful sonic representations.

The sound sketches that are created by the group during the workshop session will then be incorporated into a sound artwork. Following on from this, you will be invited to participate in a **focus group** session where you would, as part of a group:

- Be given the opportunity to hear/view the resulting sound artwork.
- Take part in a group discussion where we will explore how well you feel the artwork represents the concepts discussed during the initial workshop session.
- Be invited to give your feedback on your experience of being involved in this study, in the form of an informal semi-structured interview.
- Be asked for your permission to show the artwork to other people.

If in the case that all group members agree to the artwork being shown to other people, we will decide as a group on the format through which this can be delivered. The workshop will last no longer than 3 hours and the focus group will last no longer than 90 minutes. Data collection will take the form of written text (the words/phrases generated in the workshop session); diagrams and illustrations (if applicable); voice recording for transcription (of both the workshop session and the focus group session); audio recording of generated sounds; and photography (solely close-up photography of hands manipulating objects/props during the sound making activities).

What are the possible benefits from taking part?

Taking part in this study will allow you to talk openly and share your thoughts in a safe and supportive environment. It will allow you to engage in sound making as a form of expression, a creative process which may have potential therapeutic benefits in increasing awareness of self and others.

Your participation in this study will help me understand whether sound making is a useful tool to foster open discussion in a group environment.

Taking part will allow you to help shape a unique sound artwork. Further to this, in the case that all group members give permission for other people to view/hear the sound artwork, this could contribute to other people's understanding of the unspoken turbulence and issues that some people face in their everyday lives. Your participation in this study will help bring invisible issues to light and voice, through art, to create opportunities for reflection on the issues with which some people live.

Do I have to take part?

No. It's completely up to you to decide whether or not you take part. Your participation is voluntary and you are free to withdraw at any time before or during the workshop session and up to 10 days thereafter, without giving any reason.

What if I change my mind?

As explained above, you are free to withdraw at any time before or during the workshop session and up to 10 days thereafter. If you want to withdraw during this time, I will extract any data you contributed to the study and destroy it. Data means the information, views, ideas, etc. that you will have shared with me. Please be aware that after 10 days has passed you will no longer be able to withdraw as the data you've contributed will be anonymised and pooled with other participants' data and therefore it will be difficult to remove individual contributions completely.

What are the possible disadvantages and risks of taking part?

It is unlikely that there will be any major disadvantages to taking part and given that you have already been active in participating in an established group and that the facilitator of that group will be present for both the workshop and focus group sessions, the same level of emotional support will be available, should you require it, in the same form to which you are accustomed.

Further to this, web links and phone numbers for associated support services will be distributed in line with those that your existing group promote.

Will my data be identifiable?

After the workshop and focus group sessions, only I, the researcher conducting this study, will have access to the data you share with me.
I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will anonymise any audio recordings and hard copies of any data. This means that I remove any personal information.
Participants in the study will be asked not to disclose information outside of the workshop and focus group sessions with anyone not involved in the study, without the relevant person's express permission.

How will my data be stored?

Your data will be encrypted and stored on a password-protected computer.
I will store hard copies of any data securely in a locked cabinet in my office.
I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic).
In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

How will we use the information you have shared with us and what will happen to the results of the research study?

I will use the data you have shared with only in the following ways:

I will use it for academic purposes only. This will include my PhD thesis and other publications, for example journal articles. I may also present the results of the study at academic conferences.

When writing up the findings from this study, I would like to reproduce some of the views and ideas you shared with me. When doing so, I will only use anonymised quotes from the workshop and focus group sessions, so that although I will use your exact words, you cannot be identified in my publications.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact either myself, Emma Young, or my supervisors, Alan Marsden, Paul Coulton or Linda O'Keeffe.

Emma Young
e.young@lancaster.ac.uk

Dr Alan Marsden
a.marsden@lancaster.ac.uk

Prof. Paul Coulton
p.coulton@lancaster.ac.uk

Dr Linda O'Keeffe
l.okeeffe@lancaster.ac.uk

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:

Prof. Corina Sas
c.sas@lancaster.ac.uk

Thank you for considering your participation in this project.

B.2 PARTICIPANT CONSENT FORM

CONSENT FORM

Study Title: **Connecting with Sound: Making the Invisible, Audible.**

Name of Researcher: Emma Young

Email: e.young@lancaster.ac.uk

Please tick

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time up to 10 days after the workshop session, without giving any reason. If I withdraw from the study during this time my data will be removed and destroyed. ☐
3. If I am participating in the study, I understand that any information disclosed within the workshop and focus group remains confidential to the group, and I will not discuss the study with or in front of anyone who was not involved unless I have the relevant person's express permission. ☐
4. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher, but my personal information will not be included and I will not be identifiable. ☐
5. I understand that my name will not appear in any reports, articles or presentation without my consent. ☐
6. I understand that the workshop and focus group will be audio-recorded and transcribed and that data will be stored on password-protected devices and kept secure. ☐
7. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study. ☐
8. I agree to take part in the above study. ☐
9. Should you have any further requests regarding the usage of the data you'll share during this study, please provide details here:

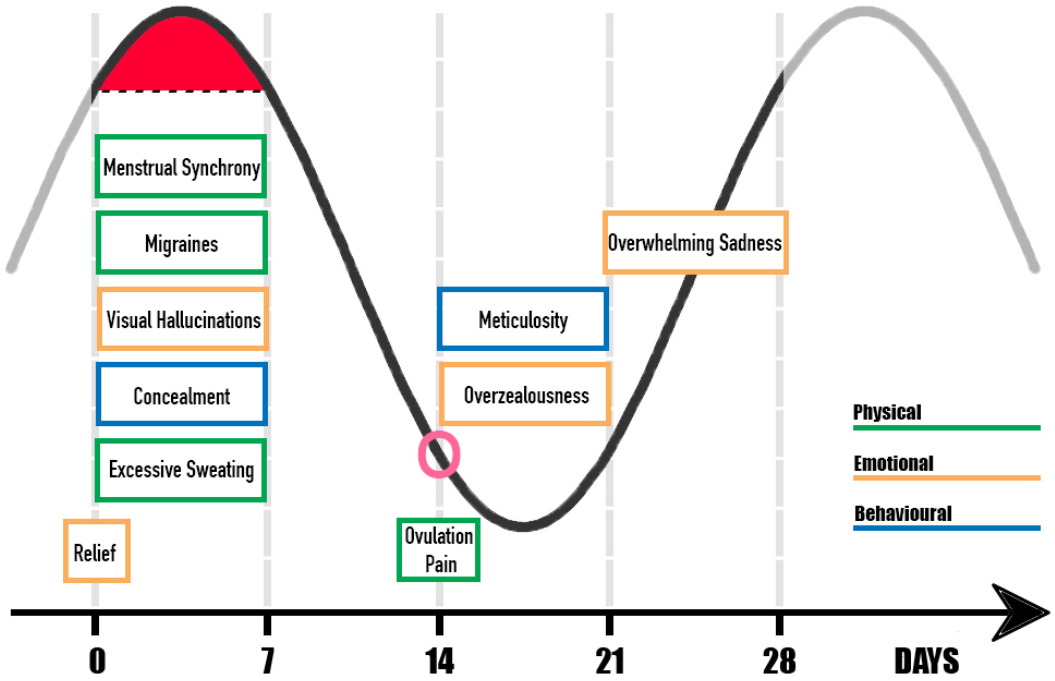
_____	_____	_____
Name of Participant	Date	Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

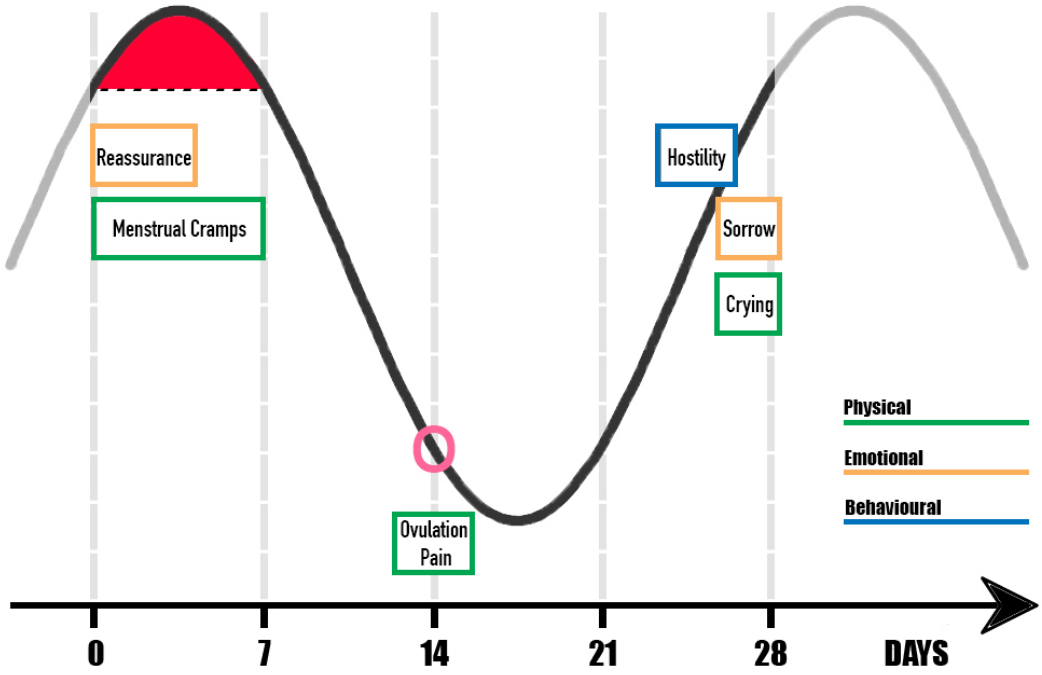
_____	_____
Signature of Researcher	Date

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

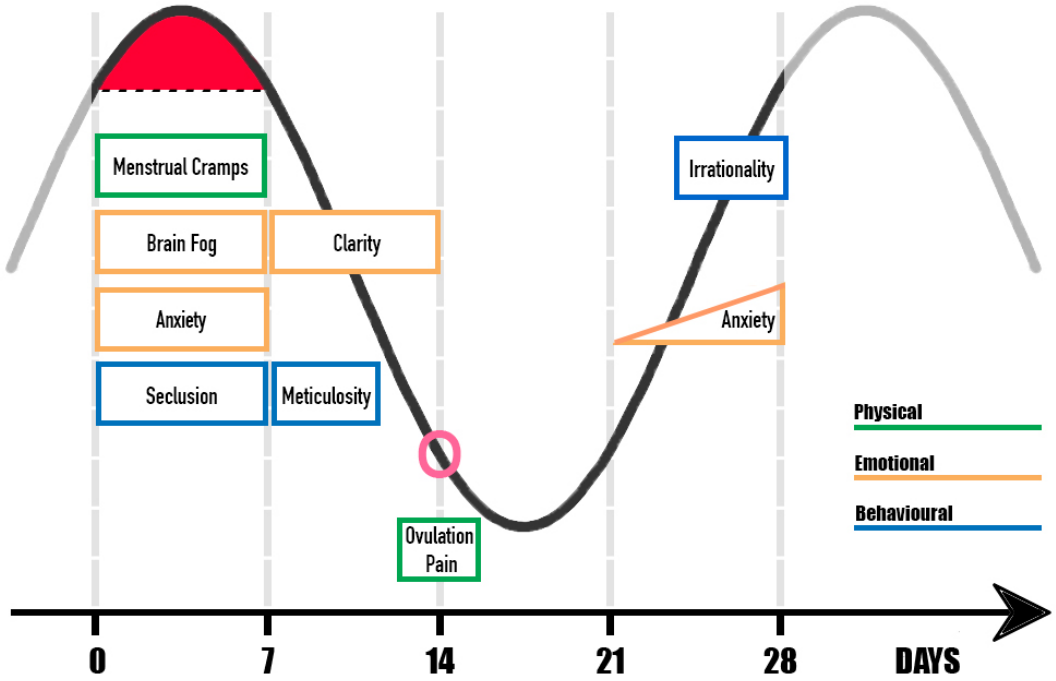
Participant 1



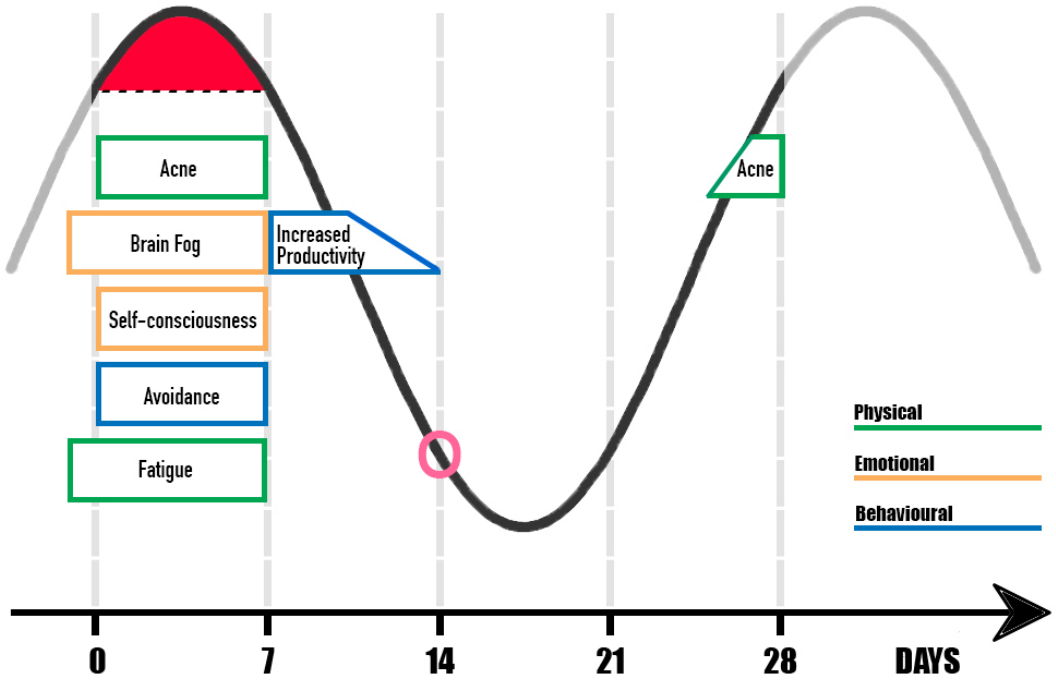
Participant 2



Participant 3



Participant 4



B.4 HER[SONIFICATIONS] - SOUND DESIGN NOTES

Effect	Description	Temporal Features
Participant 1		
Relief (E)	Thank God I'm not pregnant! = angel chorus, yay and hand clapping	Preceded by DREAD (an unnerving heavy, dragging sound) – instant change to RELIEF - a notification?
Menstrual Synchrony (P)	Affected by the moon = stretched and pulled, the sound of the tides. Natural Rhythms & syncing with peers = banging different objects, all over the place then bringing into time.	out of time then slowing syncing into time.
Migraines (P)	Migraines = rusty nails down a blackboard but a shabby, horrible scratchy but everything's going all at once - cacophony of all objects being bashed and dragged	Increase in intensity then fades away
Visual Hallucinations (E)	Hallucinations = tinkly sound followed by a big boom, it needs to resonate -	tinkly (initially sketched by tweaking the mic stand), then an absence of sound (heartbeat?) then a big boom - a low rumbling explosion
Concealment (B)	Hidden, being secretive = tiptoeing, sneaking around	
Excessive Sweating (P)	Sweaty = wet sponge, sound of a roller deodorant - watery sound	
Ovulation Pain (P)	Ovulation pain = pulling or stabbing, exercise band? Sharp stab sound - but continuous, make it last, make it resonate. Stab a melon or something but twist the knife around	
Meticulosity (B)	House in chaos then being on a mission to make things tidy - clutter, everyone throwing things into a tin then broom sweeping sounds, wiping to clean glass, polishing sound	
Overzealousness (E)	*"I always get this Yes, I can do anything! And I'll go into absolute hyper mode to a point that I exhaust myself because I think I can do so much but it feels so good and I'm like I'm just gonna run with it, I'm gonna run with it and then it stops."* Tape of speech being fast- forwarded, then starts to slow down and decrease in pitch until it can go no lower or slower. Something being built in background	
Overwhelming Sadness (E)	Sadness = atmospheric sound, loneliness - blowing softly into glass jar	
Participant 2		
Reassurance (E)	Getting comfort from everything working = clockwork, ticking away nicely	
Menstrual Cramps (P)	Cramps = Rubik's cube being cranked + Foil banner being twisted.	
Ovulation Pain (P)	APD	
Hostility (B)	Fighting, boxing, aggression, growling, bull snorting	
Sorrow (E)	La La Land - from love to despair = love then sadness - music, something happy and rhythmical to "throwing in the towel" (objects being bashed rhythmically then being thrown into tin).	Atmospheric undertone to represent the shift from HOSTILITY to CRYING
Crying (P)	*"I cry, I used to cry a lot, like two days before the period I used to get into a fight with my husband and I would cry at the end. Every month."* Crying and sobbing sounds	
Participant 3		
Menstrual Cramps (P)	APD	
Brain Fog (E)	Brain fog leading to clarity = white noise, spraying the silly string.	White noise to static tuning sound to clear sound - a pure tone or bell sound
Anxiety (E)	Stress - all over the place, lots of noise, lots going on - water pouring fast when lots going on then pouring slowly till it just trickles then drips.	Background ambience to be all peaceful during the trickle but the background noise to be ARRRGHHH during the gushing. Start with glacial cracking sounds and increase in intensity over time

Seclusion (B)	Shutting everyone out. Creaky door slamming shut. Phone ringing and not being answered or going to answering machine	
Clarity (E)	*"I'd say clarity, yeah, whether I could potentially tap into it to be productive, but yeah there's that fog where it's just the most simplest daily tasks where everything is hard work and then all of a sudden it's clarity."* *APD (follows Brain Fog)*	
Meticulosity (B)	APD	
Ovulation Pain (P)	APD	
Irrationality (B)	Being Irrational - up and down, slide whistle, like a siren. Feeling like being exactly right - pedantic - setting things down precisely and with force.	
Participant 4		
Increased Productivity (B)	*"I find that I'm more productive work wise the day after my period ends, I like look forward to it, I dunno if that's related to the head fog thing or what, but I know that I'm more productive especially the day after my period ends and then it just sort of evens out after that but I have this rush, this day of high where I'm like Oh my God I've just written 10,000 words in one day because everything's just like coming out of my brain!"* Keyboard typing, mouse and page turning sounds	From slow steady speed to a "rush" (fire blazing, rocket blasting) to very fast speed.
Acne (P)	Acne = metal pin art tray being used to suggest acne appearing slowly over time. Popping a balloon for the explosion of acne	
Brain Fog (E)	APD	
Fatigue (P)	Feeling drained = deflation (deflating a balloon), Water - being poured in reverse, collapsing in on itself.	
Self-consciousness (E)	Childhood experiences compounding fears = whispers, whisper the phrase "she's a late bloomer"	
Avoidance (B)	Avoiding things = hiding, covering yourself up with the covers - going under the blanket, shutting the curtains. Opposite of revealing something.	
Increased Productivity (B)	*"I find that I'm more productive work wise the day after my period ends, I like look forward to it, I dunno if that's related to the head fog thing or what, but I know that I'm more productive especially the day after my period ends and then it just sort of evens out after that but I have this rush, this day of high where I'm like Oh my God I've just written 10,000 words in one day because everything's just like coming out of my brain!"* Keyboard typing, mouse and page turning sounds	From slow steady speed to a "rush" (fire blazing, rocket blasting) to very fast speed.
General Sounds		
Male attitudes	Not being real to men = clown sounds, hooters, lots of male voices over the top of each other mansplaining	
Spoken Words	"They can smell it"; "Period pants"; "Migraines"; "Being Irrational"; "Sex, no sex?"; "Thank God I'm not pregnant!"; "It's not real to men"; "Pulling, stabbing"; "Cracks"; "Affected by the moon"; "Aura, hallucinations - a hole in the world"; "Stress, affecting flow"; "Worries about sanitary disposal"; "Early experiences compounding fears"; "The house is in chaos then afterwards it's tidy, clean"; "Checking chairs for leaks"; "Brain Fog"; "La la land - love, despair"; "Avoiding things - no, I don't want to go on a bike ride, I'm not going swimming, I can't wear that"; "Transition into menopause - worries... acceptance"; "Overwhelming sadness"; "Coil gives control", "Being in control", "Hidden, secretive"; "Worries over scent".	

B.5 HER[SONIFICATIONS] - PYTHON CODE FOR READING RSSI VALUES

```
1.  #!/usr/bin/env python
2.
3.  # blescan.py, BLE Scanner
    based on https://code.google.com/p/pybluez/source/browse/trunk/examples/advanced/in
    quiry-with-rssi.py
4.  # https://github.com/pauloborges/bluez/blob/master/tools/hcitool.c for lescan
5.  # https://kernel.googlesource.com/pub/scm/bluetooth/bluez/+/5.6/lib/hci.h for opcod
    es
6.  # https://github.com/pauloborges/bluez/blob/master/lib/hci.c#L2782 for functions us
    ed by lescan
7.
8.  # performs a simple device inquiry, and returns a list of ble advertisements
9.  # passes detected beacon address and RSSI to locate function in trackbeacon.py
10.
11. import os
12. import sys
13. import struct
14. import trackbeacon
15. import bluetooth._bluetooth as bluez
16.
17. LE_META_EVENT = 0x3e
18. LE_PUBLIC_ADDRESS=0x00
19. LE_RANDOM_ADDRESS=0x01
20. LE_SET_SCAN_PARAMETERS_CP_SIZE=7
21. OGF_LE_CTL=0x08
22. OCF_LE_SET_SCAN_PARAMETERS=0x000B
23. OCF_LE_SET_SCAN_ENABLE=0x000C
24. OCF_LE_CREATE_CONN=0x000D
25.
26. LE_ROLE_MASTER = 0x00
27. LE_ROLE_SLAVE = 0x01
28.
29. # these are actually subevents of LE_META_EVENT
30. EVT_LE_CONN_COMPLETE=0x01
31. EVT_LE_ADVERTISING_REPORT=0x02
32. EVT_LE_CONN_UPDATE_COMPLETE=0x03
33. EVT_LE_READ_REMOTE_USED_FEATURES_COMPLETE=0x04
34.
35. # Advertisment event types
36. ADV_IND=0x00
37. ADV_DIRECT_IND=0x01
38. ADV_SCAN_IND=0x02
39. ADV_NONCONN_IND=0x03
40. ADV_SCAN_RSP=0x04
41.
42.
43. def returnnumberpacket(pkt):
44.     myInteger = 0
45.     multiple = 256
46.     for c in pkt:
47.         myInteger +=  struct.unpack("B",c)[0] * multiple
48.         multiple = 1
49.     return myInteger
50.
51. def returnstringpacket(pkt):
52.     myString = "";
53.     for c in pkt:
54.         myString +=  "%02x" %struct.unpack("B",c)[0]
55.     return myString
56.
57. def printpacket(pkt):
```

```
58.     for c in pkt:
59.         sys.stdout.write("%02x " % struct.unpack("B",c)[0])
60. 
61. def get_packed_bdaddr(bdaddr_string):
62.     packable_addr = []
63.     addr = bdaddr_string.split(':')
64.     addr.reverse()
65.     for b in addr:
66.         packable_addr.append(int(b, 16))
67.     return struct.pack("<BBBBBB", *packable_addr)
68. 
69. 
70. def packed_bdaddr_to_string(bdaddr_packed):
71.     return ':'.join('%02x'%i for i in struct.unpack("<BBBBBB", bdaddr_packed[::-
    1]))
72. 
73. def hci_enable_le_scan(sock):
74.     hci_toggle_le_scan(sock, 0x01)
75. 
76. def hci_disable_le_scan(sock):
77.     hci_toggle_le_scan(sock, 0x00)
78. 
79. def hci_toggle_le_scan(sock, enable):
80. # hci_le_set_scan_enable(dd, 0x01, filter_dup, 1000);
81. # memset(&scan_cp, 0, sizeof(scan_cp));
82.  #uint8_t         enable;
83.  #       uint8_t         filter_dup;
84. #        scan_cp.enable = enable;
85. #        scan_cp.filter_dup = filter_dup;
86. #
87. #        memset(&rq, 0, sizeof(rq));
88. #        rq.ogf = OGF_LE_CTL;
89. #        rq.ocf = OCF_LE_SET_SCAN_ENABLE;
90. #        rq.cparam = &scan_cp;
91. #        rq.clen = LE_SET_SCAN_ENABLE_CP_SIZE;
92. #        rq.rparam = &status;
93. #        rq.rlen = 1;
94. 
95. #        if (hci_send_req(dd, &rq, to) < 0)
96. #                return -1;
97.     cmd_pkt = struct.pack("<BB", enable, 0x00)
98.     bluez.hci_send_cmd(sock, OGF_LE_CTL, OCF_LE_SET_SCAN_ENABLE, cmd_pkt)
99. 
100. 
101.        def hci_le_set_scan_parameters(sock):
102.            old_filter = sock.getsockopt( bluez.SOL_HCI, bluez.HCI_FILTER, 14)
103. 
104.            SCAN_RANDOM = 0x01
105.            OWN_TYPE = SCAN_RANDOM
106.            SCAN_TYPE = 0x01
107. 
108. 
109. 
110.        def parse_events(sock, loop_count=100):
111.            old_filter = sock.getsockopt( bluez.SOL_HCI, bluez.HCI_FILTER, 14)
112. 
113.            # perform a device inquiry on bluetooth device #0
114.            # The inquiry should last 8 * 1.28 = 10.24 seconds
115.            # before the inquiry is performed, bluez should flush its cache of
116.            # previously discovered devices
117.            flt = bluez.hci_filter_new()
118.            bluez.hci_filter_all_events(flt)
119.            bluez.hci_filter_set_ptype(flt, bluez.HCI_EVENT_PKT)
120.            sock.setsockopt( bluez.SOL_HCI, bluez.HCI_FILTER, flt )
121.            done = False
122.            results = []
```

```
123.           myFullList = []
124.           for i in range(0, loop_count):
125.               pkt = sock.recv(255)
126.               ptype, event, plen = struct.unpack("BBB", pkt[:3])
127.               #print "--------------"
128.               if event == bluez.EVT_INQUIRY_RESULT_WITH_RSSI:
129.               i =0
130.               elif event == bluez.EVT_NUM_COMP_PKTS:
131.                       i =0
132.               elif event == bluez.EVT_DISCONN_COMPLETE:
133.                       i =0
134.               elif event == LE_META_EVENT:
135.                   subevent, = struct.unpack("B", pkt[3])
136.                   pkt = pkt[4:]
137.                   if subevent == EVT_LE_CONN_COMPLETE:
138.                       le_handle_connection_complete(pkt)
139.                   elif subevent == EVT_LE_ADVERTISING_REPORT:
140.                       #print "advertising report"
141.                       num_reports = struct.unpack("B", pkt[0])[0]
142.                       report_pkt_offset = 0
143.                       for i in range(0, num_reports):
144.
145.                   if (DEBUG == True):
146.                   print "-------------"
147.                               #print "\tfullpacket: ", printpacket(pkt)
148.                       print "\tUDID: ", printpacket(pkt[report_pkt_offset -
    22: report_pkt_offset - 6])
149.                       print "\tMAJOR: ", printpacket(pkt[report_pkt_offset -
    6: report_pkt_offset - 4])
150.                       print "\tMINOR: ", printpacket(pkt[report_pkt_offset -
    4: report_pkt_offset - 2])
151.                               print "\tMAC address: ", packed_bdaddr_to_string(pkt
    [report_pkt_offset + 3:report_pkt_offset + 9])
152.                               #macaddr = packed_bdaddr_to_string(pkt[report_pkt_of
    fset + 3:report_pkt_offset + 9])
153.                               #return macaddr
154.                       # commented out - don't know what this byte is.  It's NOT TX
    Power
155.                               txpower, = struct.unpack("b", pkt[report_pkt_offset
    -2])
156.                               print "\t(Unknown):", txpower
157.
158.                               rssi, = struct.unpack("b", pkt[report_pkt_offset -
    1])
159.
160.
161.                               print "\tRSSI:", rssi
162.
163.                           ########## Store Mac address & RSSI (1st elemnt in tuple
     rssi,) as variables
164.                           ########## and pass to locate function in trackbeacon.py

165.
166.                           beaconmac = packed_bdaddr_to_string(pkt[report_pkt_offse
    t + 3:report_pkt_offset + 9])
167.                           rssituple = struct.unpack("b", pkt[report_pkt_offset -
    1])
168.                           beaconrssi = rssituple[0]
169.                           trackbeacon.locate(beaconmac, beaconrssi)
170.
171.
172.
173.                   # build the return string
174.                               Adstring = packed_bdaddr_to_string(pkt[report_pkt_offset
     + 3:report_pkt_offset + 9])
175.                   Adstring += ","
```

```
176.                     Adstring += returnstringpacket(pkt[report_pkt_offset -
    22: report_pkt_offset - 6])
177.                     Adstring += ","
178.                     Adstring += "%i" % returnnumberpacket(pkt[report_pkt_offset -
    6: report_pkt_offset - 4])
179.                     Adstring += ","
180.                     Adstring += "%i" % returnnumberpacket(pkt[report_pkt_offset -
    4: report_pkt_offset - 2])
181.                     Adstring += ","
182.                     Adstring += "%i" % struct.unpack("b", pkt[report_pkt_offset -
    2])
183.                     Adstring += ","
184.                     Adstring += "%i" % struct.unpack("b", pkt[report_pkt_offset -
    1])
185.
186.                     #print "\tAdstring=", Adstring
187.                     myFullList.append(Adstring)
188.                         done = True
189.             sock.setsockopt( bluez.SOL_HCI, bluez.HCI_FILTER, old_filter )
190.             return myFullList
```

B.6 HER[SONIFICATIONS] - PYTHON CODE FOR LOCATION DETECTION AND AUDIO TRIGGERING

```
#!/usr/bin/env python

# takes RSSI values passed from blescan.py and determines approximate distance
# tracks user movement and triggers audio files in ogg format
import blescan
import sys
import pygame
import os
from time import sleep
from subprocess import call
import glob
import random

avdistanceList = []
superavdistanceList = []
distanceList = [0]
distancemovesList = []

##################################### Audio Loading ############################

#Initialise pygame and mixer
pygame.mixer.pre_init(44100, -16, 1, 1024)
pygame.init()

#Load Sound files
try:
    sounds_leadup = []
    for snd in ['Acne.ogg', 'Anxiety.ogg', 'Hostility to Crying.ogg', 'Overwhelming Sadness.ogg','Relief.ogg']:
        sounds_leadup.append(pygame.mixer.Sound(os.path.join('Oggs/Lead_Up', snd)))

    sounds_during = []
    for snd in ['Concealment.ogg', 'Excessive Sweating.ogg', 'Fatigue.ogg', 'Menstrual Cramps.ogg', 'Migraines.ogg', 'Reassurance.ogg', 'Seclusion.ogg']:
        sounds_during.append(pygame.mixer.Sound(os.path.join('Oggs/During', snd)))

    sounds_directlyafter = []
    for snd in ['Brain Fog to Clarity.ogg', 'Increased Productivity.ogg', 'Self Consciousness.ogg', 'Visual Hallucinations.ogg']:
        sounds_directlyafter.append(pygame.mixer.Sound(os.path.join('Oggs/Directly_After', snd)))

    sounds_ovulation = []
    for snd in ['Menstrual Synchrony.ogg', 'Meticulosity.ogg', 'Overzealousness.ogg', 'Ovulation Pain.ogg']:
        sounds_ovulation.append(pygame.mixer.Sound(os.path.join('Oggs/Ovulation', snd)))

    print ("Audio is loaded and ready to go")
except:
    raise UserWarning, "Could not load or play sound files in 'Audio' folder :-("


################################################################################

def locate(beaconmac, beaconrssi):
    if beaconmac == "fe:de:59:12:d3:93":
        ####print ("RSSI is %d" % beaconrssi)
        # Add RSSI to list
        avdistanceList.append(beaconrssi)
        # If list contains 10 items, delete the first item
```

```
        if len(avdistanceList) > 10:
            del avdistanceList[0]
        else:
            pass
        # Find average RSSI
        avrssi = (sum(avdistanceList)/len(avdistanceList))
        #print ("Average RSSI is %d" % avrssi)

        #####
        # Added this 3rd List to slow down output to screen,
        # to make more readable during testing

        # Add average RSSI reading to superavdistanceList
        superavdistanceList.append(avrssi)
        # If list contains 10 items, delete the first item
        if len(superavdistanceList) > 10:
            del superavdistanceList[0]
        else:
            pass
        # Find average avrssi
        superavrssi = (sum(superavdistanceList)/len(superavdistanceList))
        #print ("SUPER AVERAGE RSSI IS %d" % superavrssi)
        #####
        track (avrssi)
    else:
        pass

def track(superavrssi):
    # Define distance level of average RSSI as 1 to 5 (1 being nearest)
    if superavrssi >= -71:
        distance = 1
    elif superavrssi < -71 and superavrssi >= -77:
        distance = 2
    elif superavrssi < -77 and superavrssi >= -82:
        distance = 3
    elif superavrssi < -82 and superavrssi >= -90:
        distance = 4
    elif superavrssi < -90:
        distance = 5
    else:
        print ("beacon not in range")

    print ("Beacon is at distance %d" % distance)

            # Add distance level to List
            distanceList.append(distance)
            #If list contains 3 items, delete the first item
            if len(distanceList) > 3:
                    del distanceList[0]
            else:
                pass

            # Check to see if the distance value has changed, determine type of chan
    ge and trigger appropraite audio
            if distanceList[0] != 0 and (distanceList[-1] != distanceList[-2]):
                print ("Beacon has MOVED!!! :-)")
                ### Store the new distance level in variable
                movedetected = distanceList[-1]

                # If the change is from R3 to R2 (Pre-menstruation)
                if movedetected == 2 and distanceList[-2] == 3:
                    print ("Pre-menstruation")
                    trigger2 = random.choice(sounds_leadup)
                    trigger2.play()
                # If the change is from R2 to R1 (During menstruation)
                elif movedetected == 1 and distanceList[-2] == 2:
```

```
                print ("During menstruation")
                trigger1 = random.choice(sounds_during)
                trigger1.play()
            # If the change is from R1 to R2 (Pre-ovulation)
            elif movedetected == 2 and distanceList[-2] == 1:
                print ("Pre-ovulation")
                trigger3 = random.choice(sounds_directlyafter)
                trigger3.play()
            # If the change is from R3 to R4 (Ovulation)
            elif movedetected == 4 and distanceList[-2] == 3:
                print ("On ovulation")
                trigger4= random.choice(sounds_ovulation)
                trigger4.play()
            # If beacon strays too far, fadeout all sounds
            elif movedetected == 5:
                print ("OUT OF RANGE")
                pygame.mixer.fadeout(1000)
            else:
                pass

        else:
            pass
```

her[sonifications]

LICA Installation Space

The designer/ethnographer pair Emma Young and MJ Brüggemann (from digifacture.info) present a sonic interactive experience to problematise the quantification of the human experience in SMART systems and the age of "qualculation" (the judging of individuals based on the analysis of their data).

We invite you to traverse our labyrinth of monthly cycles, listen deeply and immerse yourself in the sonification of female experience. The sounds you will hear are sonic representations of a group of women's lived experiences of their menstrual cycles: their stories shared, translated to sound and performed through Foley artistry by the women themselves.

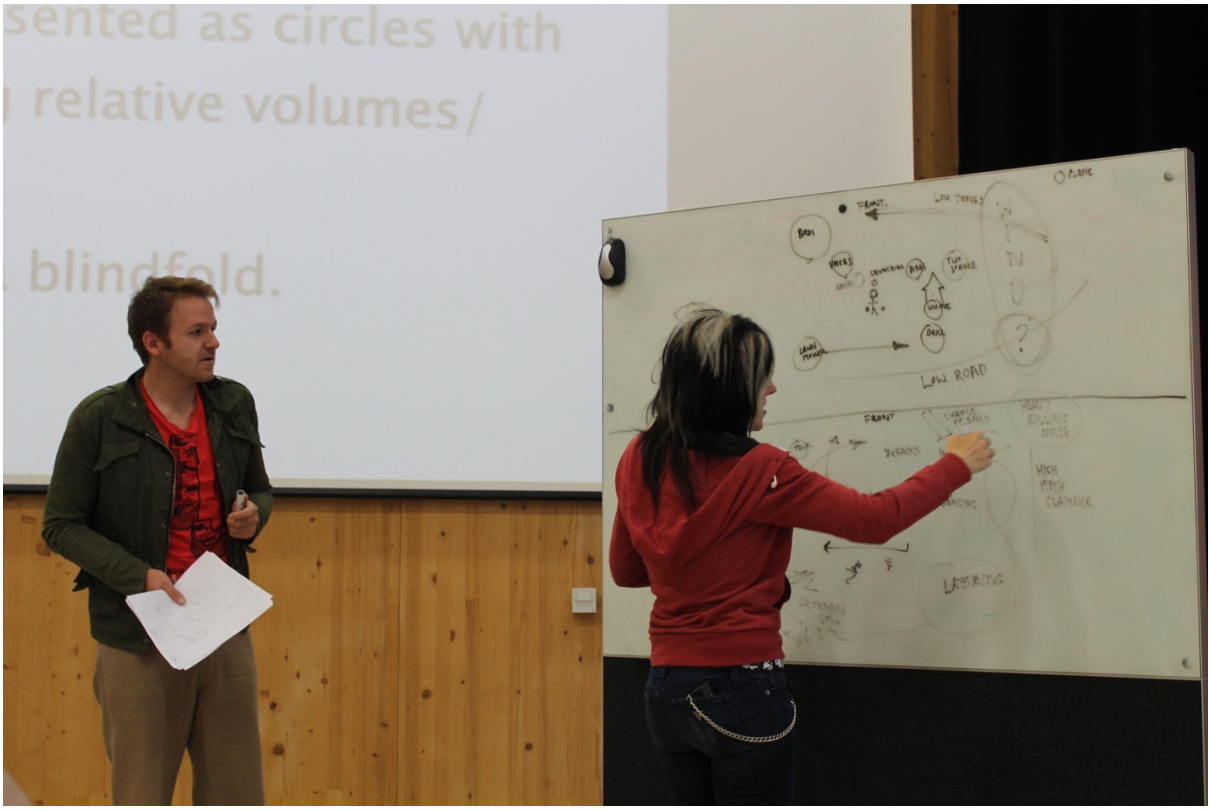
The piece juxtaposes the embodied, visceral experience of womanhood with the de-contextualised quantification of people. It stresses the bodily experience of its participants, as well as the embodied and mobile engagement of the visitor interacting with the installation.

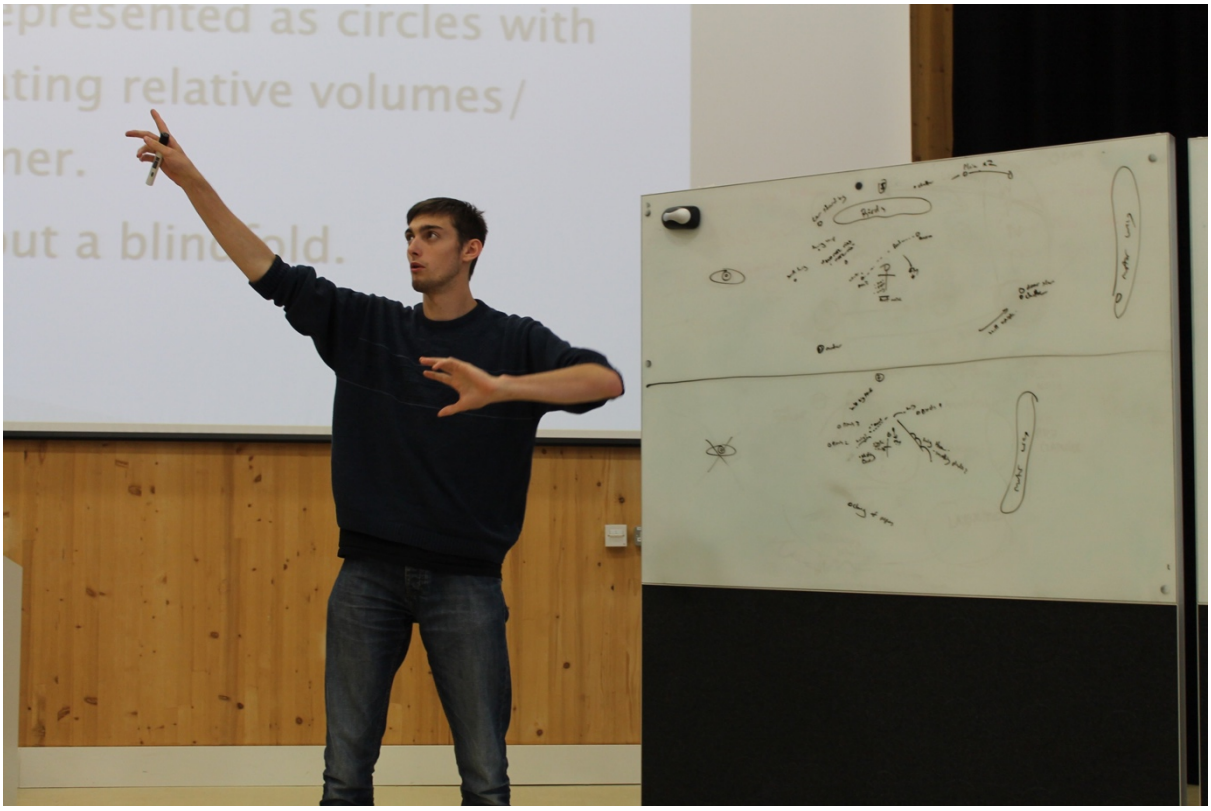
We thank our participants for the depth and honesty of the stories they chose to share. We hope to have done them justice.

#HerSonified digifacture.info High Wire Innovation for the Digital Economy An EPSRC Doctoral Training Centre

B.8 Sound Expression Workshop Photos

(Photos show: a talk about sound design for augmented reality with demo; an active listening exercise and participant sharing of outcomes; a sound expression activity using cardboard boxes; and a Q&A session with workshop leader, Chanel Summers)


sented as circles with
relative volumes/
blindfold.
LOW ROAD
FRONT
LAYERING


epresented as circles with
ting relative volumes/
ner.
ut a blindfold.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RAINDANCE
FILM FESTIVAL
ON TOUR

B.9 Emotional Machines User Testing sessions – Table of Results

(The cells highlighted in green, show the emotions that scored a recognition rate of 70% or greater)

Light	Correct Answer	Hesitancy	Curiosity	Frustration	Joy	Anticipation		Total Answers	Total Correct	% Correct
1	Hesitancy	8	8		3	1		20	8	40
2	Joy		3	14	1	2		20	1	5
3	Curiosity	7	4			9		20	4	20
4	Frustration	1	3	1	15			20	1	5
5	Anticipation	4	2	5	1	8		20	8	40
Sound		Hesitancy	Curiosity	Frustration	Joy	Anticipation				
1	Anticipation	2		2		16		20	16	80
2	Hesitancy	8	9	2	1			20	8	40
3	Frustration	2	3	15				20	15	75
4	Curiosity	8	6	1	2	2	1 x no answer	19	6	30
5	Joy		2		16	2		20	16	80
Gesture (with Face)		Hesitancy	Curiosity	Frustration	Joy	Anticipation				
1	Curiosity	2	7			1		10	7	70
2	Frustration			9	1			10	9	90
3	Hesitancy	3	2			5		10	3	30
4	Joy				9	1		10	9	90
5	Anticipation	5	1	1		3		10	3	30
Gesture (Faceless)		Hesitancy	Curiosity	Frustration	Joy	Anticipation				
1	Curiosity	1	8		1			10	8	80
2	Frustration			7	3			10	7	70
3	Hesitancy	5	2	1	1	1		10	5	50
4	Joy	1		2	5	2		10	5	50
5	Anticipation	3				7		10	7	70

Exit QR. Enter Sound: Could We Use Aural Cues For Interaction?

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ABSTRACT

Visual QR codes in an environment are now universally recognisable as a link to discoverable content and they have become ubiquitous on printed materials, in marketing campaigns and on the High Street. We know what they are and we know how to interact with them.

This early work asks the question: What if you couldn't *see* them but you could *hear* them instead? By transforming a regular sound effect into a form of acoustic-based NFC marker, we investigate the potential of introducing aural cues into an environment to act as perceptible links to discoverable content, such as media clips and information sources that are available to experience on any smartphone.

We assess the potential of this concept by testing it within a museum environment with real museum visitors and find out if providing a layer of rich, hidden content, accessible through sound, can enhance the visitor experience of an otherwise noiseless site.

1. INTRODUCTION

Acoustic-based markers that promote user interaction with discoverable server-side content are an attractive prospect. They are as inexpensive as visual markers such as QR codes, in that they require no specialised hardware for delivery other than a speaker. They can be recorded and reused, broadcast on TV and Radio and in order to interact with them, users require nothing more than a device with a microphone and a network connection.

So far, however, there has been little discussion about sound-based interaction cues within the research community and there is little evidence that they are close to becoming widely used by industry to engage people and inform them about their surrounding environment.

Very little research has been found that surveyed the potential or effectiveness of aural cues to act purely as audible markers for content discovery. A paper by Tomitsch et al [1] expresses the need for audio-based markers to enable blind and visually impaired people to become aware of the presence of NFC markers to allow them to identify and interact with them, they do not however evaluate the prospect of introducing acoustic-based markers for reasons beyond accessibility.

Nandakumar et al [2] describe a secure peer-to-peer acoustic NFC system developed at Microsoft Research India and highlight its key advantage over conventional NFC being that it is a purely software-based solution that can run on legacy phones as well as smartphones, with the only requirement for data transmission being a speaker and microphone.

An ultrasonic system that uses speakers in situ to provide position data to mobile devices is described by Lazik and Rowe [3], which highlights the ability of acoustic-based NFC to perform location-tracking in indoor environments where GPS signals are not available. The approach uses modulated ultrasonic chirps just outside of the human hearing range to transmit small amounts of data and ranging information and the receivers use time differences between arrival of the signals to determine their position.

Several publications describe the potential for acoustic-based solutions to enhance applications such as augmented reality, location-aware pervasive computing, targeted advertising and social networking [4, 5], yet little research has been found that investigates these possibilities.

2. SOUND-BASED DATA TRANSMISSION

A number of start-ups have developed and patented technologies that transmit data using sound. All of these technologies use distinct sound frequencies to represent the logical 1s and 0s used in the binary numbering system that computers use to store and transmit data. This section will provide a brief overview of some of the current technologies in use.

2.1 Chirp

Animal Systems, a UCL spin-out, released their 'Chirp' application for iOS and Android, which allows the

sharing of images, text and links between smartphones using a sound that is likened to digital birdsong. The sending device uploads the content to the cloud where it is assigned a unique shortcode. This shortcode is then encoded into a series of audible sine tones and is transmitted from the devices speaker. Any device within 'earshot' that has the app running can decode the shortcode and request the associated data from the cloud, which is then displayed on the receiving device [6]. The company intends to make their platform available to developers for creating third-party applications.

Chirp recently held a Top 20 position in the Apple App Store and has been working on a number of high-profile collaborations. One of which was with the high street chain 'Topshop' in a campaign for London Fashion Week 'AW 2013', which saw hidden content delivered via Chirp during the Catwalk show, from the retailers website and within their flagship store [7].

2.2 Wimbeep

'Wimbeep' by Fusego, is a similar photo sharing application solely for Android, with the added benefit of a Firefox extension being released for users to send data from their desktop browsers, however at the time of writing there is no indication that they plan to make their technology available to developers. The Wimbeep system also uses audible sound to transmit data and from reviewing the app reviews on Google Play, it is noted that users find the transmitting audio 'very annoying' [8].

2.3 Sonic Notify

'Sonic Notify' also uses sound to transmit shortcodes to data, and again any smartphone with a microphone can listen out for these shortcodes, decode them and pull associated content from their servers to the client device. The difference with Sonic Notify's technology is that the shortcodes are transmitted in the 19 - 21kHz frequency range, which renders them inaudible to the human ear. The company provides access to the technology via a Software as a Service (SAAS) platform, with their product being targeted to the Retail industry for proximity marketing, where they describe the main use case being the placement of beacons in stores to promote specific goods and services as people walk near them [9].

2.4 Zoosh

'Zoosh' is VeriFone's patented technology, which utilises the speakers and microphones in smartphones to securely exchange encrypted data between devices using sound. 'Way2ride' is VeriFone's first commercial deployment of the Zoosh technology, in the form of an app that enables secure wireless payments in the taxis operating in New York [10]. The company has released an open API and cloud platform for the development of third-party apps, with one of the first apps to leverage the Zoosh technology being the 'Paycloud' mobile wallet released by Sparkbase. VeriFone have a unique position within the wireless payment market, with their Zoosh technology being adopted by prominent players including Apple, Samsung, VISA and Mastercard.

3. TESTING THE USE OF AURAL CUES FOR CONTENT DISCOVERY

With a range of companies having released technologies that enable sound-based data transmission and delivery, the concept of using aural cues to point to discoverable content can be explored in its early state for experimentation without designing a bespoke system.

The Sonic Notify platform was selected for use in this project for two specific reasons. Firstly, the shortcodes are inaudible, therefore the experiment would not be subject to the confines of the pre-existing and unalterable audible sounds present in the other technologies. Secondly, the company provide a SAAS platform with a cloud-based Content Management System (CMS) to manage the linked content; as well as Software Development Kits (SDKs) for both iOS and Android which would enable the integration of the technology into a bespoke smartphone app.

3.1 Designing the Experiment

Multiple types of location could provide a suitable and interesting test bed for this type of experiment as the use of well-designed soundscapes in an environment can not only enhance the atmosphere of ones surroundings but can evoke a feeling of presence and immersion within a space [11]. Locations that were considered include nature trails, historic sites and market places, however an indoor location was nominated due to unpredictable weather conditions typical of the time of year and the need to leave multiple loudspeakers in situ for the duration of the experiment.

Lancaster City Museum was selected due to the compelling local stories told through its exhibits, which provided a rich source of inspiration for extra layers of content.

3.2 Building the 'AuralEYES' App

A basic 'listener' app was built, making use of the iOS SDK supplied by Sonic Notify, which allowed integration of the technology into a standalone app for iPhone.

Upon initialisation, the app listens for an acoustic signal using the on-board microphone; decodes the series of inaudible frequencies into a string of logical bits; sends this shortcode over the network to the server; and determines its associated content. The associated content is then sent over the network to the smartphone and is displayed on screen.

3.3 Linking Shortcodes to Content

For each museum exhibit that was selected for inclusion in the experiment, some existing content was curated and some new content was produced to provide more information about the story behind it. Each new piece of content that would be presented to the user was uploaded to Sonic Notify's online CMS and was linked to a specific shortcode. The relevant sound-based shortcodes were then encoded and saved as WAV files.

Figure 1: The launch screen and received content list on the AuralEYES application. Upon tapping on an item in the list, the linked media plays in full screen.

The inaudible shortcodes were then mixed with themed sounds that had been designed and produced for the elected exhibits in the museum and transferred onto separate mp3 players. These players, along with small omni-directional speakers, were placed in the applicable locations on the day of the experiment and set at an appropriate sound level to ensure that the shortcodes could be decoded by the app at the intended location only and not bleed into other locations.

3.4 Launching the Experiment

Museum visitors were invited to take part in the experiment upon entry and those who were interested in participating during their visit were provided with an iPhone and were shown how to use the AuralEYES app. Some test content was triggered immediately for demonstration purposes and they were instructed to visit the museum as normal and upon hearing any sounds, could decide to launch the app to discover some hidden content.

There were five separate sounds themed to a specific location within the museum and linked to associated content including two webpages, a video, a sound clip and a voucher.

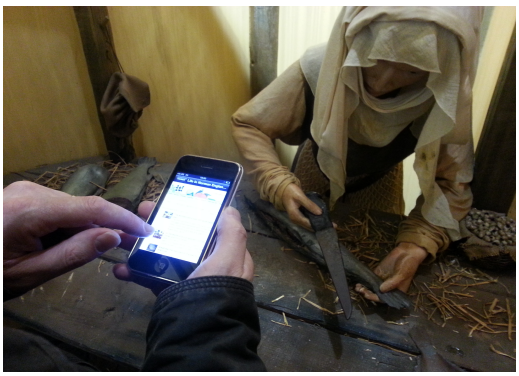

Figure 2: A participant viewing a webpage, received upon launching the application near a medieval market display.

Figure 3: A participant listening to a sound clip about a local munitions factory, received near the relevant display.

Upon their return, each visitor was asked to complete a questionnaire so that their visitor experience and their attitudes towards the experiment could be determined.

3.5 Evaluation

Of the study population, 10 participants completed and returned the questionnaire. The overall response to the experiment was very positive, with 100% of respondents stating that they particularly enjoyed their experience at the museum, with 90% feeling that the themed sounds and

discoverable content directly enhanced their visit and made it more enjoyable.

Half of those surveyed were able to find all five hidden artefacts by launching the app upon hearing a sound, with 40% finding four of the artefacts and only one participant finding less than four artefacts. Perhaps understandably, the same participant also spent the least amount of time in the museum and was also the only respondent to answer that they are 'not very comfortable' with consumer technology, as opposed to the 90% who answered as being either 'comfortable' or 'very comfortable' with it.

When the participants were asked about hearing unfamiliar sounds when out and about, 40% said they'd be 'likely' and 60% 'very likely' to launch such an app. Furthermore, 70% said they'd be 'very likely' to purchase this type of app, if it were available for their mobile platform.

In relation to the types of scenarios that they could imagine themselves using an app like this, responses included heritage sites, shops, cinemas, theatres, parks, and on walks to complement visitor information boards and plaques/signs.

The participants were also asked for their thoughts on whether or not a specific sound, as opposed to a themed sound, would have been better at providing an identifiable and obvious link to the hidden content. 50% felt unsure if a specific sound would've been better, with 40% favouring a themed sound and just 10% favouring a specific, repeating sound. The majority of those surveyed chose to give the reason for their preference, a sample of the reasons given are shown below.

> *"(Themed sounds are better) because of the gallery layout (open across the top) sound came easily – this did mean I could sometimes hear two sound clips at the same time but if all sound clips were the same it would not be possible to differentiate from where the sound came. Also, it adds atmosphere. Also, for a partially sighted person, identical sounds could be confusing and disorientating."*

> *"(I'm unsure) as it would add to the artistic feel if there was unique sounds for each artefact, but there is a chance I would miss one if it wasn't a common, identifiable 'alarm' sound (to say 'look at the app now')."*

> *"(Themed sounds are better) as a change in sound provides a sense of location and makes you aware of your surroundings."*

> *"(Specific sounds are better) as an easier way of identifying sounds around you."*

> *"(I'm unsure) as I really enjoyed hearing the themed sounds however specific sounds would act as a good prompt. Then again, it would perhaps become annoying"*

A minority of participants (1 person) indicated that they found the themed sounds obtrusive. Upon review of this outlier, a possible explanation might be that the participant misunderstood the question, viewing a sound's obtrusiveness as a positive aspect as opposed to a negative one. This can be inferred due to the fact that this particular participant offered elaboration to say that had the sounds not been obtrusive, they may have missed them as being a link to something; furthermore they also stated that they felt their experience had been particularly enhanced *because* of the sounds and the hidden content. Upon reflection, the question *"Did you find the themed sound obtrusive?"* was potentially open to misinterpretation and should have been worded more clearly.

4. CONCLUSIONS AND FUTURE WORK

Returning to the question posed at the beginning of this study, it is now possible to state that providing a layer of hidden content, accessible through sound, can enhance the visitor experience of an otherwise noiseless site.

The results of this study indicate that users within a museum environment enjoy interacting with additional content and feel that the provision of themed sounds can directly enhance their visit.

These findings, whilst preliminary, suggest support for the conceptual premise that aural cues for interaction with discoverable content, is a worthwhile area for further investigation.

Several questions remain unanswered at present, firstly, like the QR code, should the aural cue be fixed, having its own specific and distinctive sound so as to be instantly identifiable as a link to discoverable content? Or should it be variable, in tune with the context to which it relates? With 50% of participants feeling unsure about this factor, a further study with more focus on the design of the aural cue itself is therefore suggested.

Furthermore, if the aural cue *is* deemed to be more effective as a variable entity, there is abundant room for progress in determining if its design should suit the environment in which it is played or should suit the content to which it is linked. For example, an aural cue could hold the key to a discount at a store; extra product or place information; or an entry to a competition, therefore should each category of linked material then warrant its own distinguishing sound? If so, it would enable a user to decide which material to interact with and which to ignore, in the same way a QR code generally describes the material to which it is linked, as is demonstrated in the famous marketing campaign below.

Figure 4: A Calvin Klein Jeans marketing campaign where a QR code replaces the usual image of a semi-naked model that is synonymous with the designer brand.

Finally, a number of important limitations need to be considered. Firstly, the 3G network proved to be frustratingly slow at times, meaning that content was taking a considerable amount of time to load. When planning future studies of this type, this issue should be taken into consideration and steps taken to lessen the load on the network e.g., including the media files as part of the app bundle or setting up a Wi-Fi network at the location for longer term installations.

Secondly, with the small sample size and the study undertaken within a single environment, caution must be applied, as the findings might not be transferable to other, more noisy types of environment. Further research is therefore recommended focussing on different locations and with a larger number of participants before generalisations can be made and the real potential of aural interaction cues can be evaluated.

5. ACKNOWLEDGMENTS

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