Responsive and Emotive Wearable Technology: physiological data, devices and communication

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Thesis submitted to Goldsmiths, University of London for the Degree of Ph.D. in Arts and Computational Technology

July 2018

Declaration

I declare that the work presented in this thesis is my own.

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Abstract

My research practice and thesis investigates how wearable technology can be used to create new forms of nonverbal communication. Using devices developed through my practice, I explore how physiological data can be drawn from the body, then visualised and broadcast. I examine the opinions and requirements of potential users and observers of this technology, through qualitative responses in interviews and surveys from focus groups and field tests. I have analysed the resulting data to extract preferences and concerns, plus the requirements for the functionality and aesthetics of these devices. I discuss the social and cultural aspects of wearing such devices, as well as the issues, including how privacy may be affected and the implications of recording personal data.

I examine my practice in the context of the work of the communities and practitioners in the field, and introduce two new terms to label two sub-sections of wearable technology. These are 'responsive wearables' and 'emotive wearables', and they form part of the distinctive contribution that I make. Reflecting on the evolution of my practice has led to other contributions regarding the development of wearable technology. Through this, I identify and share the insights into the disciplines and processes required for the fusion of technology and design successfully to evolve electronics, code and materials into research prototypes.

I conclude by discussing findings from my practice, research and studies with potential users of emotive wearables. I comment on the impact that physiologically sensing wearable technology has on aspects of social interaction for the individual as well as for the wider community. I open the discussion on future research by revealing two new examples of emotive wearables — the *AnemoneStarHeart* and the *ThinkerBelle EEG Amplifying Dress* — which have evolved from pinpointing specific areas of the focus group and field test feedback that I undertook.

Keywords: sensors, responsive, emotive, wearable, technology, nonverbal, communication, data, prototype, aesthetics, emotions, physiological,

Acknowledgements

I am extremely grateful to my supervisors Professor Janis Jefferies and Professor Bill Gaver for their excellent supervision, encouragement, patience and support, exceptional insight, recommendations, opinions and rigour during my PhD journey. I would also like to thank Janis Jefferies for her dedication to our PhD programme and for buoying us during our voyages of discovery.

Thanks go to the staff of the Department of Computing at Goldsmiths for their assistance, also Kay McEachran, Pippa Kelly and Lesley Hewings for specialist advice, and the always helpful Student Centre team. I am very grateful to my doctoral colleagues for their energy, enthusiasm and constructive advice during my years at Goldsmiths: Bill Psarras, Rebecca Miller, Stacey Pitsillides, William Goodin, Ezwan Mokhtar, Tom Richards, Nicky Donald and especially Anastasios Maragiannis for keeping me company during the long final sprint. I would also like to thank friends Sarah Angliss, Michelle Butler and Adam Hoyle for large amounts of ear lending, encouragement, soy lattes, caek and cat pr0n. I am grateful to all the participants in my user studies, who gave insights and feedback to fuel my research. Also, thanks to friends around the world on Twitter, Facebook, IRC and elsewhere who are too numerous to mention, but who have endured, encouraged, amused and kept me company during the hermitude of my studies.

Most importantly, my research would not have been possible without the love and support of my partner and family, to whom I dedicate this thesis. I am indebted to Ciaran Anscomb, who has fed and endured me, my research, electronics experiments, piles of books, and boxes of belongings; to our fur-babies, cats BlueBelle and Ifor, who have provided much fun, purrs and stress relief during long hours of study; to my family, Pauline Swan and John Ashford, Paula Kinge and Richard Swan, who have encouraged and supported me; and to the Anscomb family, Sandra, Sheila and Chris. Not forgetting the very important people who will miss seeing me collect my doctorate, my mother and father, Lily and Bill Ashford, my uncle, Charlie Ashford, Ciaran's father, Nick and grandfather Gordon Anscomb, and my dear friend, Jim 'Babs' Wells.

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Thesis legend

Double quotation marks "..." reference authors' quotes.

Single quotation marks '...' are used for quotes inside a quote or to emphasise a word or term.

Italics are used for chapter, artwork, device, book and film titles.

Italics are also used for first usage of *Glossary* terms in *Appendices*, where short explanations of the terminology and acronyms used in this thesis can be found (p. 226).

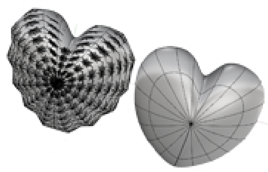
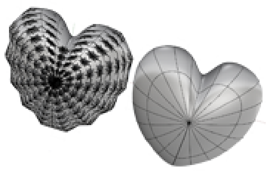


FIGURE 1: CAD (computer aided design) wireframe of *AnemoneStarHeart* (2015)

Chapter 1

Introduction



In this chapter I set out the aims of my research and this thesis. Firstly, I give a brief introduction to wearable technology and *nonverbal communication*, which are two prominent areas that I combine in this investigation. Next I introduce the research, including its roots in a practice-based approach. I then consider the aims, objectives, and questions I intend to answer in this thesis. This chapter then discusses the scope and focus of this thesis, indicating what is and is not included, followed by defining the practice itself and audiences that it addresses. The chapter then explores the context and issues of the research, introducing the user studies that I conducted to investigate possible users of research prototypes. At the end of the chapter there is an overview of the chapters that make up this thesis[1].

An introduction to wearables and nonverbal communication

In this first section I introduce two fields that I bring together in my practice and then explore through my research: wearable technology[2] and nonverbal communication. I list some of the terms that have been used to describe wearables, and illustrate and put wearables into context with some early examples. I follow this with a short definition of nonverbal communication and examples of non-spoken cues.

Wearables

Wearable computing, wearable technology, *fashtech*, *smart clothing* or, simply, wearables, are some of the myriad terms given to a broad and evolving field which encompasses the use of mechanical or electronic devices, worn on the body or embedded in textiles, clothing or accessories, and is where I base my research and practice. There are different interpretations of what the boundaries of this field are; for example, in a broad sense, the first pieces of wearable technology could be considered to include Qing Dynasty abacus rings from the 1600s (Ancient Pages, 2015) and wristwatches, which first emerged in the 1800s (Martin, 2002). For others, the digital wristwatches of the 1970s were the first examples of popular consumer-worn electronics (Finley, 2015).

The first 'wearable computer' is thought to be a computerised timing device that used a 6502 *microprocessor*, devised by mathematicians Edward O. Thorp and Claude Shannon

[1]For brief explanations of the terminology and acronyms used, please refer to the *Glossary* in the *Appendices* (p. 226).

[2]For ease of reading I shall refer to them from now on in this thesis as wearables.

in 1961. The device, concealed in a shoe or a cigarette packet, predicted the outcome of a roulette wheel and sent a signal to the user by way of a musical tone to a radio earpiece. Versions of it were successfully tested in Las Vegas (Thorp, 1998) and the device was kept secret until 1973 when it was revealed by Thorp in *Beat the Dealer* (Thorp, 1973).

Wearable computing was for many years an area of research and development that had so many false starts it seemed destined to be stuck within the confines of the lab, as its progress was held back by clunky electronics, heavy batteries and uncomfortable wiring. I investigate the emergence of wearables from the late 1990s at *MIT Media Lab* in Chapter 5 (p. 120). In describing the image of these cumbersome wearables, educator and writer Joseph L. Dvorak comments:

> "(...) this is a wearable only a geek could love. Graduate students and researchers are comfortable with carrying and using large, obtrusive and complex devices. Their focus is on pushing the envelope of current technology. Ease of use and comfort are usually a lower priority" (Dvorak, 2007, p. ix).

The above quote is pertinent as although electronic components have shrunk and become more compact since I created my first wearables in 2008, I have still fought to find inventive ways of encapsulating fairly sizeable or irregular-shaped electronic components and heavy batteries within garments and accessories.

Today, forms and materials for wearables are numerous and varied, from embedded textiles, clothing and jewellery, to 'on-skin' and implanted devices. Many of these devices, for example fitness trackers, are connected to the *'cloud'* or other networks and devices in order to exchange data via technologies such as *Bluetooth*, and are sometimes described as part of the network of connected devices known as the *Internet of Things* (IoT). Some wearables work in tandem with portable electronics, computers, smartphones or tablet computers, which are not considered to be wearable technology, but can act as engines for data processing and interfaces. The wider application of wearables encompasses usage in areas from everyday consumer items, to sports, medical, military, leisure, and space travel.

From slow and sporadic beginnings, a step change in interest over the last decade has transformed wearables into a fast paced, evolving field, incorporating different concepts and contexts, and also commerce. There is much more still to be developed, in areas such as technological discoveries and uses, answers to sustainability issues, accessibility, and full acceptance. In deciding to wear these garments and devices, the wearer or user not only makes the decision to incorporate technology as part of their lifestyle, but also their image, reflecting on how they want to be seen by others. Moreover, questions still remain about how, where and why wearables will meld with the body and connect us to others, and beyond that how wearables will fuse with us socially and culturally. In this thesis I will present my findings on how, for example, wearables might aid us to make new gestures and connections via nonverbal communication.

Nonverbal communication and cues

A simplified definition of nonverbal communication is the act of communication between humans (or other species or technology) via the exchange of non-spoken 'cues'. There are many cues, which include touch (*haptics*), distance (*proxemics*), body language, facial expressions and gestures (kinesics), time-based (chronemics), non-spoken voice, such as squeaks, humming, murmurs (paralanguage) (Littlejohn and Foss, 2009, p. 280), plus oculesics (eye movement, blinking, pupil dilation, eyebrow movement and glances). It is also possible to communicate by other means, such as non-human sounds: for example, rhythm, music, and tapping. Communication could be achieved, for example, using a specific pitch that is recognised by another, one person 'encoding' (sending) and another 'decoding' (receiving) it (Knapp et al., 2013, p. 5).

Although nonverbal communication can be carried out purposely, for example a wink or a frown, it is certainly not always carried out with the consciousness and regulation of the parties involved. Knapp, a social scientist, discussed how both verbal and nonverbal behaviour is "encoded with varying degrees of control and awareness" (Lakin, 2006, cited in Knapp et al. (2013), p. 10), which is affected by, when in a certain situation, how long one has to process information and respond to it before the body reacts. For example, in situations when it is necessary for a person to respond very quickly, they are unaware or hardly aware of why they reacted in the way that they did (Knapp et al., 2013, p. 10).

Nonverbal communication processing is not foolproof and there are many instances of conflicting signals that can communicate contradictory messages. For example, lying badly: where a person insists one thing, but their body portrays a different story, or they use sarcasm that is not emphasised enough, or, simply, their body betrays their enthusiasm with a false smile. We can also misinterpret a playful situation, for example viewing a person with their hands around someone's neck as something more sinister and vice versa (p. 13). In particular, my practice and research has highlighted the potential for 'hiding in plain sight', that is, using wearables to display emotional data that can only be understood by those initiated into their meaning, and thus preserving privacy more generally.

In my practice I have aimed to make visible the hidden and unseen, by creating new forms of nonverbal communication. I have investigated the creation of 'cues' or 'secret' language as described by participants in my user studies. I have explored this by sensing physiological data from the body and using technology to process and present it as mapped visualisations, for wearers to 'send' and observers to 'receive' and process/interpret (a formulation I will modify in the literature review).

In this section I have given a brief introduction to wearables and nonverbal communication, two fields that I combine and explore through my practice. I investigate the development of wearables in further detail and more definitions and interpretations of nonverbal communication in Chapter 5 (p. 142). In the next section I brief the reader on the nature of the research.

Introducing the research aims, objectives, questions, scope, and focus

In this section I introduce the research and how it has been conducted as a practice-based inquiry. I then lay out the aims of my research, the questions I pursue, as well as the scope and focus of my research. This is followed by defining the practice and its audiences.

Wearables as vehicles of nonverbal communication

My research investigates the possibility that through the exploration and development of wearable technology prototypes it is possible to create new forms of nonverbal communication using physiological data. I have conducted this research using practice prototypes which gather and process physiological data, then visualise and broadcast it. The *performative* impact of this data is achieved using various forms of visual display which have been designed to be worn on the body as aesthetically considered pendants and garments.

To develop my practice further and focus on the nuances of the artefacts, they were critiqued by potential users of this technology, who were recruited to take part in user studies. The studies were comprised of focus groups, field tests, and surveys, which involved demonstrating, wearing, and examining an example practice prototype. This was in order to gather feedback, opinions and concerns about the devices and the wider personal, social and cultural issues of wearing them in social and formal situations. I was especially interested in hearing women's views, as I believe they are a user group who have been underserved when it comes to design choices in technology. The organisation of these studies are documented in detail in Chapter 6 (p. 165).

During my research I have shared each prototype with my core research communities through peer reviewed papers and posters, by exhibiting the artefacts and also through informal discussions at symposia. I invited two of my core communities to contribute to my research by giving feedback on my prototypes through feedback from and surveys of focus groups. From this information I created two new bespoke prototypes, with design guided by the feedback from the user studies participants. These artefacts are documented in Chapter 8 (p. 210).

Research through a practice–based investigation

This thesis documents a practice-based approach to research, which is a means of investigation to gain new knowledge from the process and outputs of practice (Candy, 2006). This also includes the contextualisation of my work within the creative field in which it resides and which I have examined in Chapter 2 (p. 30).

In the exploration of practice-based research, my research has been dependant on artefacts created and critiqued in user studies, as mentioned previously. Candy states that in practice-based research the artefact is a basis for exploration via the making process. She argues that it is "difficult if not impossible" (Candy and Edmonds, 2011, pp. 35–36) to understand this research, without experiencing the artefacts, because textual reflections alone do not give a good enough account. In acknowledging this, I have endeavoured to present the work in this thesis to the reader through images, links to videos, the documentation of research on my blog and other examples.

Practice-based research has allowed me to connect with my fellow practitioners and communities by sharing knowledge to facilitate improving practice methods for developing multidisciplinary prototypes. Moreover, it has allowed me to exhibit my practice artefacts in the manner that Candy describes above and in the process of doing this I both shared knowledge and have received valuable validation and insight into this work. Thus my engagement with the ISWC community has been an integral feature of my practice, as I describe in Chapter 3 (p. 54).

Aims and objectives

My research aims to extend my personal practice by investigating how potential users would engage with displaying physiological indicators of emotions. This has involved creating and refining designs for artefacts for groups and individuals, particularly for women to experience and discuss in workshops or test in their own social, formal or personal environments through field tests (Figure 1.1, p. 8). I have summarised my learnings from these studies in the creation of two new designs for emotive wearables, described in Chapter 8 (p. 210).

FIGURE 1.1: Field test participant wearing the *EEG Visualising Pendant* and NeuroSky MindWave Mobile headset whilst giving a lecture to undergraduate students (2014)

Through these studies it was my intention to explore ideas, issues, and attitudes, and to learn what could be pertinent to the development of devices that might start to change our perceptions of nonverbal communication. I have achieved this through the examination of feedback for indications of how this technology might affect relationships in personal, social, and cultural terms, and have reported my findings in Chapter 7 (p. 184).

This research aims to contribute knowledge to academic peers and practitioners in the field, including key communities that I am part of, including ISWC and the Quantified Self, by presenting my research ideas and by exhibiting my practice prototypes. It was important that these communities were given an opportunity to respond and contribute to my research, as they may provide valuable insights for the future evolution of my prototypes. I met this objective by participating in ISWC and Quantified Self Europe conferences over a period of five years. This was also achieved by inviting attendees of the Quantified Self Europe Conference 2014 to take part in a focus group to discuss emotive wearables and the *EEG Visualising Pendant* and by inviting ISWC attendees to take part in my survey at the ISWC Design Exhibition 2016, giving feedback on my final practice prototype, *AnemoneStarHeart* (p. 210).

Questions

In the pursuit of investigating the creation of new forms of nonverbal communication using wearable technology, the following questions have arisen:

- How might interpreting nonverbal communication via wearable technology affect relationships in personal, social, and cultural terms?
- Who are the potential users of this technology?
- What are the design/aesthetic considerations in designing technology to be worn on the body?
- What technical and functional features are desirable?
- How might privacy issues affect this technology?

Scope and focus

Instead of carrying out an exhaustive survey of wearable technology and its history, the research focusses on the area around emotive wearables. As this is an emerging area within wearable technology, I have contextualised the work of a number of practitioners that have entered the fields of responsive and emotive wearables, or whose work overlaps in similar or relevant areas, in Chapter 2 (p. 34).

In my practice I have focussed on creating examples of emotive wearables that not only would be functional but are bespoke and personalised. This has been realised through the investigation of the requirements and preferences of potential users of emotive wearables.

What is outside or beyond the scope of this research is the in-depth exploration of the biological mechanisms relating to physiological data. I will also not report in depth on psychology or cognitive science, because to try to do this thoroughly would be impossible within the limits of the thesis. I do not provide a definitive history of wearable technology, as this is covered elsewhere, for example in Susan Ryan's *Garments of Paradise*, 2014, and Sabine Seymour's *Fashionable Technology: The Intersection of Design, Fashion, Science and Technology*, 2008, and *Functional Aesthetics: Visions in Fashionable Technology*,

2010. My focus is not on fashion design either; though some devices I cite and work with do cross the boundaries of fashionable attire. What is relevant to my research are the examples of wearable technology in and around the field.

Many of the devices, technology and ideas I have referenced are new and are still being researched and documented, so I would like to note that some of my thesis references have come from online sources, such as technology journals, social media and magazines, rather than academic papers and journals. Wherever possible, however, my references are from academic sources.

In this section I have introduced the research as a practice-based inquiry. I have then laid out my research questions. The section moves on to describe the aims and objectives, then the scope of this research. In the next section I define my practice and audiences.

Defining practice and audiences

In this section I define my practice within the area of prototypes, and discuss to whom my artefacts are directed.

Practice as prototypes

My practice incorporates a number of methodologies, as mentioned in Chapter 6 (p. 158), such as an autoethnographic, reflective and iterative approach, which ensures my practice grows and intertwines with ideas and experiments in a rhizomatic way. Although the artefacts I create are fully functioning, they are not commercial products, instead they are research prototypes.

There are varied definitions of prototypes, for example, *Collins English Dictionary* defines 'prototype' as "a new type of machine or device which is not yet ready to be made in large numbers and sold" (Collins Dictionary, 2017). Most definitions suggest that they are exploratory devices created as part of a learning process. In exploring some of these definitions, I feel my own approach has some commonality with Buchenau and Suri's description of a work in progress:

" 'Prototypes' are representations of a design made before final artefacts exist. They are created to inform both design process and design decisions. They range from sketches and different kind of models at various levels - 'looks like,' 'behaves like,' 'works like' - to explore and communicate propositions about the design and its context." (Buchenau and Suri, 2000)

I do not claim to be a pure 'designer' as my background and practice is multidisciplinary. My practice is well articulated by Lim et al.'s description, which discusses the iterative nature of prototyping. It also frames and expands the definition of prototypes in the context of design:

> "Prototypes are the means by which designers organically and evolutionarily learn, discover, generate, and refine designs. They are design-thinking enablers deeply embedded and immersed in design practice and not just tools for evaluating or proving successes or failures of design outcomes." (Lim et al., 2008)

The Anatomy of Prototypes, Lim et al.'s investigation, explores many conceptual ideas around prototypes, including how they are a manifestation of design ideas. The paper discusses, amongst others, Clark's "externalization of thought giving rise to new perceptual and cognitive operations that allow for reflection, critique, and iteration", whilst situating this discussion within Donald Schön's perspective of externalising ideas so the "world can speak back to us", helping us to understand and examine our own ideas (Clark, 2001, Schön, 1983, cited in Lim et al. (2008)).

It is through the act of making prototypes, in which I explore the concepts and possibilities that allow these artefacts to have the potential to grow and develop, that has permitted my research to proceed.

Audiences for practice artefacts

The research prototypes focus on two primary sets of audiences: potential users, and academics in the field of wearables, in particular the ISWC research community, but there are other peripheral audiences and communities to consider.

My practice artefacts are designed for the potential users of emotive wearables. A key objective of my research is to understand who might be interested in the emotive wearables I have been designing and what their needs and requirements are in order to aid my iterative approach to developing accessories and garments for them. As mentioned in the previous section, I set out to recruit women who were interested in wearable technology and discover what their preferences would be if they were interested in wearing emotive wearables. Whilst on this research journey, I discovered there were other user groups for this technology that I should test, such as the Quantified Self movement, who are dedicated self-trackers and who would be interested in the *EEG Visualising Pendant* as a self-tracking device, but would also have interesting feedback on areas such as its design and functionality. It was also pertinent to test the pendant with potential users in differing real-life formal and informal situations. These latter two groups I decided should be mixed gender not only for reasons of diversity, but also because I had many enquiries from men wanting to join the studies, which persuaded me that they belonged in the potential user groups of this technology. The results from my user studies can be found in Chapter 7 (p. 184).

In this section I have introduced the research and laid out the research questions that I answer in this thesis. I have looked at the aims and the objectives of my research and also its scope. This section also defines my practice by establishing it within the area of prototyping, and artefacts as research prototypes. I have also clarified to whom my artefacts are directed, and also the academic community my research is aimed at. In the next section I give an overview of my research's contribution to knowledge.

Research contributions and outcomes

In this section I give indications of how my research has contributed to knowledge and outcomes. This research offers insights into the possibility that wearable technology can be used as a vehicle for new forms of nonverbal communication through the development of practice research prototypes. By means of user studies, the research investigates the preferences and concerns of people who might wear these artefacts. The research process, which has resulted from a combination of methods and methodologies, has generated a body of work that has relevance for the future design, concept, theory and usage of a subset of wearables artefacts called 'responsive wearables' and 'emotive wearables'. My key contributions are in the following areas:

Introduction of terms

I have introduced two terms to describe the field in which the practice is situated within the larger domain of wearable technology/computing. The first to emerge was 'responsive wearables' and, as the name suggests, these devices 'respond' to the wearer's environment, interactivity or physiological data from *sensors* placed around the body. The resulting data is processed and amplified as sensory output to the wearer and observer, such as through visual, aural or tactile means. In order to pinpoint my field of research further, I introduced a subset of responsive wearables, called 'emotive wearables', which focusses on visualising physiological data that can be associated with nonverbal communication or 'cues' or assigned to communicate or imply the mental states, emotions or moods of the wearer. Further descriptions and examples can be found in Chapter 2 (p. 33). These two terms have proved important for describing my practice in academia and for sharing with the communities that I have become part of. The terms have been taken up and used by practitioners and academics when describing this field[3], which confirms that these new subsets have contributed to the field of wearables.

Generation of research prototypes

My practice has generated four new artefacts in the form of research prototypes, all of which have been exhibited and shared with my research communities through published papers, posters, and exhibitions[4]. These artefacts show how data can be conveyed, broadcast or amplified from physiological and environmental information as a form of nonverbal communication or 'cues'. These cues signal or convey information to the user and those around them in a social or formal situation, via mapped light that can be decoded if the user wishes to divulge what the shapes and colours indicate. User studies' participants likened this to a 'secret' or covert visual language, for which potential users suggested various uses and scenarios from private to public use.

User studies considering the first two of these artefacts, the *EEG Visualising Pendant* and the *Baroesque Barometric Skirt*, informed the development of the final two as bespoke and personalised research prototypes. These are the *AnemoneStarHeart* and the *ThinkerBelle EEG Amplifying Dress* and are described in Chapter 8 (p. 210).

[3]To give an example of the usage of the term 'emotive wearables', it is used in the context of *EEG* sensor wearables systems in *Where to Wear It: Functional, Technical, and Social Considerations in On-Body Location for Wearable Technology 20 Years of Designing for Wearability* (Zeagler, 2017, p. 154).

[4]Published papers, posters, presentations and exhibited works are listed in *Appendix: Research History* (p. 299)

My research has explored a gap in knowledge that represents new approaches to working with personal data and the generation of aesthetically bespoke and personalised artefacts. Although there are other projects looking at similar or connected areas around emotive wearables, such as methods of displaying data and connected design concerns, my approach has involved the gathering of user studies data which revealed concerns, aesthetics and design preferences, and technology requirements of an evolving technology. This information is also necessary and of use in order for the wider field to begin to address who these artefacts are for and can be found in Chapter 7 (p. 184).

The information I have gathered from the development of research prototypes is envisaged to be useful for the future development of functionality, design, and aesthetics, the latter two being contentious issues for wearables, informed by a perceived lack of consumer satisfaction in these areas (p. 23). These new research prototypes have been created to inform my research communities as well as the wider field of emotive wearables practitioners and those who have an interest in the broader field of wearables and communication, or, for example, covert methods of communication.

However, it is still the case that wearables developers have no alternative but to persevere with hardware, software and applications that were not specifically designed to work together or for wearables. Also, technologies designed for hobby use are not suitable for long-term use, nor do they address issues such as the comfort of the wearer, which restricts the usability and acceptance of wearables. Furthermore, I have discovered through my practice that we cannot rely on our digital artefacts and their current on-board storage solutions to keep important data, such as physiological information, images, and recordings, safe for long periods of time. Moreover, any data regarded as important should be backed up to trusted forms of storage. Further discussion can be found in Chapter 2 (p. 50).

Exploring a method for creating multidisciplinary artefacts

Although there existed useful methodological approaches that I have used to underpin my practice such as reflective action and rhizomatic methodologies, as discussed in Chapter 6 (p. 159), I found there was something slightly lacking when using these approaches with regard to working with the combination of electronics, code, and garments/materials to create wearables. It was important to find a very focussed method for keeping my evolving practice moving forward, due to complexities arising from working in a multidisciplinary way, which presented various problems to be solved.

Working with differing types of media can be unwieldy and difficult to manage due to their each having complex learning curves, characteristics, and intricacies. These can include operational and interoperability constraints regarding usage and working with other media that have a bearing on the success or achieving the aim of each component in a working prototype. The method I developed focusses on the construction of wearables in particular, and in the case of my practice the three essential specialisations I bring together have to do with configuring new arrangements of electronic components, developing new software, and pursuing aesthetic/design ideas with combinations of electronic and analogue (e.g. fabric) materials. The method comprises a series of prompts to aid the practitioner on an iterative journey to develop and push forward with the progress of their artefacts. It is intended that the practitioner uses the prompts to ask questions of their project's progress and tests regularly to maintain control of how specific areas and media are working together and if more research or changes need to be done on an aspect in order to proceed.

Extending on 'rhizome' or 'rhizomatic' as a metaphor for my practice, which has allowed me to visualise how ideas, concepts, and different media could intersect in a botanical, entwining way, a new method for developing artefacts began to evolve from my practice. It directed focus on key stages of prototype development to acquire knowledge, test, and advance the progress of multidisciplinary wearable devices that require different materials and technologies to work together. This evolved into a three-stage cyclic, iterative process of 'Identifying, Concluding, and Updating'. The three stages included: questioning requirements, gathering knowledge, and making necessary changes to code, hardware, and the aesthetic/physical design and construction of artefacts. Testing at each stage was also very important to keep across the development and progress of my practice prototypes. In my experience, it is usual for practitioners to work in a team or collaborate with others to develop wearables as they don't necessarily have all the skills required across electronics and code, as well as design. Coming from an education that included fine art, electronics engineering, and programming, as well as vocational experience, I work on all the aforementioned aspects myself, thus one of my original contributions to knowledge is a bespoke method for academics and practitioners who are working on multidisciplinary prototypes.

Understanding audiences for practice prototypes

The research has focussed on establishing that there is a potential audience for wearables that convey forms of nonverbal communication by broadcasting representations of physiological data in the form of visual display. This has been achieved through a dedicated approach to participant research that I have designed and structured, based on my experiences conducting user tests around interactive media, to recruit and understand the feedback and concerns of possible wearers of such devices. This research extracted pertinent and useful data by teasing out feedback from demonstration, discussion, experience of wearing and observation, regarding an emotive wearable. In my research, I combined focus groups, field tests, and surveys as methods of investigation. From the data captured I have identified preferences regarding what bespoke and personalised forms of this technology might look like, and also its functionality. User studies have identified potential uses and situations in which emotive wearables might be worn and preferences to where on the body they could be located. It has also uncovered situations and locations that some users might find awkward or uncomfortable. I was able to make observations about how this technology may affect relationships in personal, social, and cultural terms, for example user studies' participants discussed examples of how they expected they could use the visualisation of physiological data as a new form of nonverbal communication between friends in intimate and informal situations, also at work and other formal settings, or in public spaces with many people able to view the device. This understanding of audiences and their concerns is directed at future academics and creators of such artefacts who are developing emotive wearables or other forms of nonverbal communication.

Focus on women audiences for emotive wearables

I have paid particular attention to the understanding of women audiences for emotive wearables. Through my previous vocational experiences of interviewing women regarding their experiences of using technology, I believe women to be underserved when it comes to its design. I have contributed new knowledge to the field of emotive wearables, practitioners, and my academic communities through user studies, discussing and sharing the concerns and issues raised by women participants as users of emotive wearables. This includes requirements such as functionality and aesthetics, plus how and when this technology might and might not be used, which have been highlighted in Chapter 7 (p. 184).

These insights from discussions and experiences have been transcribed from audio recordings and surveys, and are presented through analysis of qualitative data. This information has allowed me to create the two new research prototypes mentioned earlier in this section, *AnemoneStarHeart* and the *ThinkerBelle EEG Amplifying Dress*.

Commonality between wearers of emotive wearables

Through user studies, it was discovered that wearers of emotive wearables have a commonality in that they are interested in finding out more about themselves. Many of the people who were interested in wearing emotive wearables already owned activity trackers and sports wearables, which introduced them to the area of self-tracking. This has led to their interest growing in exploring personal data and curiosity to find out more about themselves via technology, but has also introduced them to new and perplexing issues around privacy, surveillance, and ethics. In particular they raised issues about what happens to their data being collected from wearables and then processed, stored, and shared.

The user studies revealed that users are predominantly from technology backgrounds or have technology interests. They are not intimidated by technology, but are aware of privacy issues and make their own judgements about what they share. Attitudes that separated them were choices for functionality, aesthetics, design, and uses, and they were keen to express differing ideas on personalisation, which indicated that potential users would like wearables to reflect their personalities and aesthetic sensibilities, and that they would like customisable functionality. Together these findings indicated that there was not a 'one size fits all' expectancy for wearables.

Emotive wearables and relationships

Through user studies and by exploring projects in the field, I was able to make observations about how this technology may affect relationships in personal, social and cultural terms. For example, wearers gave examples of how they expected that they could use the visualisation of physiological data as a new form of nonverbal communication between friends, as mentioned earlier in this section. However, some participants did not feel comfortable broadcasting data in public for reasons of privacy or feeling self-conscious about drawing attention to themselves by wearing technology so prominently on the body.

Emotive engineering

Through the development and investigation of the usage of my practice artefacts has led to my introducing the term 'emotive engineering' as another contribution to the field. The term is used to describe the occurrence of a user's visualised physiological data being purposely changed or played back in a differing synchronicity to enhance or manipulate how the user is perceived by those viewing the displayed data. This could be used by the individual, for example, as a confidence boost in stressful situations, also by professionals, such as doctors, police, or teachers, to inspire confidence or quell an intense situation, for example by appearing calm or attentive.

I first began to experiment with the notion of emotive engineering in public via the manipulation of heart rate data, visualised on a proxemics driven wearable named, *You make my heart flutter*; it's use is described on p. 39 and a description of the artefact's construction can be found in Chapter 4 (p. 89). In order to investigate this area further and for users to be able to experiment with using their recorded EEG data in different circumstances, I added record and playback functionality to three subsequent research prototypes that I developed. These artefacts were EEG-driven emotive wearables. Emotive engineering is evocative of Goffman's theories around presentation of the self, such as "fronts" and "dramatic realization" (p. 146), when a person puts emphasis on certain actions to embolden them to others (Goffman, 1959, p. 40). Emotive engineering takes self-presentation a step further and fills a gap in the technological age by allowing wearables to become a vehicle for adapting and enhancing how we present ourselves to others. This practice has personal, societal, and cultural ethical dimensions to consider regarding the manipulation of data, for example, whether it is considered to be used to deceive or for therapeutic use.

Identifying gaps in the literature review

The literature review enabled me to identify the gaps in the fields I have addressed. In the case of the area of context-awareness, responsive wearables fills a gap in which bespoke and personalised artefacts communicate beyond the wearer and device's screen using non-verbal cues in the form of visualising data outwards to also communicate with others in their environment (p. 122). The review also raised issues that concern *head-mounted displays* (HMDs) and headsets such as *Google Glass* and those I have found that involve the usage of the EEG headsets that I have employed in my practice and studies (p. 172), which have led me to encounter a gap in the exploration of personalisation and the bespoke in order to make these functional and cumbersome devices more attractive and comfortable to confront issues around wearability (p. 184).

In this section I have given indications of the contribution of my research to knowledge and outcomes, which focus on the introduction of three terms concerning wearables, the generation of unique research prototypes, the exploration of a methodology for creating wearables which brings together multidisciplinary specialisations, understanding potential audiences of emotive wearables, and investigation of the notion of emotive engineering and manipulation of physiological data. In the next section I discuss the background and motivation for my research.

Research background and motivation

In this section, I describe the background and context of my research. I discuss my previous experience of working as a woman in technology. I describe my experiences of conducting user studies for testing and opinion gathering for technology products, in which time and again I was informed by women how unintuitive common and everyday technology was to use. I go on to discuss how in delving deeper I have found examples of design where stereotypes have been used to market technology products to women, which has led me to believe that there is a need to ask women how they would like their technology to function and look. I also discuss a backlash in the media due to a need for design and aesthetics to be applied to consumer wearables. This connects to my research aims in my practice of creating bespoke and personalised wearables.

Background as a woman in technology

Before I began my doctoral studies, I worked as a senior producer for the *BBC*, a UK public service broadcaster, producing and commissioning interactive technology projects for television, radio, and online. My experiences of working using an iterative approach to developing projects has led me to focus on locating potential users of emotive wearables and developing and testing research prototypes.

I was also very active in the UK and international technology communities, attending conferences, symposia, and events such as *hackathons*. Through attending these events it became very apparent that there were comparably few women working and overseeing the creation of technology, or speaking at events and on panels. As a reaction to this I organised a Women in Technology group at my workplace, which met monthly to discuss relevant and current issues, and learning and job opportunities for women. I also joined a steering group, comprised of senior women in business and education, who were looking at ways to encourage more young women to pursue an education and careers in programming and computing subjects, to address the imbalance of diversity in technology roles. During discussions, the topic of how to present technology attractively to women was a constant and contentious theme.

In my day job, one of my responsibilities was creating and assessing content that was very specifically targeted at certain audiences and demographics, which entailed working on many user-testing sessions with the public (which was useful for my research user studies). The context of the user-testing sessions was to gauge user interaction and experiences with web-based technologies in the pursuit of creating useful and usable websites and interactive applications. Women participants frequently reported that common devices such as TV remotes, mobile phones, and digital cameras, were not easy to use nor was documentation created for them to easily understand in terms of language, terminology, and layout. I also found that technology and tools, when aimed at women, embody stereotypes that can be quite patronising, such as using unnecessary pink or pastel colouring (Figure 1.2, p. 21), or being accompanied by other condescending accoutrements or texts.

FIGURE 1.2: Pink tool kit, in the window of a hardware shop in Marylebone, London (2010)

Technology and stereotypes

In delving deeper, I discovered that women have historically been an underserved target group regarding the choices and design of technology and have been subject to gender stereotyping in technology usage and products. For example in 2009, a marketing website aimed at women by computer technology company Dell, called *Della*, was lambasted for its patronising and stereotyping of women due to its emphasised pastel laptops and content that included 'tech tips' for finding recipes and calorie counting (Laird, 2010, p. 3). Because of such examples, I have paid particular attention to women's views and preferences in my user studies by specifically asking groups of women to join my studies on emotive wearables and give feedback.

FIGURE 1.3: Fitbit with pink detail (2012)

The colour pink

In 2012, I wore a clip-on *Fitbit* activity tracker, which came in a choice of black enclosure with a pink (named 'plum' by the manufacturers) or blue underside, which to me upheld an obvious western gender stereotype of pink as feminine and blue as masculine (Figure 1.3, p. 22). I did not want to offer such stereotypically gendered choices in my practice. Instead, I wanted to design devices to suit personal aesthetics and, in a reactive and bespoke way, to give the wearer a choice. I also did not want to design wearables 'for women' as a group, rather I wanted to know what women would wear and their concerns, opinions, and feedback in order to create new iterations of existing practice and contemplate future artefacts. In a number of my research prototypes, I have chosen specific colours, red and green, to represent the EEG channels of 'attention' and 'meditation' (see Figure 1.4 (p. 23)), not just in terms of their contrasting nature, but also colour theory, I discuss this further in Chapter 4 (p. 116).

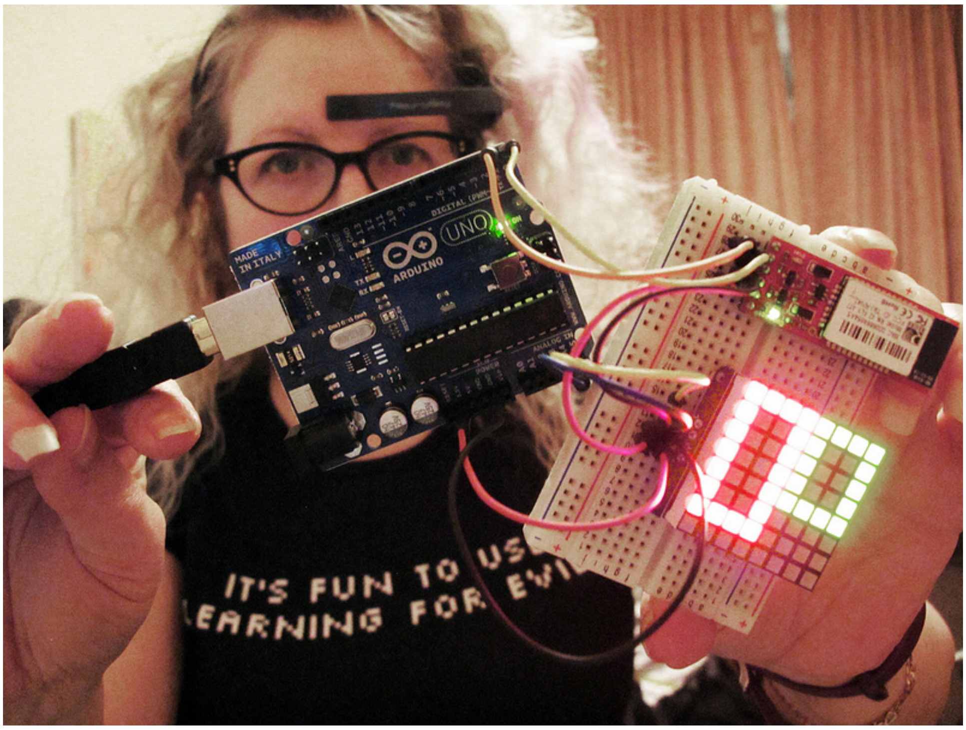


FIGURE 1.4: Developing the *EEG Visualising Pendant* and experimenting with using red LED light mapping for 'attention' data and green for 'meditation' data (2013)

Style, desire, and products

After an initial surge in interest and hype of wearables following the success of activity trackers such as the Fitbit and a tide of other devices a backlash occurred. This came from the tech media and in style blogs bemoaning the lack of design and aesthetic choices for wearables, articles began to emerge with titles such as *Why is wearable technology so damn ugly?*. In the case of this particular article it reviewed the 2014 Consumer Electronics Show (CES)[5], describing devices as ugly and masculine, and in the following terms: "Not only were most devices useless, they were also utterly unwearable by any self-respecting woman" (Arthur, 2014), which underlined the lack of appealing and useful devices that were being developed and promoted.

At the same time, many technology companies had invested in divisions within their business to explore wearables, but did not have the design expertise to make aesthetically desirable devices. One of these companies, Intel[6], who are renowned for their computer processor chips, called a meeting to begin a collaboration with the fashion industry to try to bridge

[5] CES is a world renowned technology show, held every January since 1967, in Las Vegas, USA, to premier the latest consumer technology: http://www.ces.tech

[6] https://www.intel.co.uk/

that gap. In 2014 Intel also launched a competition, *Make It Wearable*[7], which offered \$1.3 million in prize money for wearables ideas using their Edison technology (Rosenberg, 2014). The winner was *Nixie*, a camera drone launching bracelet (Intel, 2016). Although novel and fun, it was not particularly practical or useful for increasing acceptance of everyday wearables. Unveiled at CES 2014, the Edison technology was intended to be used as a system for wearables and IoT devices, though take-up and emerging projects of the Edison were said to not be as forthcoming as those on established *Arduino* or Raspberry Pi platforms and the technology was discontinued in 2017 (List, 2017). From a user's point of view, I had experimented with the Edison platform (Figure 1.5, p. 24) at an Intel workshop and found it complicated to set up and so did not favour it for my own projects.

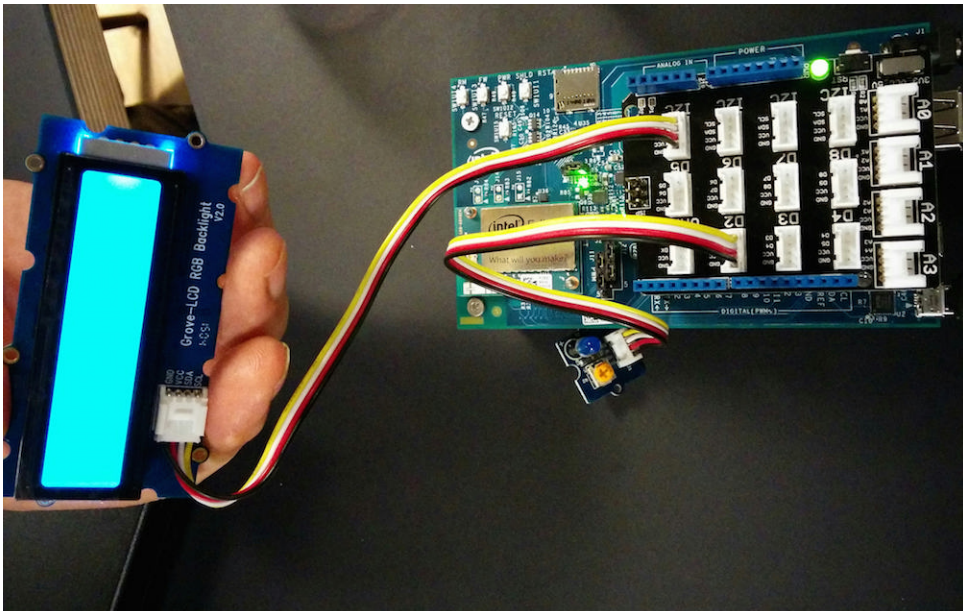


FIGURE 1.5: Experimenting with the Intel Edison prototyping platform (2015)

In 2017 the availability of garments that incorporate technology is still limited compared to the vast choice in fitness devices and smartwatches. For example, the Fitbit range has increased from its early clip-on trackers to include wrist-worn bands and smartwatches, and it now also produces accessories that allow the wearer to customise their device, for example designer enclosures in the form of necklaces and bracelets plated with gold and other metals (Fitbit Inc, 2017). There would seem to be a correlation with small compact wearables and proliferation and commercial success, which may reflect the limitations that embedding technology in garments currently presents, such as washability, battery

[7]https://iq.intel.com/wearables-need-to-be-out-of-sight-in-2015/

life, and weight, but also in finding reasons for embedding technology into garments that potential users actually desire.

Examples of companies in the autumn of 2017 who are chasing the desire to launch technology-enhanced garments include the established clothing brand Stone Island. They have used thermo-sensitive yarn on top of wool in a double-knit construction to create a limited *Ice* range of knitwear that is described as 'dramatically' changing colour, creating three-dimensional effects, when exposed to low temperatures (Chaya, 2017). Colour-changing thermochromic textiles and clothing are not new as this technology has been explored by researchers and designers, such as Rainbow Winters, who has created a number of colour-changing artefacts including water and sun-reactive garments for her *Rainforest* collection (Winters, 2011).

There is still much to investigate in the area of design and aesthetics for wearables, especially because customers do not share the same needs and desires. However, although what is appearing in the commercial sector is of interest to my practice because it will affect the acceptance and future development of wearables, I am not working in the commercial sector but I am creating personalised and bespoke research prototypes, as I described earlier (p. 10).

This section has given some background and context to my research in terms of my previous experience of working in technology, where I discovered through user testing that women found everyday technology unintuitive and difficult to use. I go on to discuss stereotypes in technology marketing and the use of pink in products aimed at women. I then discuss a backlash regarding the lack of design and aesthetics in technology for wearables and give an example of how one company, Intel, brought wearables into its company, followed by more recent examples. In the next section I give an overview of the structure of this thesis.

Structure of thesis

In this introductory chapter, I have given a short introduction to wearable technology and nonverbal communication and an overview of my research, the questions it answers, its aims and scope, and my background. In *'Chapter 2: Communicating via wearables'* (p. 30)

I discuss the practice of some of the artists alongside whose work I situate my own practice. In *'Chapter 3: Developing wearables with the ISWC community'* (p. 54) I contextualise my work as a backdrop and contribution to the academic community of the International Symposium on Wearable Computers (ISWC). This chapter is partly a history of my contributions and partly a log of the research of others that has had an impact on my research. In *'Chapter 4: A practice in responsive and emotive wearable technology'* (p. 89) I describe and explore my practice, which involves the development of responsive and emotive wearable technology. In a description of each artefact I discuss my creative process, which includes investigating ideas, testing code and circuits, and also the unexpected challenges that working in a multidisciplinary process presents. In *'Chapter 5: Literature review'* (p. 120) I investigate the themes that have been important to my research and practice around emotive wearables. Accordingly, this text reflects upon, critiques, and supports my research, and has assisted in identifying the gaps that have led to the development of my contributions to knowledge. In *Chapter 6: Methods and Methodology* I describe the methods and methodologies for my research. Beginning by situating my research methodology, it then moves on to discuss my methods for user studies. *'Chapter 7: Results and discussion'* (p. 184) presents the results from user studies and the discussions related to my research questions investigating the possibility of creating new forms of nonverbal communication and the potential users of this technology. In *'Chapter 8: Practice post-user studies'* (p. 210) I describe the two new research prototypes that have evolved from the feedback and opinions of participants of the focus groups and field tests. These studies featured the *EEG Visualising Pendant* as an exemplary emotive wearables device for review. Finally in *'Chapter 9: Conclusions'* (p. 220) I present the conclusions from my research and discuss the new knowledge that I will contribute to the field of wearable technology and disciplines including *e-textiles*, art, design, electronics, programming, psychology, and creative computing.

Conclusion

In this chapter I have summarised the research journey that I have traversed in this thesis. I began by giving the reader a brief introduction to wearables and nonverbal communication which are key areas that I explore through my practice.

Next, I discuss the questions that I have pursued, which probe the potential for wearables that visualise physiological data as a means of nonverbal communication and ask questions regarding the design, aesthetics, functionality, and technology of these artefacts. I also investigate the personal, societal, and cultural implications of wearing these devices.

This is followed by aims and objectives, plus the scope of the research. Finally, I suggest that this research is intended for two basic audiences: the research community centred on the ISWC conference, and the potential users of my designs.

This is followed by indications of my claims to new knowledge. I have introduced three new terms to the field of wearables, which I have investigated through my practice and studies. Two identify responsive wearables and emotive wearables as subcategories of wearables more generally. The former sense, and react to, the wearer's environment, interactivity or physiological data, the latter broadcast physiological data that can be associated with nonverbal communication to imply the mental states, emotions or moods of the wearer. The third term, emotive engineering, is an outcome of my practice exploring emotive wearables. This concept concerns the consequences of using pre-recorded physiological data at a later date or time to influence or manipulate a situation. I have developed three of my research prototypes to be able to practice this, incorporating options for live or recorded and replayed EEG data, as suggested by my user studies. However, to become a useful tool, the practice of emotive engineering would first require cultural acceptance. This is one of the areas I investigated through user studies, which have contributed new knowledge on the potential users of this technology, as well as detailed insights into the multiple concerns and issues of wearing emotive wearables in social, formal, and private situations. This also included preferences for bespoke and personalised functionality and aesthetics, especially focussing on the opinions of women users.

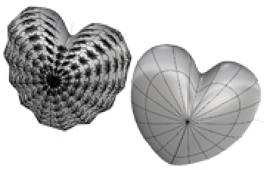
As part of the development of my practice, my methodology grew to embrace the process necessary to develop multidisciplinary artefacts that include electronics, programming, and design. This filled a gap in the methodologies that I was using to help move my projects forward. The methodology uses a series of prompts to aid the practitioner on an iterative journey to develop and progress with their artefacts.

In the next section I describe the background context to my research, discussing my experiences working as a woman in technology, which has been a motivation for my research. This includes my pre-doctoral observations during product user testing with women, where they mentioned that everyday technology was not intuitive to use. I also discuss stereotypes being used in marketing regarding technology for women. These experiences led me, during my user testing, to approach three age groups of women for their views. I briefly discuss the area of style and desire, and how technology companies such as Intel have striven to include wearables in their offer as an indication of how wearables have been explored by the technology industry. I have also described other groups that I decided should be included in my user studies, including members of the Quantified Self, those who would wear and test the pendant in real life social and formal situations, plus attendees of the ISWC Design Exhibition.

In the next chapter, *'Chapter 2: Communicating via wearables'* (p. 30), I discuss responsive and emotive wearables, where I situate my practice and discuss examples of research and devices in these fields.

Chapter 2

Communicating via wearables



This chapter considers communications via wearable technology by categorising the use of sensors and *actuators*. The chapter then moves on to responsive and emotive wearables, and emotive engineering, which are my research focus. I describe what these subcategories are and how they have evolved to fit into the ecosystem of wearables. I give examples of my practice in these areas, contextualising them alongside practitioners and artefacts working on similar issues, including forms of intimate and overt communications, data, and displays. To illustrate this, I have mapped some of the triggers and responses used in emotive wearables for discrete and hidden communication and listed examples of how they have been used by practitioners.

Wearables: Navigating the field

Starting out: Key groups using sensors and actuators

Initially, I encountered a very broad field of wearable research. In order to locate myself within it, I mapped out the emerging groups that used sensors and actuators for the input and output of data. This enabled me to gain clarity for my own work.

I plotted key areas of sensor and actuator usage and made lists of how they were used in wearables and the textile field. They were put into categories as I evaluated their importance as early as 2011. The chart produced (see Chart 2.1 (p. 32)) is not exhaustive, but it was useful for seeing where technology was going.

Comparing categories, sometimes blurring boundaries, indicates that the biggest range of sensors are concentrated in the military/extreme environment, self-monitoring/lifestyle, and artist/maker categories. This information was important to my research because it gave insights into who was pushing forward with wearables, had the most funding, or was the most experimental. It also stood out that the category with probably the least funds were artists and makers, who at the time were probably equally as interested in a plethora of technologies and potential outcomes as the richest and most funded: military and medical. Berzowska describes how many innovations using the combination of sensors and e-textiles have arisen from funded military programmes (Berzowska, 2005). This includes the development of integrated sensor arrays for clothing and backpacks, in particular for tracking vital signs and giving feedback on the physiological state of the wearer. It also includes innovations in environmental sensing, such as sensors for detecting biochemical threats or sounds emanating from remote objects.

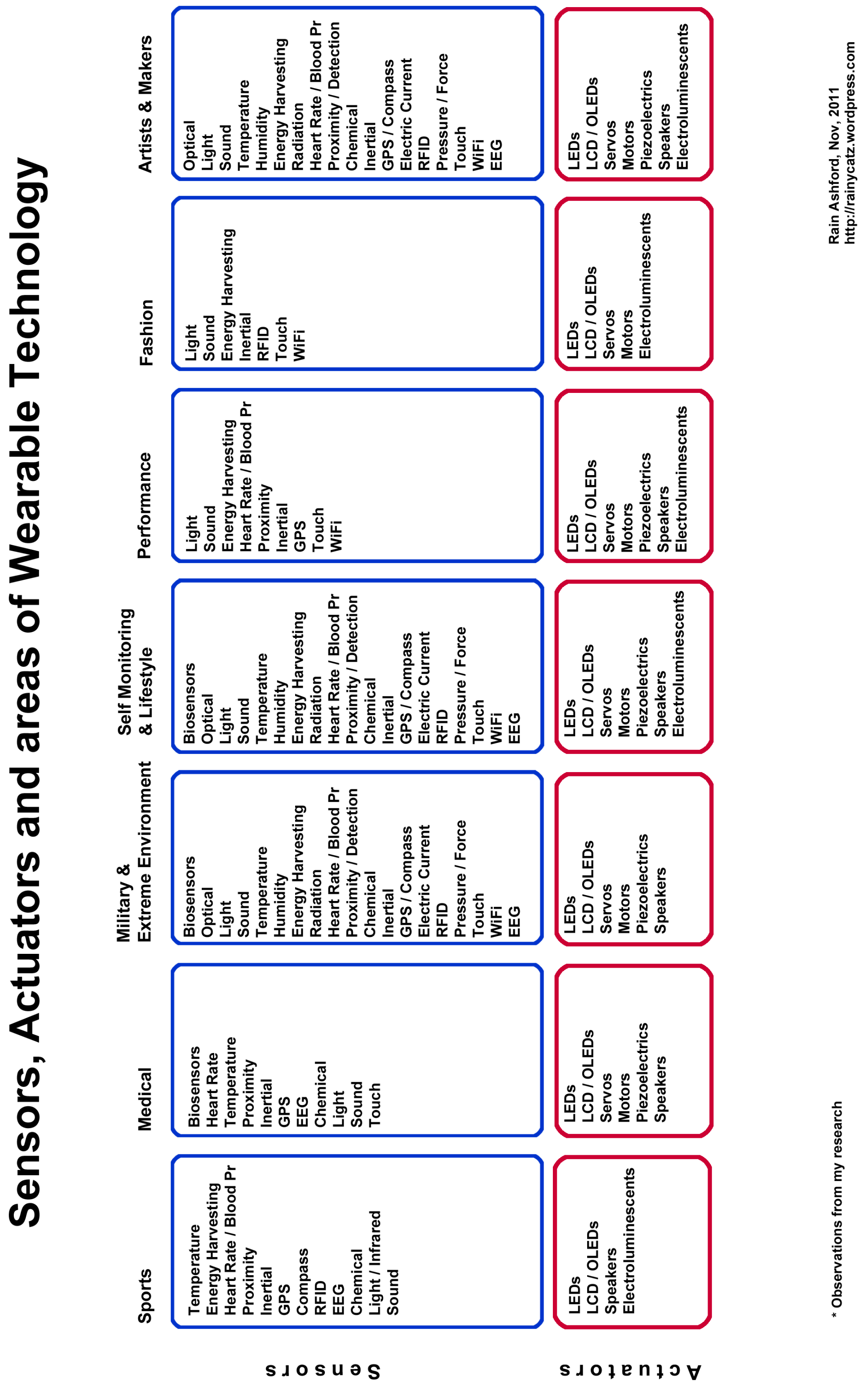


CHART 2.1: Sensors, Actuators and Areas of Wearable Technology, a diagram mapping out the perceived usage of sensors and actuators in groups who were creating wearables in 2011

Introducing responsive and emotive wearables

Since 2011, the field has expanded beyond my expectations. I had determined an area on which to focus my research and practice, but this area, in 2013, did not have a specific name. In order to situate my practice within this field, it was required that I create a term that would adequately describe the area I was investigating, so I introduced a very specialised term, 'responsive wearables'. The second distinctive term I introduced in 2013, was 'emotive wearables', this was because responsive wearables no longer adequately described artefacts that concentrate on the use of data from the body and I needed to drill down further.

Responsive wearables

The area of responsive wearables encompasses bespoke garments, jewellery, and accessories that react to the wearer's environment, interactivity or physiological signals taken from sensors around the body, then process and display it. This term also refers to wearables that intercept, process, and display data from personal computers, smartphones, tablets, smartwatches, and other devices. An example device could be a smartwatch, that alerts the wearer of an incoming *SMS* (Short Message Service) message, email or diary date delivered from a smartphone while on the move.

Responsive wearables have similarity with context-aware devices from, e.g. the 'lifestyle' and 'fashion' categories in my diagram. I describe this in more detail and give examples in Chapter 5 (p. 122). Responsive wearables differ, however, in that they focus on *amplifying* data, that is they take a signal and represent it in a more obvious way, for example through visual, tactile, or aural means. In the case of my doctoral practice they evolved to focus on the visual through displays. Finally, they become bespoke and personal to the user through functional, aesthetic and design choices which have developed alongside the technical evolution of the artefact.

FIGURE 2.1: The *Baroesque Barometric Skirt*, an example of responsive wearables (2012)

Examples of environment–sensing responsive wearables

One example of a responsive wearable that I created as part of my practice is the *Baroesque Barometric Skirt* (2012). This garment combines the traditional crafts of dressmaking and hand-painted textiles with electronic circuitry (e-textiles), programming, and data. Via bespoke imagery, aesthetics, sizing (made-to-measure), and the user's data, it connects a personal artefact with the sometimes impersonal nature of surroundings and environmental data. It also approaches sustainability through its removable electronics apron for washability.

The garment visualises the wearer's physiological data entwined with that of their environment, to create a visual display of one's current status for oneself and for others. As well as physiological data in the form of the wearer's temperature, the skirt collects and processes data from a *barometric* sensor, which includes ambient temperature, pressure, and altitude (Figure 2.1, p. 34). See Chapter 4 for an in-depth description (p. 93).

Cosmic Bitcasting (Psarra, 2017) is another example of a responsive wearable. It provides sensory feedback in the form of light, sound, and vibration driven by invisible cosmic radiation passing through the human body, and it extends the notion of connecting the body with the environment. It has other connections to my practice; for example it is part installation, part attire, and has a performative implication. An additional example which is of interest due to its use of *horripilation* to signal 'electrosmog' in atmospheric data is the *Taiknam Hat* (2007) and is discussed in Chapter 5 (p. 139).

FIGURE 2.2: Ars Electronica/Martin Hieslmair *Cosmic Bitcasting/Afroditi Psarra*, [image] At: `https://www.flickr.com/photos/arselectronica/34654144496/` (CC BY-NC-ND 2.0) [Accessed on: 2017-10-10] (2017)

A different approach to the presentation of responsive wearables has been taken up by Lauren Bowker who leads the *THEUNSEEN* materials exploration house. They use performative descriptors such as 'magick' and 'alchemy' to present their artefacts, which combine art and design with materials-driven technology research (THEUNSEEN, 2017). Their artefacts connect to my research interests via their exploration of responses to physiological and environmental data visualised via colour-changing inks, dyes, and materials. Bowker's research began at Manchester School of Art where she researched inks and dyes that would change colour from yellow to black in the presence of carbon monoxide. She has since collaborated with biochemists to create inks such as *Pollution* for garments whose aim is to protect the wearer from environmental hazards such as passive smoking and fuel emissions (Kettley, 2016, p. 146).

Emotive wearables

Emotive wearables focus on visualising, amplifying, and broadcasting physiological data that can be associated with nonverbal communication or cues as described in Chapter 1 (p. 4), for example data that can be interpreted in terms of the mental states, emotions, or moods of the wearer. The intention of these artefacts is to make physiological or emotional states that are covert, hidden, or obscured, visible to the user and to others. An example of an emotive wearable is the *EEG Visualising Pendant*, which I have designed, programmed and built the hardware for as part of my practice, and have used as an example of an emotive wearable in my user studies as described in Chapter 6 (p. 165). The pendant visualises two streams of EEG data sent via Bluetooth from a *NeuroSky MindWave Mobile* EEG headset. Visualised data reveals otherwise hidden aspects of the wearer's state as a form of nonverbal communication, amplified for the user and those around them to interpret (Figure 2.3, p. 37).

FIGURE 2.3: The *EEG Visualising Pendant*, an example of emotive wearables (2013)

Emotive wearables is a fast growing field. Technology companies and start-ups are looking for commercial opportunities to tap into people's lifestyle. I hold the view that people who have invested time and money into fitness tracking devices will also be attracted to emotive wearables. My research has clearly identified that women in particular are not just interested in the aesthetic qualities of what they wear, but also in displaying emotional data that can only be understood by those initiated into their meaning, which helps preserve privacy more generally.

Ethics and integrity

Emotive wearables and emotive engineering have social and cultural barriers to overcome before they might appear as everyday attire, or be acceptable without causing awkwardness or distrust in their intentions. My studies indicate that not everyone is ready to share their data with others in such an open manner; there are issues with privacy to be considered. Ethical implications also exist regarding mining or tapping into another's hidden states via physiological data, whether given consensually or not. For example, how this data could be used in the future to determine a person's guilt, honesty, or employability, as has been the case with the use of polygraph machines, commonly known as 'lie-detectors'

(National Research Council, 2003, p. xiii). Focussing on the area around my practice, I have looked to user studies to research perceived issues with emotive wearables, I have obtained both positive and negative feedback, which I have discussed in detail in Chapter 7 (p. 184).

Emotive engineering

An outcome of my practice investigating emotive wearables is concerned with how we can manipulate our physiological data and what the consequences are of doing so. What I have called 'emotive engineering', is the practice of affecting the output of emotive wearables by practising techniques to affect one's own physiology, or recording and playing back previous physiological output to influence or engineer a result in a different situation. Emotive engineering is shown as an outcome of emotive wearables in the structure of the field of wearables I work in (Chart 2.2, p. 39).

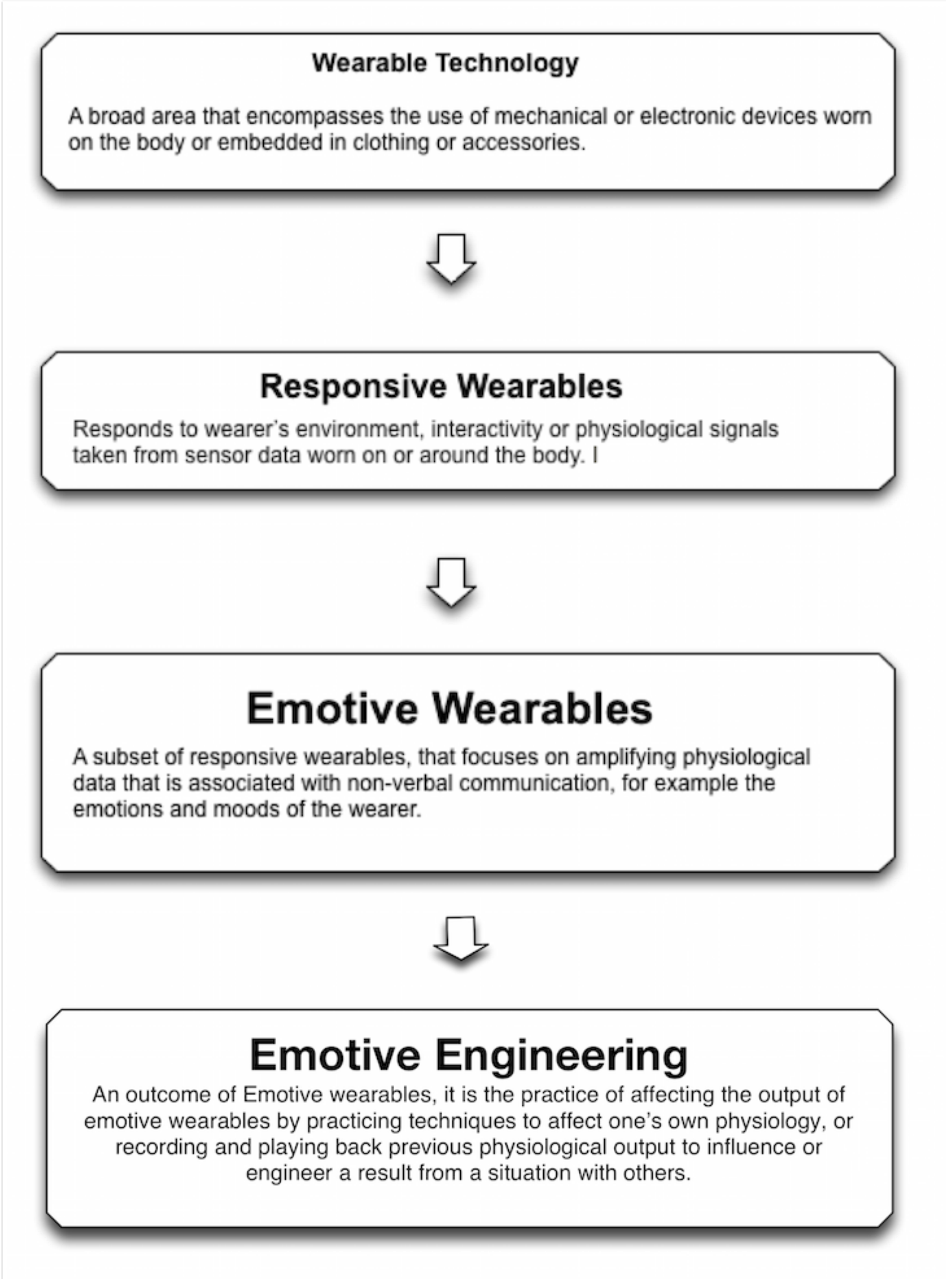


CHART 2.2: Emotive engineering in the structure of the field of wearables as an outcome of emotive wearables

I initially became aware of the possible impact of emotive engineering while using my *You make my heart flutter* (2011) heart rate pendant *hack* (Figure 2.4, p. 40). When giving presentations or in social situations, I discovered that one could appear calm and unflustered by using a heart rate 'fake' mode, which pulsated the *LEDs* at a steady and calm 70 *BPM*, instead of using live heart rate data to control the LEDs on the pendant. I noted how the pendant's flashing LEDs drew a lot of attention and led to discussion around the rate they pulsated. I found that by increasing my heart rate, by walking fast or by taking the stairs, I could appear to be excited or anxious by increasing the pulsing of the LEDs. This became a curiosity to observers and generated discussion and speculation about the perceived reasons for the increased heart rate.

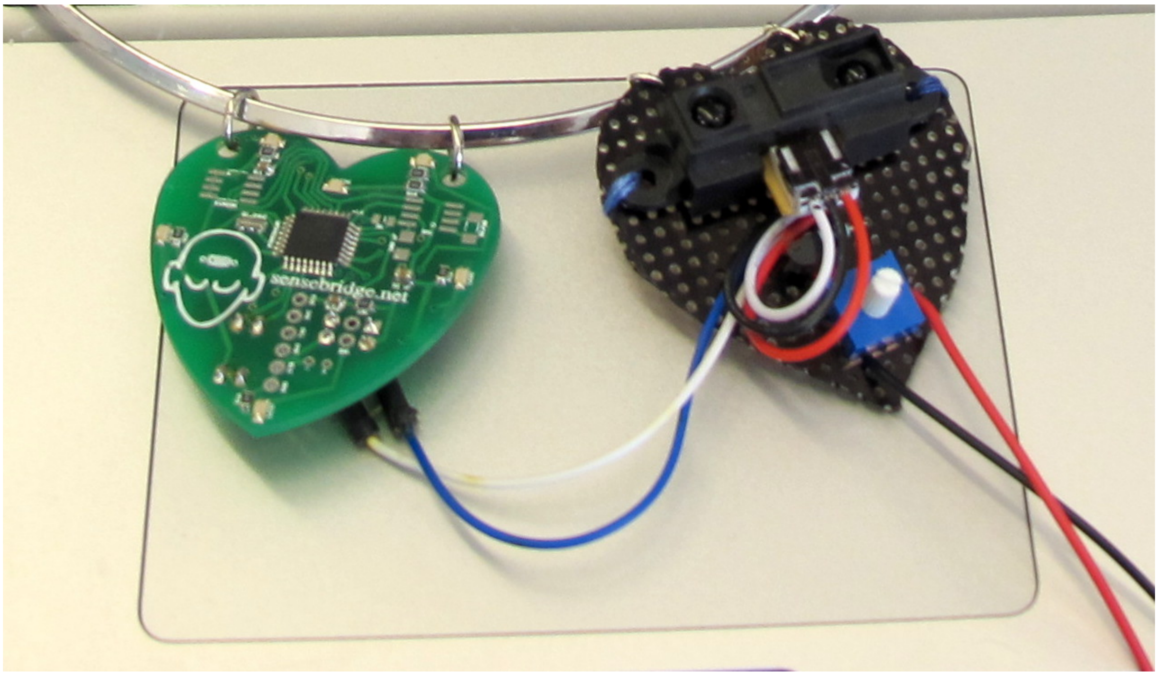


FIGURE 2.4: The *You make my heart flutter* proximity-detecting and heart rate visualising necklace, which also has a fake heart rate mode (2011)

This reaction compelled me to research emotive engineering further by incorporating record and playback modes in three of my research prototypes and obtaining reactions to this concept. This allowed the wearer to record their EEG data and play it back at another time or location. Someone might use this functionality in a situation such as a job interview, to make the wearer appear very attentive to the interviewers by a proliferation of 'attention' data being shown on, for example, the LED matrix of the *EEG Visualising Pendant*. Conversely, if a wearer wanted to seem more relaxed, they could record and play back 'meditation' data on the pendant's LED matrix. Visual cues might become useful in situations, such as when a user wishes to seem more attentive and confident, for example, a person in authority trying to defuse a tense situation, or a waiter taking an order and wanting customers to feel attended to.

These examples of manipulating data visualisations in social and formal situations might be viewed as similar to what Erving Goffman described as a "dramatic realization" that:

> "While in the presence of others, the individual typically infuses his activity with signs which dramatically highlight and portray confirmatory facts that might otherwise remain unapparent or obscure." (Goffman, 1959, p. 40).

There are ethical considerations to take into account when using a device to manipulate how one is seen to others, especially when this manipulation could be used to deceive or influence a situation to the detriment of the observer and/or onlookers.

Mapping triggers and responses used by emotive wearables

There is an expanding group of practitioners and researchers who, opposed to the wider and more commercial field of wearables, are devising individual approaches to developing discrete and hidden sensing and communication technologies. They are using physiological signals and other means to sense, interact, create feedback, and allow reflection on various forms of communication and intimacy in social and other specific situations.

Focussing on how practitioners have developed their practice in emotive wearables, I mapped how responsive and emotive wearables were evolving, finding that they tend to fall into different categories related to how the data are displayed or output, such as light or haptic responses. These categories also include more unique outputs, for example mimicking horripilation. As emotive wearables are a subcategory of responsive wearables, it was not surprising to find that there was some overlapping and blurring of boundaries in terms of data and outputs. I have mapped these in the chart below (Chart 2.3, p. 42) and have followed this with a table giving examples for each response with an output and an artefact (Table 2.1, p. 42). This is not an exhaustive list and I expect more responses to be added as further research is made into visualising and amplifying physiological data.

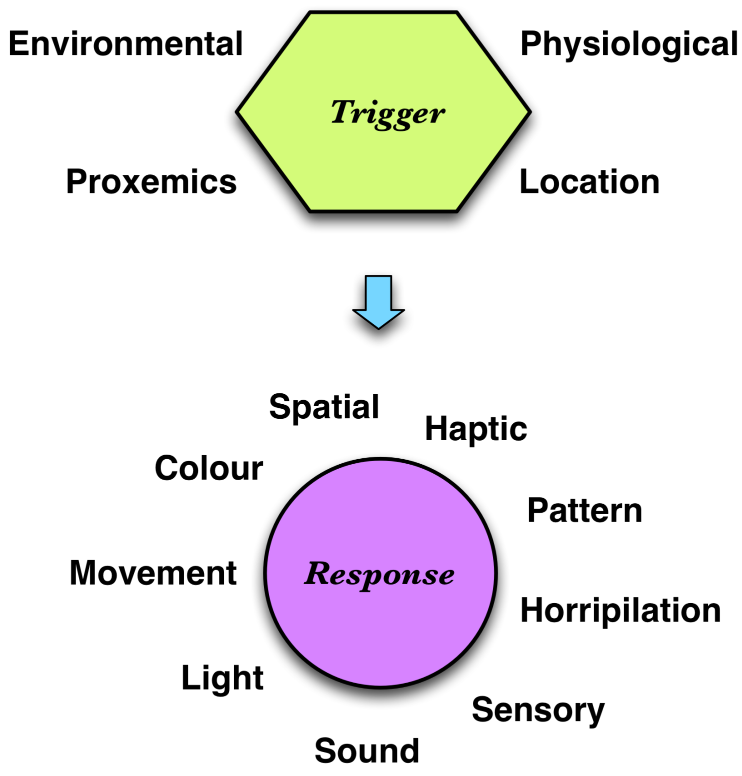


CHART 2.3: Mapping triggers and responses that relate to responsive and emotive wearables

Response	Output	Wearables example
Spatial	Artefact expands into space	*Hövding*, A. Haupt & T. Alstin, 2005
Haptic	Vibration	*HugShirt*, CuteCircuit, 2002
Pattern	Change in pattern	*EEG Visualising Pendant*, Rain Ashford, 2013
Horripilation	Feathers stand up/move	*Taiknam Hat*, R. O'Nascimento, E. Kurbak & F. Shizue, 2007
Sensory	Olfactory / aroma	*Scentsory Design*, Jenny Tillotson, 2008
Sound	Music/voice	*Wearable Absence*, J. Jefferies & B. Layne, 2012
Light	Mapped LED / brightness	*AnemoneStarHeart*, Rain Ashford, 2015
Movement	Open/close/speed	*Spider Dress*, Anouk Wipprecht, 2014
Colour	Colour change / representation	*Mood Sweater*, Sensoree, 2013

TABLE 2.1: Table reflecting examples of responsive and emotive wearables that relate to responses to triggers in Chart 2.3

In this section I have documented how my research began, pinpointing categories of wearables and their usage of sensors and actuators. I then position my research and practice within the field of wearables, in which I have introduced two new terms for specific areas relating to wearables: responsive and emotive wearables. The third new term was an outcome of my research, emotive engineering, which concerns the manipulation of data. The section moves on to map the triggers and responses used in emotive wearables for discrete and hidden communication technologies and give examples of how they have been used by practitioners. In the next section, I look at examples of emotive wearables.

From emotive wearables to the wider field

In this section I contextualise the area of emotive wearables by exploring several examples that use physiological data in differing circumstances. I have gathered these examples as 'intimate' or 'overt' to reflect their usage. For example, intimate emotive wearables are used in private or personal situations, such as at home with friends and family or bespoke self-usage. Conversely, overt emotive wearables are used in public spaces and can be viewed, though not necessarily decoded, by those in the vicinity. I then investigate examples from the wider field of wearables that have similar design concerns to my practice.

Emotive wearables for wellbeing

Jenny Tillotson's *eScent* (Tillotson, 2017, p. 96) concept responds to the wearer's emotional and vital signs, and reacts by dispensing a 'scent bubble' from a wearable to the nose, using fragrances that are associated, for example, with relaxation or reducing anxiety. In common with my own research, *eScent*, is multidisciplinary, its aim is to complement orthodox treatment and enhance wellbeing by creating bespoke emotional wearable technology tools exploring areas, such as psychology, aromachology (the study of aroma on behaviour), fashion, biotechnology, and computer sciences.

Tillotson's research is of interest to my practice as it concerns the use of personalised technology in investigating emotions. Although its goal is to improve the wellbeing of the individual, it is conceivable that the technology might also be useful for those wishing to influence or manipulate a social or formal situation, in the manner of emotive engineering, for example, by using an uplifting aroma to evoke calm or relaxation within a group of people. The research also features an aesthetic element in the embedding of technology into garments and jewellery.

Intimate communication

The following examples illustrate the variation of interpretation, anticipated designs, and projected users in projects that relate to intimacy and the personal. Firstly, a unique approach to covert and social communication via a garment and use of its 'material' was envisaged by Dutch social design lab Studio Roosegaarde for their *Intimacy* (2011) project.

Working with designers Maartje Dijkstra and Anouk Wipprecht they created two socially reactive dresses from opaque smart e-foils that become increasingly transparent based on close and personal encounters. The couture dresses are cut from a single piece of e-foil and were designed to respond to the wearer's heartbeat, which is used as a measure to determine the fluctuation between opaqueness and transparency of the dress, revealing the wearer's body when the heart beats faster (Roosegaarde, 2011). The project is of interest as it relates to artefacts in my practice, which have sought to reveal the wearer's physiological state to those in their personal space. Whilst the *Intimacy* dresses are perhaps too revealing for some social situations, they in part fulfil a wish for intimate communication, which was requested by a number of participants in my user studies. This feedback resulted in the creation of my prototype intimate wearable, *AnemoneStarHeart*, which was designed for revealing physiological data in personal spaces and is documented in Chapter 8 (p. 210).

A different feeling of intimacy to the Roosegaarde project is conjured through memories appropriate to the individual in a series comprising interactive textiles and garments in Barbara Layne and Janis Jefferies' *Wearable Absence Project* (2012). These garments, intended as everyday wear, are of interest to my practice because they react to physiological data, in the form of heart rate and *galvanic skin response* (GSR), but instead of broadcasting data, the artefacts respond to the wearer's physical state by playing back data files in the form of visual and aural messages from memories of a character that the wearer selects to 'channel' throughout the day (see Figure 2.5 (p. 44); Jefferies (2012, p. 154)). Such personal artefacts question what kinds of responses we might want to be triggered by our physiological data and how we would engage with them.

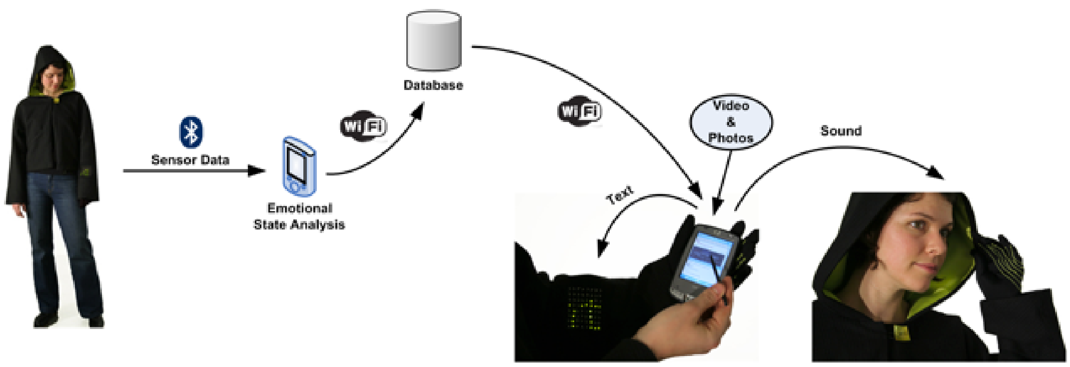


FIGURE 2.5: *Wearable Absence* (2010)

In another approach to personal data, which connects to my practice due to the personalised nature of the artefact, Jayne Wallace (Wallace et al., 2013). has explored intimacy through memories, mental health, and dementia, via garments, textiles, and jewellery. The aim of her research is to extend conventional uses of technology, whilst also exploring how artefacts that held personal meaning could in turn extend notions of the self, reflection and communication. One of these, *Locket* (2013), which used a small screen and *USB* port to upload digital images, was created from research into the personal journey of a woman who was in the early stages of dementia and was being supported by her husband. It was inspired by the value the couple placed on family photos. As the title suggests, Wallace's device was fashioned as a locket necklace.

Locket and the aforementioned *Wearable Absence* are two projects that have different objectives and users, but share an objective of being keepers of precious memories and remembrance. They give an indication of how personalised digital artefacts and the personal might be shaped, stored and worn on the body. These intimate artefacts also form part of practices that explore how such data and devices could be employed as poignant or comforting personal artefacts and heirlooms for the individuals or their families in the future.

Overt intimacy

A very different kind of intimacy is expressed by SENSOREE's *GER: Galvanic Extimacy Responder Mood Sweater* (2013), (Figure 2.6, p. 46). It uses galvanic skin response (GSR) electrodes attached to the hands to "read excitement levels and translate the data into a palette of affective colors" and promote what SENSOREE describes as "extimacy — *externalized intimacy*" (SENSOREE, 2013), which alludes to the notion of visualising the wearer's inner feelings towards those around them.

FIGURE 2.6: SENSOREE Mood Sweater — Glazed Conference After-Party (2013)

The *Mood Sweater* is an overt and eye-catching wearable, it is not a discrete communication artefact. The 'intimacy' aspect refers to the source of the data from the wearer, which is ascribed to reflecting personal mood data, rather than the situation it is worn in. In contrast to aforementioned artefacts, its design is not bespoke or personalised to the wearer but it is of interest as, akin to my practice, it also uses *RGB LEDs* to respond to physiological data and reflect the wearer's emotive state.

In contrast to the *Mood Sweater*, an earlier approach to visualising and broadcasting physiological data via colour coding and opening it up to public interpretation was the *Body Blogger* (2010) project. It involved the constant visual display of heart rate data, 24 hours a day, 7 days a week, for a period of over a year on various websites. On the *Physiological Computing* website[8], the main banner was turned into an online mood ring and set the colour scheme of the site according to the wearer's physiological state (Figure 2.7, p. 47), (Gilleade, 2011).

[8]http://www.physiologicalcomputing.net

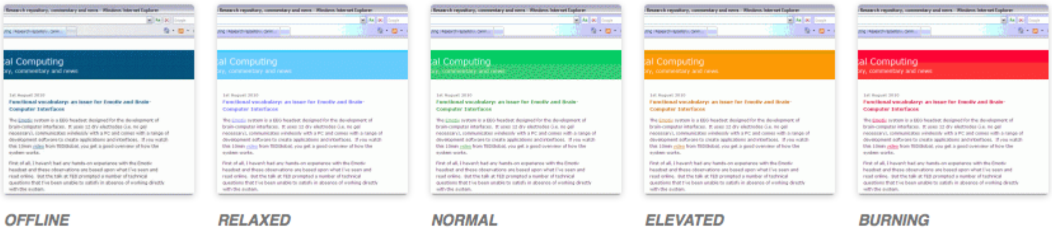


FIGURE 2.7: Kiel Gilleade's *Body Blogger* project indicated heart rate states through changes to the website's colour scheme (2010)

By allowing heart rate data to appear in the public domain, it increased its reach. This brought forth the question of who was watching and how might they interpret such data, also issues around privacy, which connects with the concerns of participants of my user studies. The public hosting of the project led to the data unintentionally becoming a vehicle for nonverbal communication as various interpretations and speculation on the wearer's health, wellbeing and psychological state began to occur. The SENSOREE and the *Body Blogger* projects illustrate how it is possible to choose differing methods to visualise and make one's physiological data public.

In this section I have discussed various examples of emotive wearables, particularly those which explore intimate themes. This is followed by looking at two contrasting forms of emotive wearables which could be considered overt in their method of display. In the next section I investigate examples of projects in the wider field of wearables that have similar design concerns to my practice regarding displaying or using data.

Display and visualisation in the wider field

Outside the field of emotive wearables there are various practitioners working with displays and visualisations. In the next paragraphs I will give examples of those that are of interest to my research who combine design, aesthetics and communication in unique and bespoke ways.

Bringing design and technology together

Studio Waldemeyer has developed a practical technology solution for a video capable colour LED display, which they have used on *Video Jackets*, (2011), and costumes for music videos and live performance, which is able to display animations at "video speed" (Waldemeyer, 2011*a*). This technology has been combined with bespoke fashion garments by couturiers such as Hardy Amies[9] and Alexandre Vauthier[10], and worn in performances by international artists such as Will.I.Am, Take That and Rhianna (Waldemeyer, 2011*b*). My research interests connect because I have found solutions to mapping live physiological data which requires using reactive display methods that will show the fluctuation of data as movement of patterns and brightness on artefacts that will be clearly visible. I have achieved this through experimentation with technology such as LED grids, *fibre optic filament*, combining strips of LEDs, and diffusion. UK-based wearables duo CuteCircuit have also worked in the area of embedded displays in garments and accessories using their own patented and patent pending CuteCircuit technologies, which stand out because of their modular system design for easy recycling and repurposing. They have designed wearables collections for their online shop, haute couture and special projects collections. Their clients include international music artists such as Katy Perry and Nicole Scherzinger (CuteCircuit, 2017).

In 2016, Moritz Waldemeyer was invited to redesign the stage appearance of Jay Kay of Jamiroquai, who is known for wearing oversized and distinctive headwear. He created a futuristic concept piece for the music video *Automaton* which updated the artist's persona to resemble a *cyborg* or *chimera*. The headpiece was constructed with robotic 3-D printed pangolin-style scales and colour-changing lighting from within that resulted in a reactive display that came alive and appeared to be an extension of the body (Waldemeyer, 2016). This is of interest to my practice as I have also found *3D printing* useful for creating enclosures for my research prototypes. *Laser sintered* nylon can be used to create light and durable enclosures. When designing *AnemoneStarHeart*, part of the design process was defining the opaqueness of the enclosure, which would allow me to control the desired amount of dissipation of light through the artefact. This was necessary for the visualisation of data and to achieve the required aesthetic.

[9] https://hardyamies.com
[10] http://www.alexandrevauthier.com

Embodiment with space, culture, and technology

Waldemeyer is also known for his collaborations with Turkish Cypriot fashion designer Hussein Chalayan[11], whose approach to design has been an exploration of bodies in relation to art, spaces, culture, and technology. In an early creation of a video display, Waldemeyer put together the technology for Chalayan's LED video dresses, which played video sequences across the whole surface of the dresses. Chalayan went on to produce a number of collections in which attire was controlled wirelessly or used automated commands. This included the *Remote Control Dress*, (2000), which in common with themes I have explored through responsive wearables, he described as exploring the body and the hidden and invisible elements of the environment around it:

> "The dress expressed the body's relationship to a lot of invisible and intangible things—gravity, weather, flight, radio waves, speed, etc." (Quinn, 2002, pp. 359–368).

His sleek, moulded *Airplane Dress*, (2000), is said to be perhaps the first fully functional electronic example of couture attire. It is made from fibreglass, with hidden technology that could be controlled from offstage to open and close flaps. Other garments which opened, closed or unfolded were a revelation to fashion at the time, changing notions and expectations of how fashion could reach out into other genres such as architecture and fine art (Ryan, 2014, p. 154). Chalayan's collection *Readings* (2008) included iconic highly structured dresses which Waldemeyer engineered to create a display of laser beams refracting light through Swarovski crystals. This resulted in a spectacle "evoking phantasmagorical new-age sun gods", transforming garments that were static objects to constantly changing, living forms (Waldemeyer, 2008). Many of Waldemeyer and Chalayan's concepts and designs are distinctly futuristic and cyborgian, which is an aesthetic which has been influential to my practice. For my projects that include movement, I have experimented with embedded servos, that move in reaction to data from sensors.

Chalayan's technology driven pieces differ from those of the aforementioned CuteCircuit in that these larger-than-life designs are one-offs and are very different in style compared to Chalayan's commercial fashion collections (Ryan, 2014, p. 154). In contrast, CuteCircuit's practice is generally technology driven, but the pieces are available in more usual forms of

[11] http://store.chalayan.com/

attire such as ball gowns, dresses, skirts, tops, and accessories. Some of these react to environmental factors such as sound and temperature with light and colour or send haptic feedback and can be regarded as responsive wearables.

Physiological sensing and the crowd

Emotive data is not only useful for the individual, but has applications for groups or crowd usage. London-based Studio XO[12] was founded by creative technologist Benjamin Males, and fashion designer Nancy Tilbury. Nancy was previously part of the Philips Electronics Design Probes Team known for creating early emotive wearables such as the *Bubelle Dress* discussed in Chapter 5 (p. 132). Their *XOX* emotion technology, which they claim can register your 'psychic state' via emotional sensors, has been used in wristbands by advertising agency Saatchi & Saatchi[13] to gauge audiences' reactions to a show reel (Compton, 2014).

Researcher Daniel McDuff (2017) discusses how marketing research using physiological data is gaining in popularity due to the possibilities of real-time monitoring, advertisement reaction analysis, and "emotion based targeting", which is when audience groups showing higher emotional engagement to specific content are targeted with similar content. Capturing simultaneous reaction data from groups of people, such as those in focus groups, cinemas, concerts, and public spaces such as transport hubs, may indeed be useful for marketing and academia, but there are possible negative issues to consider, such as the reliability of technology and the interpretation of data. In addition, they are similar to other methods of collecting data in that they raise privacy and ethical issues, around subjects such as obtaining consent, keeping data anonymous and storing data (McDuff, 2017, pp. 327–342).

Degrading technologies and precious data

Before we trust emotive wearables to store precious data, it's important to consider how frequently we renew personal technology, such as phones and laptops. One need only look at one's personal collection of failing devices and peripherals, such as hard drives, media (for example, various disks), and software applications, to realise how quickly technology becomes obsolete and is superseded. Through my practice I have discovered that certain technologies and hardware have already become difficult to use due to changes in

[12] http://www.studio-xo.com
[13] http://saatchi.co.uk/en-gb/

standards, sizes, software, and support. Because of these issues we cannot rely on our digital artefacts and storage to keep important memories, such as images and recordings, safe for long periods of time. Employment of digital curation, a set of activities which are used to manage data and to maintain the history of its provenance and access to it, and manage how it can be moved, copied and deleted, is necessary. Currently this kind of data maintenance is usually provided by specialist archivists and not generally employed by the individual (Higgins, 2012, pp. 17–20).

Availability of appropriate technology

The lack of availability of interoperable and suitable technology designed for wearables usage is a recurring problem for my practice. This gap creates the need for me to push technologies together in ways that they were not specifically designed for. This has resulted in difficulty realising ideas and projects, and also making changes and updates to artefacts hard and sometimes impossible. This observation is crucial and needs addressing by technology manufacturers, otherwise the design and development of wearables may be held back due to the lack of suitable technology and bespoke components, which combine necessary sustainability traits such as washability and upgrading. This is a problem that echoes the issues that early wearables pioneers Mann and Starner encountered when trying to create wearables from computer and gaming hardware, which did not help the progress of wearables in areas of hardware, software, and design, and which I discuss in Chapter 5 (p. 121).

Conclusion

In this chapter I began by discussing the early stages of my research, which included researching groups interested in the use of sensors and actuators in wearables as diverse as medical and maker/hackspaces. This became a useful exercise in contemplating the potential for wearables and audiences, in order to consider how wearables might develop in the future. This was also helpful in situating my own research and practice, in which I have introduced the terms responsive and emotive wearables to reflect the fields in which I have been developing my practice. I have also described one outcome of my research and practice in emotive wearables, emotive engineering, in which ethical concerns are raised by the recording and playback of physiological data when used to manipulate the outcome of social and formal situations.

To contextualise my practice further, I have discussed a number of examples of practice by researchers and practitioners who are working in the fields of responsive and emotive wearables, particularly exploring those in the realms of covert and overt communication, intimacy, and emotions. These examples indicate how there are many ways to express physiological and other personal data, such as memories and images, shedding light on how these technologies might affect relationships in personal, social and cultural terms. It also touches on related issues around privacy, both for individuals and larger audiences, indicating how decisions must be carefully made by those recording data.

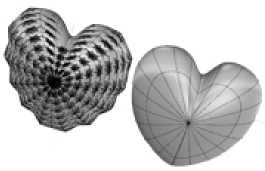
This section then moves on to discus the practice of practitioners whose work creates a spectacle and therefore has fittingly been used for entertainment in music and performance. It also reveals instances where practitioners have developed their own hardware in order to allow such pieces to be able to be controlled offstage, while being reactive to elements such as music, and flexible and robust enough for dancing and performance.

Finally I discuss how practitioners, researchers, technologists and users need to be mindful and alert to safeguarding personal data stored in digital devices that has become obsolete or lost.

In the next chapter, *Chapter 3: Developing wearables research with the ISWC community*, I look at the communities for whom I have developed my research, and how they and my practice have grown alongside the ongoing research in the field of wearables. The two communities are the academic community of the International Symposium on Wearable Computers (ISWC) and the Quantified Self international community.

Chapter 3

Developing wearables with the ISWC community



Wearable computing evolving as an academic community

The purpose of this chapter is to describe the academic community of the International Symposium on Wearable Computers (ISWC) as the context and primary audience for my work. I have constructed this chapter as part history of my contributions and part log of the research that has impacted on my research. It begins by way of introducing the ISWC community through two key technology events in the US, sponsored by the Defense Advanced Research Projects Agency (DARPA) and Boeing, which brought about the founding of an academic community dedicated to wearables, namely ISWC.

Following these early wearables events, I describe ISWC and its co-located event, Ubicomp (International Joint Conference on Pervasive and Ubiquitous Computing). Next I discuss my experiences with the ISWC community over five symposia (2012–16) (Figure 3.1, p. 55) and how my research has had an impact on and has been affected by this event. I pinpoint some of the themes, devices, workshops, and events that have been prominent and have informed my work such as: social interaction, personal *informatics*, design, new technologies for wearables and their challenges. Throughout this chapter, I reveal how I have contributed my ideas and research to the community by exhibiting eight practice prototypes to the ISWC Design Exhibition, delivering papers about the prototypes, demonstrating my work via posters, presenting my work at the Doctoral Colloquium, and contributing to workshops and broadening diversity events.

I discuss the Quantified Self, a community that has a commonality of themes and interests with ISWC/Ubicomp in areas of self-tracking, such as health, wellbeing, sports, and personal interests, and where I have presented my work at three conferences, including giving the opening plenary at the first Quantified Self Europe Conference and conducting a focus group with attendees which has informed my research.

FIGURE 3.1: *Welcome keynote*, ISWC/Ubicomp 2016, Heidelberg, Germany (2016)

Predicting the future of wearables in 2005

Events shining a spotlight on wearable technology had been occurring in the US for a few years leading up to the millennium. A forward-thinking workshop, considered to be the first organised wearable technology event, was 'Wearables in 2005', held in July 1996, where attendees predicted the future usage of wearable computers. Predictions for future wearables included "computerised gloves for reading *RFID* (Radio-frequency identification) tags, flower brooches which react to emotions and body mounted cameras" (Winchester, 2015). The event was sponsored by DARPA, which is the research and development agency for the US Department of Defense. Wearable computing was defined as "data gathering and disseminating devices which enable the user to operate more efficiently. These devices are carried or worn by the user during normal execution of his/her tasks." It was attended by industrial, university, and military visionaries to work on a common theme of delivering computing to the individual (DARPA, 1996, cited in (Randell, 2005)).

Assembling themes for the future at Boeing

'Wearables in 2005' was followed in August 1996 by a workshop held at Boeing in Renton, US, whose focus was "platforms, peripherals, software systems, and applications associated with wearable computers". Breakout sessions listed in the schedule already began to group key topics that would shape the future of wearables and are still relevant today: hardware, software and support, networks, communications and local data sharing, human factors and psychology, plus applications and markets.

The organising committee, as stated on the wearcam.org workshop information page, consisted of a representative from Boeing, and academics from the universities of New Mexico, Oregon, Carnegie Mellon, and *MIT* (Mann, 2007). The Boeing workshop was a success and attended by 200 people from academia and industry, discussing and presenting prototypes and products, thus indicating serious interest in wearable computing and paving the way for a longer peer reviewed event (McCann and Bryson, 2009, p. 9). Thad Starner, representing MIT on the Boeing workshop committee, went on to become a founder of ISWC.

The International Symposium on Wearable Computers

Today ISWC is a yearly international forum for the presentation of cutting edge research in the field of wearable computing and on-body mobile technologies, which brings together a diverse group of researchers, designers, engineers, scientists, industry professionals, and artists. In 2018, ISWC will be 22 years old.

Over a period of five years of participation I have identified themes and challenges at the events which are relevant to my research, including privacy issues, design concerns and form factors, social interaction, and hardware challenges such as component availability and battery life. Embedding my work within ISWC's research community has therefore placed the research practice I have undertaken at an international level. The early ISWCs were distinctly hardware and software focussed, but as the symposium expanded, papers from psychology and the social sciences gained visibility, for example, concerning the use of wearables in social interaction, health, and wellbeing.

The ISWC/Ubicomp connection

In recent years, ISWC has been co-located with a complementary research symposium, Ubicomp, where attendees discuss the design, development, and deployment of *ubiquitous* and pervasive computing technologies, as well as how these technologies facilitate the understanding of human experiences and social impacts (Ubicomp, 2016).

The combination of ISWC and Ubicomp works well due to wearable computing's connection to ubiquitous computing, via issues such as the notion of continual connection and data gathering and exchange between multiple devices. There is also synchronicity between the symposia through the range of interchangeable questions and topics that come up around areas such as interfaces, users, design, hardware, data, and ethics.

As we are already used to being surrounded by complex computing devices in our daily lives, it seems as though the logical next step for technology, as imagined by Xerox PARC's chief scientist Mark Weiser, is ubiquitous computing, which is to say that devices will be effortlessly integrated into our lives — a future made more probable since devices could be secreted into our clothing. In 1991, Weiser said that "The most profound technologies are those that disappear. That weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser, 1991, pp. 66–75). This metaphorical quote on ubiquitous computing seems to be predicting the melding of technology, and cloth and brings to mind e-textiles.

An example of a Ubicomp session which impacted on my research was *Sensing and Using Emotion*, a session presented at the Heidelberg conference in 2016. Three research presentations were notable, and all three investigated how data pertaining to emotion could be used, and the outcomes of doing so. One in particular (Costa et al., 2016, pp. 758–769) demonstrated the possibility of helping individuals regulate their emotions with mobile interventions that leverage the way we naturally react to our bodily signals. The researchers designed a wearable device to regulate the user's anxiety by providing false feedback of a slow heart rate, and conducted an experiment that showed that the device kept the anxiety of participants low, compared to a control group.

This investigation relates to my own examination of wearable devices for social situations, using a fake slow heart rate visualised as pulsating LEDs to appear calm when giving presentations, as discussed in Chapter 2 (p. 39). It also relates to what I call 'emotive engineering', which is the exploration of how and why we can use technology to manipulate our physiological data in similar ways to the latter example, to present ourselves in a different light to others (p. 38). I discuss self-presentation further in terms of Erving Goffman's theories in Chapter 5 (p. 40).

Emotion and affective wearables

Research discussing emotion and wearables was presented at the first ISWC, in 1997, by Rosalind Picard and her colleague Jennifer Healey, who discussed wearable systems that used sensors and tools to enable the recognition of the wearer's affective patterns (Picard and J. Healey, 1997, pp. 90–97). This included the expression of emotion using physiological data, such as heart rate, muscular electrical activity and skin conductivity. The research described new applications of affective wearables, which gathered data during everyday activities and suggested uses could overlap with medical wearables.

It was proposed that devices that worked as a memory aid or an anxiety detector could be used to help people who suffered with anxiety attacks or to prevent currently healthy people from suffering from anxiety. Picard and Healey's (Picard and J. Healey, 1997, pp. 90–97) research suggested that an affective wearable should ideally be able to sense and recognise patterns corresponding to underlying affective states and respond intelligently. As they found there were no existing devices that could do this at the time, they set out to create a prototype that partly responded to the needs they defined. The device they created had the ability to simultaneously monitor a number of skin surface detectable data signals and present them on a text display screen. The data gathered from sensors was time stamped and stored. Crucial discoveries were made from the building of this prototype in terms of the need for comfortable devices that were lightweight and efficiently powered and how to present information to the wearers through interfaces. They also noted the importance of robust sensors that would make reliable contacts with the skin (Picard and J. Healey, 1997, pp. 4–6).

In 2016 Rosalind Picard returned to ISWC to give the closing keynote speech (Picard (2016), see Figure 3.2 (p. 59)), from which I learned first-hand of her history in developing wearables that glean physiological data and what could be extracted from the data. This research is being used to develop health and wellbeing products such as the Empatica Embrace wristband to help detect seizures[14]. Although my research is not concerned with developing medical wearables, Picard and Healey's research into gathering and using physiological data for affective wearables has influenced my research and prototypes.

[14] https://www.empatica.com

FIGURE 3.2: Rosalind W. Picard presenting the closing keynote at ISWC/Ubicomp 2016, Heidelberg, Germany (2016)

To summarise this section, I have given an overview of the academic community of ISWC, the primary audience for my research, and how the ISWC community has grown from two key technology events in the US. This is followed by a description of the connection between ISWC, its co-located event Ubicomp, and affective wearables, a recurring topic of interest at both conferences and an area which is connected to my research. In the next section I describe in detail how I have become part of the ISWC community.

ISWC: Becoming part of the community

What follows in an account of my experiences at ISWC over the period of five symposia. This includes some of the research, issues and themes that have had the most impact on my work and connect with my output. I describe my participation in workshops and the experience of exhibiting eight prototypes in the ISWC Design Exhibitions.

ISWC 2012: Discovering new research

My first attendance at ISWC was at Newcastle University, UK in 2012. Wearable technology was gaining momentum, in part due to self-tracking becoming fashionable via the rise of the Quantified Self, resulting in health, wellbeing and fitness trackers, such as Fitbit and *Nike FuelBand*, growing in popularity. These devices also reflected the acceptability of new form-factors and technology that was designed to be worn continuously on the body. Smartwatches, whose functionality was driven by smartphones, were also becoming popular. At ISWC, *Google Glass* was a much anticipated technology along with other heads-up devices (HUDs) (Starner, 2012). The symposium exposed me to new research, discussion and hands-on experience of artefacts in and around the field of wearables. Through conference sessions on topics such as inputs and interfaces I discovered peers working in similar or connected areas and at different stages of their research.

Examples of doctoral research and areas of interest

I was able to establish my frames of reference by meeting participants and discussing research through the Doctoral Colloquium, with topics on communication and social interaction of particular interest. Nanda Khaorapapong's *Icebreaker T-shirt* (Figure 3.3, p. 61) for shy and socially anxious people is comparable to my research as its aim is to enhance social interaction. The t-shirt was created to aid face-to-face facilitation via *computer-mediated communication* (CMC). When two people wearing the t-shirt shake hands, RFID technology used as a control system exchanges identity data about the wearers, which is reflected on the t-shirt using heat-sensitive inks in a vertical bar that changes colour to represent compatibility. In my practice I have used the mapping of coloured light to visualise data, representing values with different colours and also using lighting strength and diffusion to infer changes in data input. When using such methods to visualise data it requires the wearer and the proposed viewer to be informed about how to read the visualisations and know what they represent.

Using an empirical method to compare wearers' behaviour, Khaorapapong's t-shirt was tested on participants at a speed dating event, with 73% reporting that the garment was helpful when meeting strangers. However, it was reported that a second version of the t-shirt was being developed to increase the number of people participants would introduce themselves to from two to four people. This new version of the t-shirt used a distance-enabled sensor network (WSN) to replace a physical handshake (Khaorapapong, 2012, pp. 61–62).

Although a large area of the t-shirt was devoted to colour changing-sections that allowed participants to view their compatibility, the results do not consider if a more unobtrusive method of viewing the changes would be more appropriate for shy and anxious users. I took a contrasting approach in development and form factor choice for my user studies, by choosing to create a small pendant. In field trials I found that participants had varying views on what they found acceptable (for example in terms of size and visibility) to wear in public places. I discuss this in Chapter 7 on p. 184.

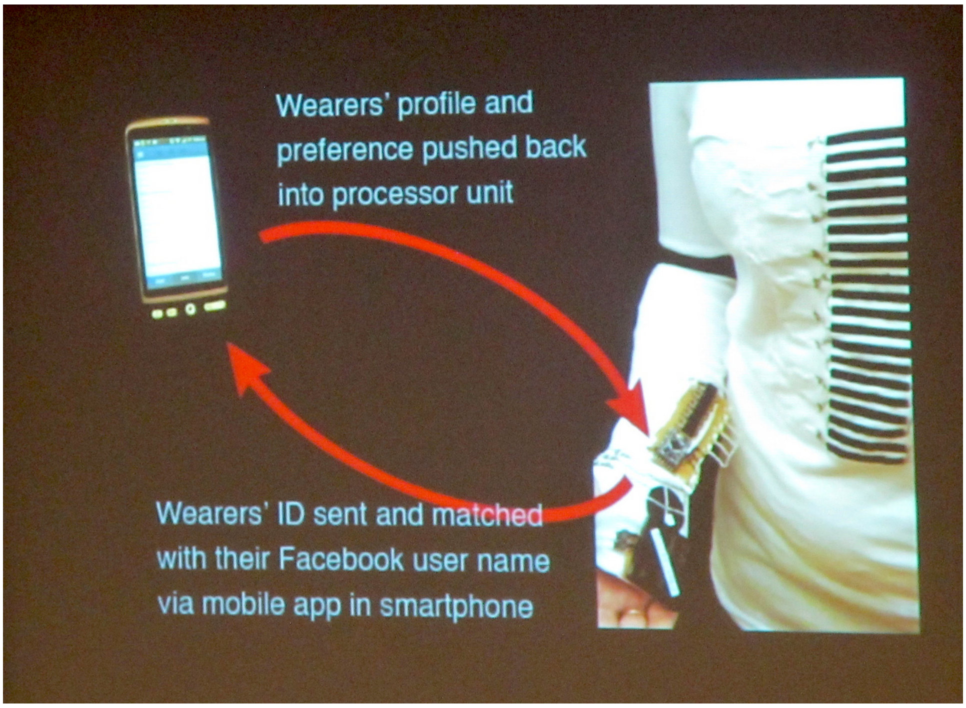


FIGURE 3.3: Nanda Khaorapapong's *Icebreaker T-shirt* for shy and socially anxious people, ISWC 2012, Newcastle, UK (2012)

Kiraz Candan Herdem presented a different perspective on improving the quality of social interactions. Their doctoral research investigated interactions between friends instead of between strangers. This allowed them to study the different behaviour displayed by people who know each other, such as avoiding contact with someone you know is angry. The study analysed mobile phone usage behaviours using accelerometer and gyroscope sensors on devices for emotional context input, plus *GPS* and compass data to discriminate location-based emotional changes. The results that emerged from testing the mobile social interaction tool and collecting emotion-tagged sensor data was that, by being able to recognise a friend's emotional state, users could decide when it was best to interact with them (Herdem, 2012, pp. 59–60). This directly relates to my research practice in terms of self-presentation during social interactions, using wearables such as the *EEG Visualising Pendant* (p. 66).

Running concurrently, there were presentations on how wearables can be developed for groups of people requiring communicative and assistive technology, and this was also reflected in the Design Exhibition. For example, the *Flutter* shirt's objective was to assist in navigating external environments by detecting and alerting the wearer of warning alert sounds, such as fire alarms, assisting those with hearing impairments. The shirt incorporates a network of tiny microphones that amplify auditory information to deliver tactile feedback. The dress responds to sound by activating vibrating motors which cause fabric 'leaflets' on the shirt to 'flutter' as the auditory signal moves in space (Profita et al., 2012, pp. 44–45).

Although it was not possible to test the *Flutter* shirt at the ISWC exhibition, the researchers did get feedback from exhibition attendees and a hearing loss online community where there were positive responses regarding garments developed for accessibility. However, the developers acknowledged that more testing was needed to fully evaluate the system. The researchers discussed the need for embellishments that support the technology, while not interfering with the wearability of the garment (Profita et al., 2015, pp. 359–362). This is an important issue for wearables, because if they are to be acceptable as everyday attire, the technology needs to be supported by the garment, but also unobtrusive and comfortable to wear. Zeagler (Zeagler, 2017) points out that knowledge of the design and construction of garments would help with the embedding of technology, for example connecting wires and leads for electronics should run vertically rather than around the body.

If it was possible to repurpose or add new functionality to the *Flutter* system for an emotive wearable, it could be used as a subtle form of social interaction or proximity alert system, by signalling to the wearer of approaching footsteps or someone entering their personal space. This is an issue I address in my piece *You Make My Heart Flutter* (p. 89).

Practice and research contributions

I shared my first three prototype wearables garments with the wearables community at the ISWC 2012 Design Exhibition (Figure 3.4, p. 63). The *Temperature Sensing T-shirt (Yr In Mah Face!)* was my first emotive wearable. It visualises fluctuations in the wearer's temperature as LED light to inform those around them that they are invading the wearer's personal space. *Don't Break My Heart*, a proximity-sensing jacket for cyclists, uses bright LEDS to warn vehicles approaching from behind if they are too close. *Twinkle Tartiflette*, a musical shirt that allows the wearer or observer to learn to play a tune by touching embroidered lyrics with a stylus. At the exhibition, I presented a paper for each of the three garments and displayed a poster alongside them at my stand. The lessons I learned from this first experience of exhibiting at ISWC were around answering questions and conveying the methods, ideas, and the results of my practice to peers.

FIGURE 3.4: *Temperature Sensing T-shirt (Yr In Mah Face!)*, *Twinkle Tartiflette* and *Don't Break My Heart*, plus associated posters, exhibited at the Design Exhibition, ISWC 2012, Newcastle, UK (2012)

Summary

Attending ISWC confirmed that there existed a rigorous academic community which probed the field of wearables. I discovered that my research and practice had an interested audience in which I could discuss my prototypes and raise questions that were important to their development. The diversity of topics covered revealed that the field of wearables was a much bigger and blurred field than I had previously encountered. In terms of my research, I found peers who were investigating similar areas around social situations and communication who I learned from, and who helped me focus on my specific questions and contributions. The next section gives an overview of my participation at ISWC 2013.

ISWC 2013: Case studies and interfaces

ISWC 2013 was held at the Federal Institute of Technology in Switzerland, ETH Zurich. Research that was particularly useful was around issues of design and purpose. I discovered research exploring case studies for interfaces and communication that was enlightening and helpful for considering the organisation of my own studies. ISWC 2013 was also the year that *Google Glass* became part of the spectacle at the symposium, with a keynote on the device from ISWC founder and *Google Glass* technical lead Thad Starner and many attendees wearing the limited edition prototype.

Contrasting approaches to interfaces and communication

An exhibit at the 2013 Design Exhibition that demonstrated, due to the garment's strictly objective purpose, that it is not a requirement for all wearables to include an aesthetic treatment for visualising physiological data was *Garment with Stitched Stretch Sensors that Detects Breathing* (Berglund et al., 2013). The artefact's purpose was to track physiological data in the form of respiration to monitor the activity of crew members on NASA missions to the International Space Station. The garment, a fitted sleeveless t-shirt, used machine-stitched stretch sensors across the chest and abdominal areas (Figure 3.5, p. 65).

Whilst the aesthetic look of the garment was not such a priority, comfort was a consideration as it was worn close to the body. As the data was recorded, it was visualised as a fading LED as the wearer exhales, and it was intended that the viewer could see this rather than the wearer for validation that the sensor was working. This tracking method could be used in other areas where the detection of respiration is studied, such as sports and wellbeing. However, contrary to NASA's requirements, an aesthetic approach to the visualisation or garment may be welcomed by the wearer. Although my practice is concerned with aesthetics through personalisation, this research connected with my practice through its objective functionality to visualise data in a clear manner and to be comfortable for the wearer.

FIGURE 3.5: *Garment with Stitched Stretch Sensors that Detects Breathing* at the Design Exhibition, ISWC 2013, Zurich, Switzerland (2013)

The session *Touch and On-Body* provided relevant case studies on interfaces and communication for my research. For example, differing approaches to how data is collected and displayed, and where studies have provided insights that allow future iterations of devices to be tailored to end users. Profita et al.'s (Profita et al., 2013, pp. 89–96) research on obtaining observer feedback on a user interface proved to be the most methodologically relevant to my investigations into the user experience of emotive wearables. It reported the methods and results of capturing data regarding cross-cultural social acceptability of the placement of wearable interfaces on the body. The research built on the exploration of e-textiles being used as interfaces as far back as the first ISWC in 1997, where E.

Rehmi Post and Maggie Orth included research on circuits fashioned into keyboards and touchpads on garments.

Practice and research contributions

At the ISWC 2013 Design Exhibition, I debuted the *EEG Visualising Pendant* research prototype, including a paper that described this research. The pendant is a key prototype for the development of my practice and has been used in focus groups and field tests to obtain insights for future iterations. It was exhibited with a number of interchangeable frame designs, created to investigate personal aesthetics and the bespoke nature of my practice, which were 3D printed or hand-fashioned (Figure 3.6, p. 66). As this prototype had not yet featured in user studies, I could not convey any results. However, the prototype was met with intrigue and useful questions around its operation. Nonetheless, I was able to demonstrate how it operated and how it could be used for the concept of emotive engineering. The pendant was also featured in BBC News Technology coverage of the event. A full description of the prototype can be found in Chapter 4 (p. 103).

FIGURE 3.6: *EEG Visualising Pendant* at the Design Exhibition, ISWC 2013, Zurich, Switzerland (2013)

Summary

ISWC 2013 was important because relevant connections were made between my practice and that of my peers working with sensor-driven wearables. Testing prototypes with audiences was enlightening and I was able to consider approaches that would aid my own studies and research prototypes. Sharing and discussing my research prototypes at the ISWC Design Exhibition drew interesting feedback and questions that would aid me in the contemplation of different elements of my research such as the design and usage of future artefacts. The next section discusses my participation in ISWC 2014.

ISWC 2014: Prototypes and moving practice to product

At ISWC 2014, there were many prototypes of interest to my practice, including investigating aspects of sensing and conveying physiological data. What stood out for me was the interest in the commercial possibility of wearables. An industry panel discussed the excitement around start-ups and the business possibilities that were being generated around wearables. The *Transitioning from ubiquitous and wearable computing research to business practice* panel was arranged to discuss opportunities and collect examples of research transforming into practice and to understand the challenges of projects progressing from research to product.

Inspiration for the development of prototypes

Discussion around the 'doing' of garments, such as addressing their productive purpose, was an issue that Amy Ross (Ross, 2014), who leads the development of NASA's extravehicular pressure garments, ordinarily known as space suits, pursued in her opening keynote. She examined the key factors and issues when designing these wearables, which, through a carefully tested and deployed combination of e-textiles, electronics and design, are capable of supporting life. Ross discussed the evolution, and some of the lessons learned, from developing these highly technical garments. These included making crucial choices in materials and systems and small ergonomic design decisions that take into account the ease of use and mobility whilst wearing heavy and cumbersome attire in a zero gravity environment (Figure 3.7, p. 68). I found the presentation thought-provoking and inspiring with regards to how I would approach the stages of design when scoping out future projects.

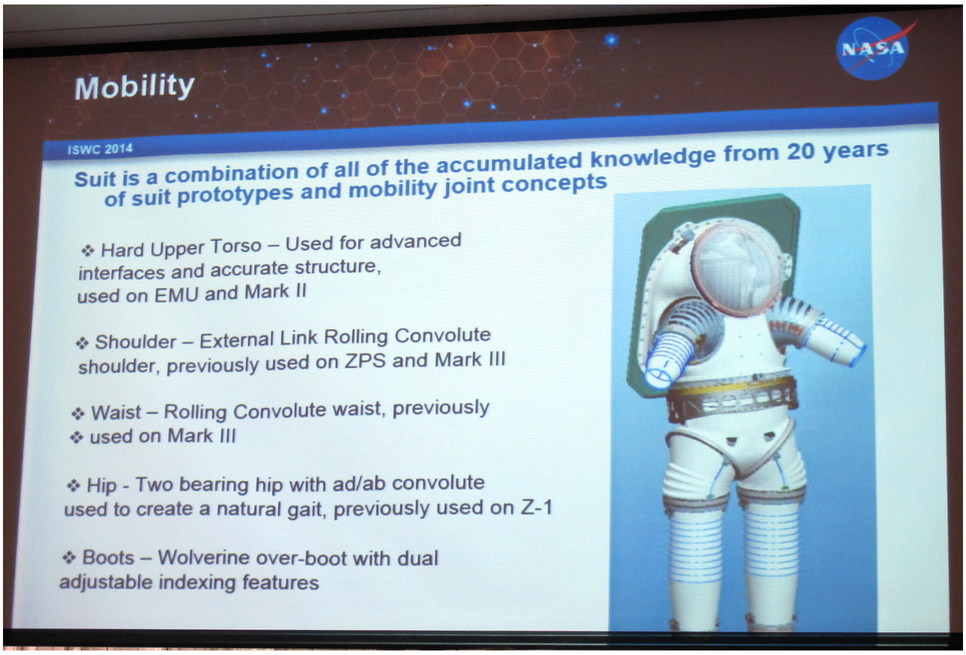


FIGURE 3.7: A slide from Amy Ross's presentation discussing issues and innovations around mobility in the design of space suits, ISWC 2014, Seattle, USA (2014)

Practice and research contributions

I was able to communicate my research progress in detail as I was selected to present my work at the Doctoral Colloquium to a group of international students and doctoral chairs for which I received feedback and insight to help prune, focus, and strengthen my research and practice prototypes. ISWC 2014's selection of doctoral projects reflected the increase in uptake of public-facing and commercial wearables. The projects featured wearables that covered research subjects as varied as fitness and wellbeing, activity recognition, eyewear, and canine-human interaction. The event also touched on increasingly important areas, such as privacy, legal, ethical, and society and culture. This contrasted from the aforementioned 2012 Doctoral Colloquium projects, many of which featured communication, interfaces, and advances in materials. At the evening reception I presented my research as a poster that explained my research in responsive and emotive wearables, and I also gave a demo of my *EEG Visualising Pendant*. The Doctoral Colloquium featured several shared events and panels with the Ubicomp Doctoral school, which encouraged open and inclusive discussion on a number of themes, such as making decisions for future careers in academia and industry.

FIGURE 3.8: *Baroesque Barometric Skirt* at the Design Exhibition, ISWC 2014, Seattle, USA (2014)

At the 2014 ISWC Design Exhibition, staged at Seattle's Experience Project Museum (EMP), I exhibited my *Baroesque Barometric Skirt* research prototype (Figure 3.8, p. 69). The garment senses and records both physiological and environmental data and was developed as a responsive wearables research prototype. At the exhibition I was able to discuss the prototype and receive feedback and suggestions on developing my practice, such as the different types of technology I could adopt and the types of situation in which the garment could be useful.

After the *Baroesque Barometric Skirt* was displayed at the ISWC Design Exhibition, it was dismantled and reassembled at the Microsoft Research Studio 99 Gallery, in Redmond, USA, where it was exhibited over the following six weeks (Figure 3.9, p. 70). An image of the skirt on display at the ISWC Design Exhibition was featured in the September 2014 edition of *New Scientist* magazine. A full description on the skirt can be found in Chapter 4 (p. 93).

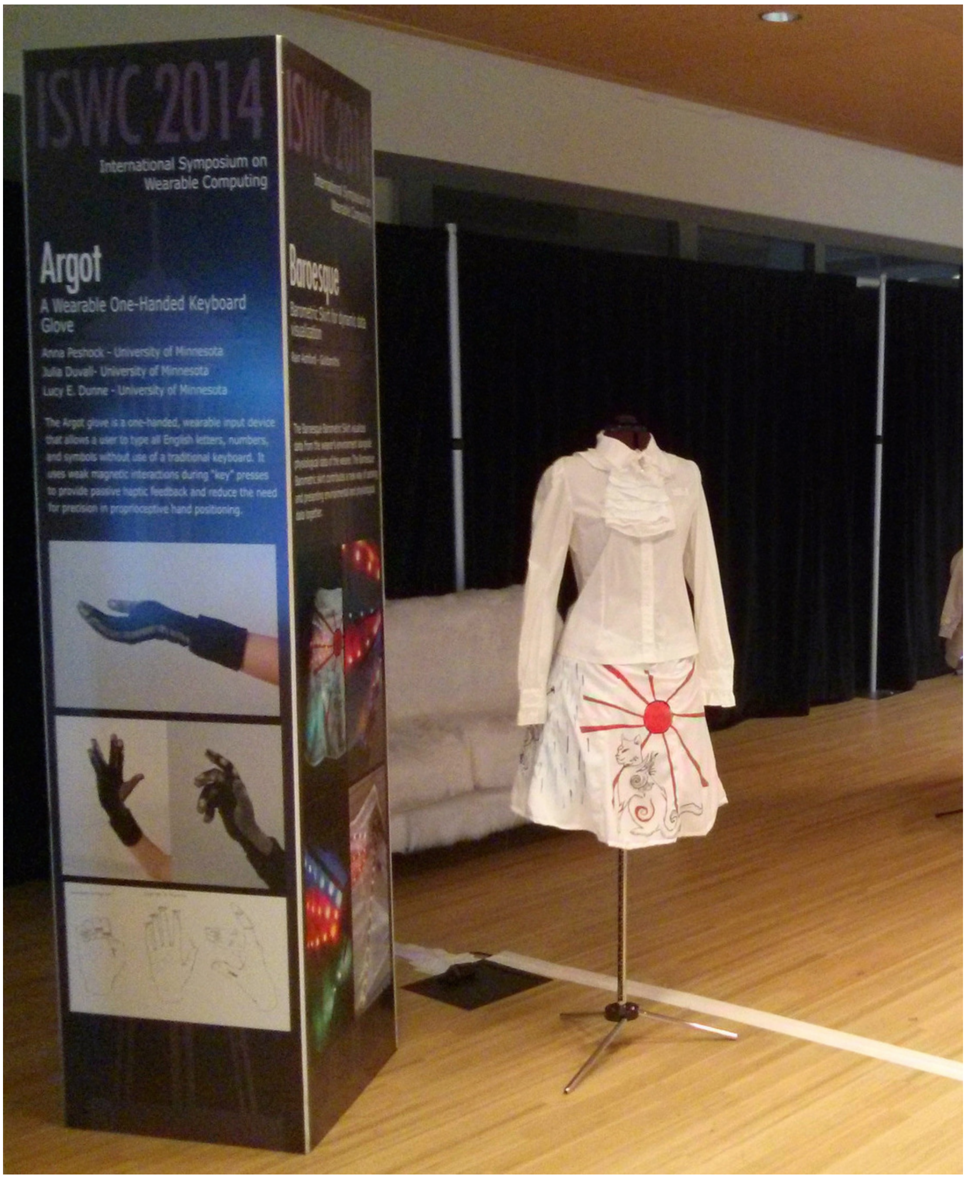


FIGURE 3.9: Hallam, J. (2014) *Baroesque Barometric Skirt*, on show at the Microsoft Research Studio 99 Gallery, in Redmond, USA

Summary

ISWC 2014 saw my participation in the community growing and I found the symposium becoming more beneficial and rewarding. I found particularly inspiring the feedback and advice I was given during the ISWC Doctoral Colloquium. From participating in this event I received valuable reflections and feedback on my research through the interpretations and experience of my peers, and also the organisers, who were comprised of academics working in the field. The main piece of advice that I took away from this experience was to narrow down my research goals and focus in on my user studies and the development of research prototypes from the information collected.

ISWC 2015: Overlapping fields and joint interests

ISWC 2015 was held at Grand Front Osaka, Japan. In recent years ISWC and Ubicomp's shared interests, such as *machine learning* and *affective computing*, had been blurring boundaries between these co-located conferences and in 2015 the events seemed to complement each other more than ever. The 2015 Doctoral Colloquium saw ISWC and Ubicomp join forces and several of the presentations were related to the rise in personal informatics and investigating the self through the use of sensing technologies and activity trackers.

Usage and hardware challenges

Again, it was inspiring to find out about the research that was underway at the time by attending the Doctoral Colloquium, particularly with regards to the personal use tracking devices. My research does not directly concern activity trackers, but they are indirectly linked to it, in that they help to show why users lose interest in devices that track physiological data. One example investigated the theory, design, and implementation of a 'lived informatics' *framework*, which considers the everyday experiences and behaviours people endure whilst tracking themselves, such as selecting the tracking tool and the act of lapsing and then resuming (Epstein, 2015, pp. 429–434).

At Ubicomp, activity trackers and informatics were also being considered, for example in relation to the barriers to using them and the resulting personal workarounds and customisation. Harrison et al. (Harrison et al., 2015, pp. 617–621) listed reasons for these devices being abandoned, including: unreliability in step counts, inflexibility in terms of different lifestyles and pursuits, lost devices, unattractiveness of design, and the novelty of using them wearing off. Personal customisation was particularly of interest to my research and included novel ways of wearing devices to collect data and get round the unsuitability of clip-on trackers for certain attire, such as dresses. Personal informatics also provoke ethical questions around the ownership of data being gathered, such as where does the data end up and who owns it? I discuss the area of data ownership further in Chapter 5 (p. 150).

The Wear and Tear: Constructing Wearable Technology for the Real World[15] workshop, organised by Georgia Tech's Wearable Computing Center pushed my research further. I had not encountered a conference workshop before that was dedicated to looking at the

[15] Wear and Tear website: http://wcc.gatech.edu/wearandtear

hardware challenges of wearables. At Wear and Tear, attendees discussed their most challenging problems and issues regarding prototyping and developing their work. Particularly of interest for the development of my prototypes were discussions around design considerations for harsh environments (Quitmeyer and Perner-Wilson, 2015, pp. 1285–1293), solving sensor problems through design (Zeagler et al., 2015, pp. 1319–1325) and the ruggedisation of electronic devices (Quitmeyer et al., 2015, pp. 1307–1312).

The workshop began with an informative keynote by Thad Starner, Director of Georgia Tech's Contextual Computing Group and ISWC co-founder, who gave an historical account of wearables, revealing his personal observations of the challenges and changes that have faced wearable computing. This focussed on his research on heads-up displays, where he gave examples of the issues that had emerged around this technology. This included headset considerations, such as the distribution of weight on the head and comfort. Also he discussed wearables as consumer products and a timeline of what might be practical and achievable (Figure 3.10, p. 72). His insights were useful for the critical evaluation of headsets, such as the EEG headsets that I have used in my practice and user studies.

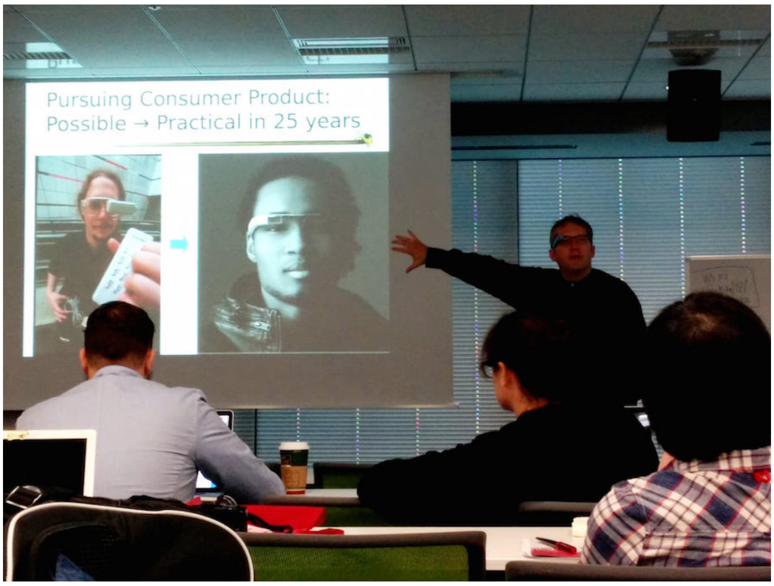


FIGURE 3.10: Thad Starner keynote at Wear and Tear workshop, ISWC 2015, Osaka, Japan (2015)

An encouraging aspect of the Wear and Tear hardware workshop was that there were a number of women attendees. From my personal experiences of being a woman working in technology and usually being in the minority at previous technology conferences and events, this is a comparable improvement. I was also very inspired by Ubicomp's diversity workshop which I describe in the next paragraph.

I believe diversity is important to academia and so I applied to take part in the Ubicomp Broadening Participation Workshop 2015[16] for students. The event is also an example of how relevant issues cross over both Ubicomp and ISWC conferences. The workshop was created to increase and engage participation of women and underrepresented groups in the wearable and ubiquitous computing community. At the workshop I presented a poster on my research on emotive wearables, answered questions from my peers and also asked questions on their research.

Coming from a computing and electronics background, where I have observed a lack of women working in these fields, I was very engaged in discussion on issues around diversity for women working in participation in the wearables and ubiquitous computing community, and STEM areas. Panel discussion with invited speakers and mentors included career paths, finding a job, funding matters, finishing PhDs, work/life balance, plus topics relevant to the challenges and opportunities for women and minority groups in computer science (Figure 3.11, p. 73), which would have also been of general interest to doctoral students attending the symposium.

FIGURE 3.11: Mujibiya, A. (2015) *Broadening Participation workshop, ISWC 2015, Osaka, Japan*

[16] https://ubicomp2015broadeningparticipation.wordpress.com/

Practice and research contributions

The highlight of my participation at ISWC 2015, was exhibiting a new research prototype, which grew out of my practice but was also informed by feedback from user studies. This prototype was the *ThinkerBelle EEG Amplifying Dress* exhibited at the ISWC Design Exhibition held at Grand Front Osaka's Knowledge Theatre and discussed in the context of my research in a paper included the proceedings. I was able to discuss the development of the dress with my peers and how decisions were made about its design as an iteration of the *EEG Visualising Pendant* and through feedback obtained in user studies. I also discussed various uses and contexts of the dress, and how data was mapped to its fibre optic filaments. Further information on these prototypes can be found in can be found in Chapter 8 (p. 214).

FIGURE 3.12: The *ThinkerBelle EEG Amplifying Dress* at the Design Exhibition, ISWC 2015, Osaka, Japan (2015)

Summary

More than in previous years I felt that the interests of ISWC and Ubicomp were becoming more entwined and interesting, which led to my investigating connected fields to my research. I found engaging with technology challenges of colleagues through the the *Wear and Tear* workshops useful for developing and building prototypes, which would assist my practice. I heard about challenges, but also inspirational stories and shared advice, for those working in the area of technology and academia which face women and underrepresented groups through my participation in the *Broadening Participation Workshop 2015*.

ISWC 2016: Health, wellbeing, and sensory research

The 20th ISWC took place in Heidelberg, Germany in 2016. Health and wellbeing was still a hot topic for researchers with apps for monitoring user's physiology discussed as well as current trends. Sensory feedback and sensing was explored in a number of ways at both ISWC and Ubicomp, through collar-sensed gestures from dog-human communication and touch sensitive textiles for gestural input for smartwatches and haptic feedback was also examined through displays, tactile interaction, and 3D space. The aforementioned Ubicomp session *Sensing and Using Emotion* was a highlight of the conference, with issues relevant to my research explored such as technology for social interaction (p. 57).

Design, functionality, and critical challenges

UnderWare: Aesthetic, Expressive, and Functional On-Skin Technologies was workshop that I participated in whose goal was to broaden research and form a research community around emerging technologies that are focussed on novel classes of interactive wearable devices that can be worn directly on skin, nails, and hair. It was organised by MIT Media Lab and Microsoft Research and the event comprised of presentations and discussion aimed at researchers and practitioners from various disciplines, such as *HCI* (Human-computer Interaction), fashion, and interaction designers, plus material and medical sciences researchers. The workshop's aim was to discuss and analyse what constitutes the boundaries of technology as worn or integrated with the body and to create an agenda for future research and technology (MIT, 2016). The session connected to my research through themes that included exploring aesthetic design to investigate the combination of interactive technology and personalised fashion elements, and technical function, including novel fabrication methods, technologies and their applications.

I was particularly interested to hear about projects and issues linked to design and technology, as this connects to my practice. One presentation of interest to my research highlighted problems around innovation and commercial success. It reported that fashion designers and technologists still need to be pushed collaborate in order to produce wearables that are desirable and are functional. Marina Toeters (Toeters, 2016, pp. 922–926) (Figure 3.13, p. 76) presented six examples of E-fashion (Electronica-integrated Fashion) garments that matched current streetwear trends, but made the point that only one was commercially available.

FIGURE 3.13: Designer, Marina Toeters, presents her practice at ISWC/Ubicomp workshop, *UnderWare: Aesthetic, Expressive, and Functional On-Skin Technologies*, organised by MIT Media Lab and Microsoft Research (2016)

The session drew an international group of attendees whose ideas not only investigated developments in their respected fields, but also underlined cultural influences in regard to problems and solutions, of which one garnered a particularly strong reaction. The example being research addressing the problem of keeping vaccination records for children in Africa (Jeong, 2016, pp. 937–941). This was regarding a conceptual solution to use functional and aesthetic tattoos for recording this data on the body. A substantial part of the research was concerned with the aesthetic and design elements, proposing that such tattoos could incorporate a design element derived, for example, from African tattoos that symbolise wisdom and aspects of life. Whilst the need for a solution for the problem of record keeping was accepted, a significant number of the workshop's participants argued that it was unacceptable to tattoo children or groups of people for the sake of keeping administrative records.

Conversely, a hidden or unseen technology solution to a problem facing women in Bangladesh was required from another presentation. Street harassment is a problem facing women in urban, suburban and rural areas and a group of researchers have been looking for a wearable solution that does not attract the attention of the harasser. The project requirements needed it to be low cost and able to be developed using locally sourced materials and technology (Ahmed et al., 2016, pp. 918–921). A discussion followed, suggesting various solutions and ideas on the researcher's requirements for it to be a sensor driven technology triggered by a small movement, that could work with a hidden mobile phone to send an alert. The technology was seen as a lifeline to women who found themselves in dangerous and uncomfortable situations.

Personal safety for women isn't an issue confined to Bangladesh, women all around the world need to feel safe in their day-to-day business. Discussion on this subject was raised by women in one of my focus groups, carried out for the *EEG Visualising Pendant*, regarding an idea that hidden signals emitted from an emotive wearable could be used to alert friends if feeling uncomfortable or being hit on when socialising. This suggestion is discussed further in Chapter 7 (p. 186).

The discussion culminated in the group devising a set of critical challenges as an agenda for future research and technology in this field:

1. What technical advances are required and what is so far missing, in terms of what technology is not here yet and what gaps need to be filled.
    - How do we use existing technology, is it too early for some applications and is the technology robust enough?
    - What the form factors might be, what are the challenges for commercial deployment, and is there a killer app?
    - How do we include research prototyping, toolkits, and platforms?
2. Is there a 'killer application' for this field and do killer domains exist?
    - Looking at what we are create - do people want it? What do people want?

- Possible domains: medical/healthcare, fashion, sports, *lifelogging*, and erotic.

3. Form factors for on-skin technology
   - What is on-skin technology? What is not?
   - How close should devices get to the skin?
   - What are the most promising locations?
   - How long should we be able to wear them for?
   - How do we enable personalisation and expression/aesthetics?
4. What are the challenges for commercial deployment?
5. How do we tackle medical safety?
6. What are the acceptability issues?
7. What are the ethical issues?

At a top list level, this set of challenges could be transferred and reused a used as a methodology or template for critiquing various forms of wearables during the conceptual stages of a device. The list underlines the importance of having a multifaceted and ethical questioning approach when developing wearables as there are many non-trivial aspects to consider. This may lead to substantial problems later down the design and development process if ignored.

Upon reflecting on this agenda, I came up with a set of relevant issues to add and items to change. One is sustainability and e-waste, as these areas are often overlooked and if not considered will cause environmental problems in the future. I would also suggest replacing the term 'killer app', both because it is very aggressive and because its commercial connotations make it unsuitable for academic research. An alternative I would suggest to use is 'fundamental app', as it suggests an application that would be important and useful, but does not try to single it out as indispensable. I would also discourage the use of 'killer domain' for the different fields or subject areas for wearables, it would also be more logical to perhaps look at a hierarchy of major categories, which then split into subcategories. An example category might be health, with the subcategories of heart monitors or insulin pumps. Finally, an additional gap and top level question which should be added is, "What materials are available and suitable?". This would reflect issues that I have encountered in finding materials to encapsulate and form enclosures or secrete into textiles and garments.

Practice and research contributions

The focal point of the 2016 Design Exhibition was to exhibit my research prototype *AnemoneStarHeart*, and the inclusion of a paper on this research in the proceedings. The pendant is the second artefact which has developed out my practice and is also informed by feedback from user studies. The pendant provoked questions and discussion with my peers on the use of data in private and public situations. It also generated comments on personalisation and aesthetics of wearables generally. During the Design Exhibition I invited attendees to participate in my research by taking part in a survey on emotive wearables and to give feedback the pendant, the results and a full description of the pendant can be found in Chapter 8 (p. 184).

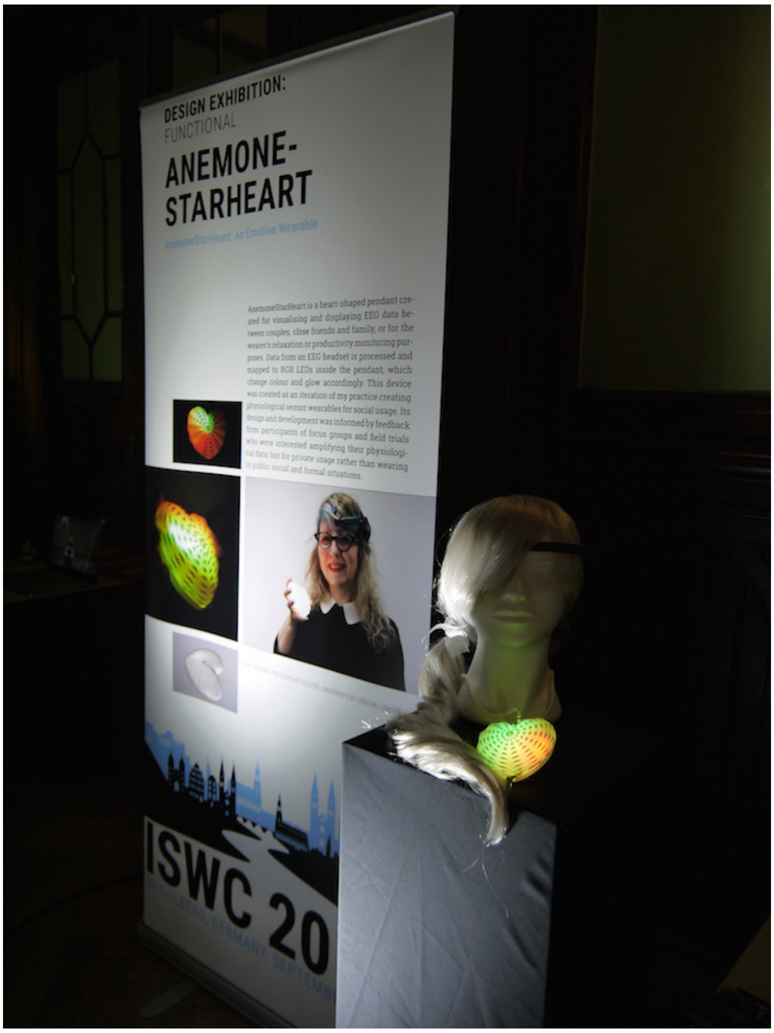


FIGURE 3.14: AnemoneStarHeart at the ISWC Design Exhibition, Heidelberg, Germany (2016)

Summary

At ISWC 2016, the topics of health and wellbeing, sensory feedback, and sensing were explored at both ISWC and Ubicomp. It was an important year for my research in that my participation involved discussion, sharing knowledge and ideas, exhibiting the results of my research and practice, and in turn gaining feedback on this from the community. I also participated in a workshop which through presentation of ideas, discussion and debate created an agenda addressing critical challenges for future research and practice of on-skin technologies.

To summarise this section, I have given an overview of subjects and areas of research that have been useful to my research and practice at ISWC and also Ubicomp over five consecutive years of attendance. I have described how I have participated and shared my research in various ways through exhibiting my research prototypes, contributing papers documenting my research in the proceedings, posters, presentations, demos, and workshops. In the next section I discuss my participation in the Quantified Self community.

The Quantified Self community

Another significant community I am part of is the Quantified Self and in this section I describe my participation in this community that has many links, interests, and participants in common with the aforementioned communities of ISWC and Ubicomp.

Self-tracking and personal informatics, as mentioned in earlier sections of this chapter as discussed at ISWC, are two prominent subjects that lie at the core of the Quantified Self. The movement has stimulated interest by popularising the discussion of these topics at its worldwide Quantified Self meet-up groups, of which there are currently 232 (January 2018) and has promoted tracking one's personal data, via various data logging methods both analogue and digital (Quantified Self, 2017). The first Quantified Self meeting was in held in Pacifica, California in 2008, and was organised up by journalists Gary Wolf and Kevin Kelly (Wolf, 2016, p. 67). Meet-ups typically comprise of a show-and-tell event, with different members and guests presenting their tracking story, or a company who want to show their product. The movement also documents show and tells via blog posts and mailing lists with videos, for sharing to the wider community.

FIGURE 3.15: Quantified Self London Meet-up, University College, London (2011)

As a member of the Quantified Self community since 2011 (Figure 3.15, p. 81), I have attended and presented my research at local meetings of the London, Amsterdam and Seattle groups, various spin off events, and also presented my practice prototypes and research at three Quantified Self Europe Conferences held in Amsterdam, the Netherlands.

My observations and experiences of this welcoming community recall how the sharing of personal experiences is encouraged and also how participants often return to update the community of their results, stories, and outcomes. This community shares a passion for wearables and ubiquitous computing with ISWC/Ubicomp and welcomes novel and diverse approaches to uses and findings related to wearable and ubiquitous computing.

FIGURE 3.16: Laurie Frick, closing keynote, *The Art of Tracking*, at the first Quantified Self Europe Conference, Amsterdam (2011)

Co-founder of the movement, Gary Wolf, describes the Quantified Self's meetings and conferences as attracting a diverse groups of attendees, who critically examine their self-tracking practice, including anthropologists, sociologists, and public health researchers. This includes members working in computing, engineering, design, consulting, and in founding start-ups. The community also engages individuals from all walks of life, unrelated to academia or industry who are looking for answers, help or to share their journeys. Often very personal stories and approaches to tracking sleep, mood, emotion, weight, illness, disease, and other health matters are described (Wolf, 2016, pp. 67–69).

The Quantified Self is constantly changing shape, perhaps because of its very flat hierarchy and the fact that anyone can start their own meet-up group. Quantified Self Europe conference regular and organiser of the Manchester group, Ian Forrester, describes the movement as shifting

> "(...) from the heydays of super stardom on the front of wired magazine; to everywhere and nowhere. By nowhere, I mean its not really talked about because its actually everywhere. The amount of people with some kind of app

> or device which they are actively tracking something is so huge" (Forrester, 2017).

An example of the diverse nature of Quantified Self projects and how the movement has attracted others who visualise physiological data in an aesthetic way comes from American artist Laurie Frick, who makes art informed by self-tracking data[17] (Figure 3.16, p. 82). At the third Quantified Self Europe conference in 2014, Frick explained how coming from a tech background she became interested in making artworks based on time and by measuring sleep data. She described how she "started to see patterns in the data that felt meaningful", defining the results as self-portraiture, about identity and "who am I?" (Ramirez, 2014).

Whilst my data visualisation prototypes have an aesthetic through the mapping of data and coloured light, they represent captured moments in time rather than static pieces, as Frick has been creating. Although what my prototypes do have in common with Frick's work is a sense of identity, in that it portrays an extra, unseen dimension of the wearer.

Presentations and involvement of attendees in my research

At the first Quantified Self Europe conference (QSEU), in 2011, I was invited by Gary Wolf, co-founder of the Quantified Self, to deliver the opening plenary on sensing wearables. In *EEG Visualising Pendant* I outlined the plethora of sensors and actuators available and gave examples of their usage, for example in medical and military settings (Figure 3.17, p. 84). Although there were many attendees who were familiar with electronics and wearables, there were also many who were just becoming familiar with wearable technology through self-tracking and had not been introduced to the various areas of wearables or for example, sensing technologies.

For the second QSEU in 2013, I presented my research on *Visualising Physiological Data*, including my *EEG Visualising Pendant* and *Baroesque Barometric Skirt*. Both presentations incurred feedback as a number of considered and useful questions about my work around what situations the pendant could be used for and also discussion around the NeuroSky EEG headset and comparisons with other headsets and technologies such as the Emotiv Epoc[18] versus *open source* EEG kits and projects such as OpenEEG[19].

[17] http://www.lauriefrick.com
[18] https://www.emotiv.com/
[19] http://openeeg.sourceforge.net/doc/

When I attended the third QSEU, in 2014 I gave a presentation on the *EEG Visualising Pendant* and conducted a focus group on emotive wearables with conference attendees, I discuss how I organised this in Chapter 6 (p. 165).

FIGURE 3.17: Taking audience questions, with Gary Wolf, after presenting the opening plenary on *Sensing Wearables*, at the first Quantified Self Europe Conference, Amsterdam (2011)

The Quantified Self and ISWC/Ubicomp workshops

The *QS: New frontiers of Quantified Self: finding new ways for engaging users in collecting and using personal data* workshop took place at ISWC, in Osaka, 2015. The organisers aimed to gather researchers in the unique environment of ISWC/Ubicomp to imagine how personal data can be tracked, managed, interpreted and visualised in the future. The workshop had a summary list of objectives to explore, which included finding new methods to engage users in self-reporting and interrogating data, including how to visualise and manipulate it.

Managing data was highlighted as a main challenge due its often unstructured form and the way that tools scatter it across "autonomous silos". Finding methods of creating meaningful data and ways to understand it for those who were not "expert users" was seen as a major aim (Rapp et al., 2015, pp. 969–972). At the first workshop twenty papers were accepted, covering topics including investigating the drivers needed to sustain data collection over long periods of time, opportunities and challenges for self-experimentation with tracking methods, and achieving *behaviour change* or the desired goal from the effort of tracking.

At the second workshop in 2016 the aim was to refocus the Quantified Self debate on the value of data for exploring new personalised services in areas such as: education, entertainment, and transportation (Rapp et al., 2016, pp. 506–509). This reflects a trend in affluent societies where more data than ever before is being gathered daily through the availability of wearables and apps for tracking. This data is being collected not only through targeted projects such as health and wellbeing, but also through work, infrastructure, transactions, people movement, and leisure time.

The Quantified Self's approach to meet-ups and conferences differs form ISWC in that there is no peer reviewed paper call, instead a more empirical approach is favoured to the presentation of ideas, personal experience, and knowledge. Attendees volunteer to present their practice and experiences in the form of show-and-tell talks at meet-ups and in-depth 'how to' and breakout sessions at conferences. This approach has allowed me to present and discuss to what I am working on at the time of the conference, rather than present a paper I have prepared months earlier. However, I value the rigorous peer feedback system of ISWC, which has helped me reflect upon and fine-tune my submitted papers.

The spread of the Quantified Self movement's meet-ups in towns and cities around the world allows local academics, engineers, designers, and self-trackers to meet on a regular or an ad-hoc basis, as opposed to a once-a-year conference. Having a local Quantified Self group has benefited my research in that I have been able to discuss ideas and issues on a regular basis with attendees. I have also learned of new and local projects and research from my peers, about which I might not otherwise have heard.

Conclusion

This chapter has given an introduction to the two main communities with which I share my research and practice, ISWC and the Quantified Self. These communities have overlapping interests, themes, and issues that are important to my research, such as physiological data, personal informatics, communication, design, technology, and privacy. Both communities have affected the development of my research, and I have learned from their collective research, experiences, and feedback. In turn, by the submission and acceptance of my research to these communities, I have contributed to two international platforms concerned with the discussion of wearables.

Over the years that I've been involved with ISWC I have been exposed to pioneering research from academia and industry, for example from Doctoral School peers, who have inspired me through their approaches to research and their organisation of methods for user testing wearables. These have helped me plan and carry out my objectives. What I have seen at the ISWC, including emerging technologies and new materials and approaches, has influenced my research. The symposium has also made available research in overlapping and connected fields, which has also informed and motivated my own research.

ISWC has given me a platform to contribute and publish my research and exhibit my practice. It has allowed me to gain feedback on my research from academics, peers, and those working in the industry of wearables both informally and formally through inviting them to join my user studies survey. ISWC has introduced me to the co-located conference of Ubicomp, which has uncovered connected areas and has broadened my knowledge of ubiquitous computing. The serendipitous instances of mutual interest between the ISWC and Ubicomp communities, in areas such as emotion, mood surveying, and communication technologies, allow me to encounter useful research.

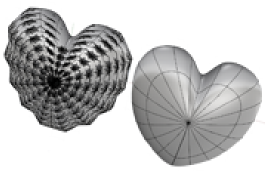
I have also benefited from learning experiences at workshops, which have included case studies, demonstrations, and also hands-on experimentation with electronic components. For example, since the MIT/Microsoft Underware workshop/sub-community, I have reflected on its agenda, to which I contributed, on the critical challenges for future research and technology, and have suggested new recommendations and identified gaps in the agenda, for instance regarding sustainability and e-waste.

Being a member of Quantified Self has encouraged me to look deeper at self-tracking and what we do with our data. It has provided me with a local community meet-up group where I can present and discuss my research with others who are interested in a wide variety of subject areas, for example around emotions and moods. This community often uses methods, such as lifelogging and keeping diaries, that are different from the ones I have used in my research, but these have been enlightening to hear about and discuss.

In the next chapter, *Chapter 4: A Practice in Responsive and Emotive Wearable Technology*, I examine my practice and prototypes in detail, including the iterative development and investigative processes followed to create responsive and emotive wearables (p. 89).

Chapter 4

A practice in responsive and emotive wearable technology



In this chapter I develop my practice using responsive and emotive wearable technologies. The creation of research prototypes was also described on (p. 33). Here, garment and accessory design using programming and electronics are presented together with the methodologies best suited to multidisciplinary projects outlined in Chapter 6 on (p. 158).

The ideas, testing code and circuits for each artefact are shown within the context of the unexpected challenges that a research faces working in a multidisciplinary process.

Background to a practice in design, code, and hardware

My practice is multidisciplinary and includes programming, electronics, art, and design. What interests me is how different construction processes can inform each other. For example, how soft shimmering and brightly coloured yarns and fabrics can meld and work alongside colder, harder materials, for example the metals, ceramics, and plastics that are used to create electronic components, batteries, wires, and prototyping board. My experience is not dissimilar to the inventor of the *LilyPad Arduino microcontroller* board, Leah Buechley who has spoken of a similar journey:

> "Today, after almost six years' working in e-textiles, it still seems deliciously incongruous to me that electronics can be constructed from such soft, sparkling, colourful stuff." (Buechley et al., 2013, p. 20)

Alongside Leah Buechley, artist-technologists Hannah Perner-Wilson and Miko Santomi, have explored the area where soft fabrics and technology meet. They have developed a huge range of online tutorials[20] that investigate how yarns, soft fabrics and inexpensive conductive materials can be brought together to craft unique electronic components, such as tilt switches, pressure sensors, knitted accelerometers, and embroidered potentiometers. They have called this collection "a kit of no parts" and define it as "new sensors and a new style of working", so that "people can *craft* their own technologies" (Buechley et al., 2013, p. 55). This research was one of the key drivers behind my decision to work with many different communities, which has informed my research.

[20] The Kobakant website: http://www.kobakant.at/DIY/

Exploring social space with two early examples of emotive wearables

FIGURE 4.1: *Temperature Sensing T-shirt (Yr In Mah Face!)* (2011)

Two projects preceding my doctoral research were influential in how I investigated one of my key research areas, nonverbal communication. The first was *Temperature Sensing T-shirt (Yr In Mah Face!)* (2011), which uses the wearer's temperature, space, and proximity to highlight social awkwardness and sensitivity to the closeness to others (Figure 4.1, p. 90). This garment was also the first that considered and approached the sustainability issues associated with the use of electronics embedded in textiles.

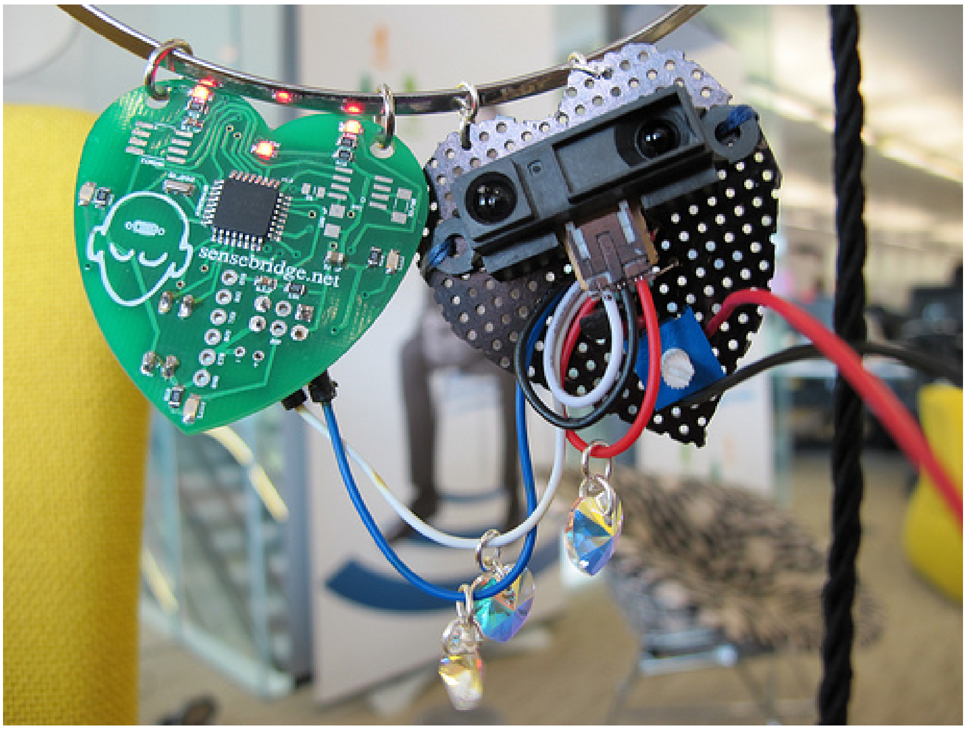


FIGURE 4.2: *You make my heart flutter*, proximity-detecting and heart rate necklace (2011)

The second was *You make my heart flutter* (2011), a double pendant necklace that draws attention to heart rate via pulsating LEDs which illuminate when someone enters the personal space of the wearer. I repurposed Canadian technologist Eric Boyd's *Heart Spark printed circuit board* (PCB) pendant[21] by creating new functionality for the device. This was achieved by constructing a second pendant with a circuit that incorporated an *infrared* proximity sensor which functioned with the electronics circuit of the *Heart Spark* (Figure 4.3, p. 92). The new functionality indicates when someone is entering the wearer's personal space by illuminating red LEDs on the pendant, with further LEDs pulsating along with the wearer's heart rate, allowing for the wearer's reaction to be interpreted (Figure 4.2, p. 91). The infrared sensor that I use has a range of 80 cm, which as an indication is just 3.8 cm more than Edward Hall's proxemics 'personal space' outer range, which I discuss further on p. 147. The second pendant includes a potentiometer to allow the wearer to change or limit their personal space range, which triggers the LEDs, dependant to how they are feeling and in what situation they would like to visualise their data.

[21] Eric Boyd's *Heart Spark* is open source. All the schematics, code and information about the device have been made available by Boyd on the Sensebridge website http://sensebridge.net/projects/heart-spark/

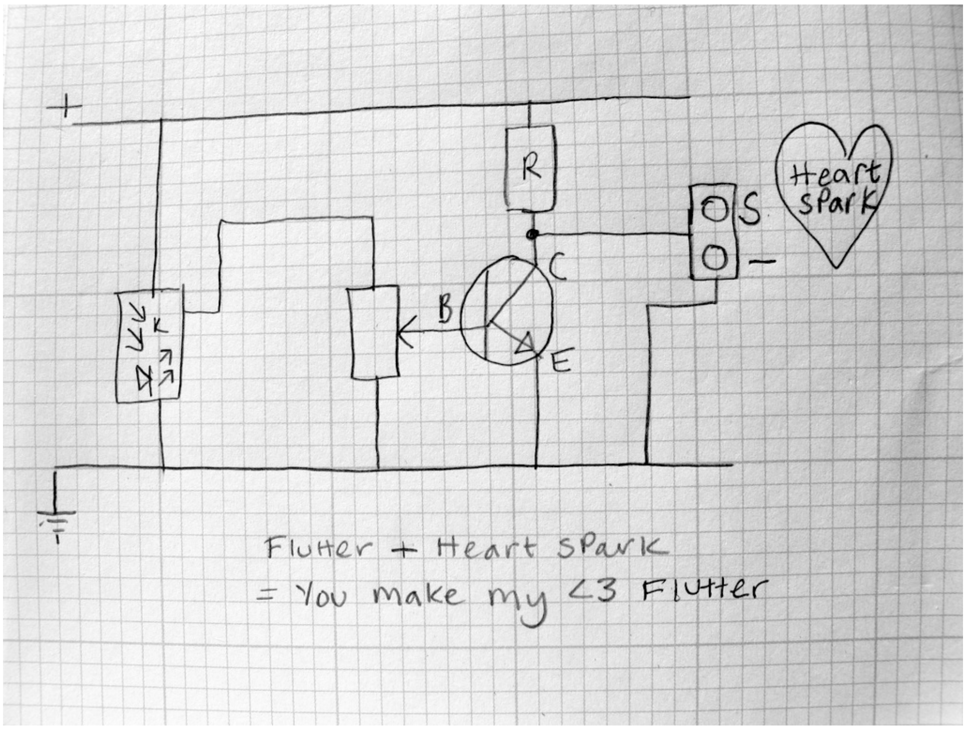


FIGURE 4.3: Bespoke circuitry diagram for *You make my heart flutter*, proximity-detecting and heart rate necklace, taken from my practice notebook (2011)

This device has received attention at events and conferences as observers are intrigued to see how their presence in my personal space might affect my heart rate and also to speculate the possible reasons for any changes. The device has been worn when giving presentations and I have experimented with it in terms of emotive engineering (p. 38), by switching the pendant into a fake mode, which displays the heart rate at a constant 70 BPM, to indicate 'calm'[22]. By exuding calmness, it has helped me give better and more confident self-presentations. From these experiences I was able to produce a key research prototype in the early part of my PhD research, the *Baroesque Barometric Skirt* (2012).

[22]NHS Choices (UK) states that: "most adults have a resting heart rate of 60–100 beats per minute (BPM)" (NHS, 2017).

An exploration of the *Baroesque Barometric Skirt*

FIGURE 4.4: The *Baroesque Barometric Skirt* being demonstrated at Smart Textiles Salon, MIAT, Ghent (2013)

The *Baroesque Barometric Skirt* (2013) (Figure 4.4, p. 93) is a responsive wearable developed to investigate how physiological data can be displayed alongside that of the elements that surround us. It looks at the bigger picture by entwining this data to give a more complete picture of the wearer in their surroundings. The skirt also includes sustainability features, such as removable electronics for washability.

The skirt draws the attention of the wearer to how they and their surroundings are constantly changing, whether they are stationary or in motion. The garment also gives a means of reflecting on how environmental conditions may be affecting their physiological state. For example, it is possible to record the data from the sensors on the skirt and use it to keep a daily record of atmospheric and personal data. The wearer can use this to match their emotional state against variations in atmospheric and weather data, and their own temperature. This may be of use to those, for example, who wish to track SAD (Seasonal Affective Disorder), which is a recurrent depression that usually affects sufferers at the onset of autumn or winter and then goes into remission in spring (Lam and Levitan, 2000, p. 469).

The garment may also appeal to those who enjoy practising *mindfulness* by way of appreciating aspects of their surroundings that they do not usually consider. For example, as the wearer moves around spaces indoors and outdoors, it will alert the wearer to changes in ambient temperature, pressure, and altitude, and also to their personal temperature in the form of a colourful visualisation of the data from the skirt's four sensors (Figure 4.5, p. 94).

FIGURE 4.5: The *Baroesque Barometric Skirt* (2013)

Design considerations and methods

There are a number of considerations that are essential for me to contemplate when creating a prototype. The first is around my creative process, which includes the following: ideas regarding what I want to make, the aims of the project, what it will look like and what the functionality of the resulting device will be. I try to remember to write all my ideas down in my sketchbook of designs, circuits and code concepts. This is because the connection between ideas and problem solving can be fleeting and it is crucial to write as much down as possible, so that ideas and possible solutions are not wasted.

Before touching any components, research needs to be done into the feasibility of ideas and how they can be developed. During the exploration of ideas for electronic prototypes many more layers of complexity start to become an issue, with the use of code and algorithms, components, and power, and hard and soft materials. There is also the question of further assets, such as sound and video input, and accompanying applications such as image, video and interaction software.

When bringing several unwieldy media or platforms together, it creates an elaborate jigsaw puzzle to solve, and choosing the right puzzle pieces is key to creating an end piece that works in the way one intended. An example of this jigsaw puzzle approach is the *Baroesque Barometric Skirt*. The idea for the overarching project came first, next came the prototyping of the electronics and code, the cut and style of the skirt came later when the approximate size and weight of the electronics were known and could be factored into the choices of fabric, length, and tailoring of the skirt.

In designing new wearables, you also have to learn about and study new elements, for example if you are using bespoke electronic components it usually means that you'll need to use code libraries to drive them, or if you are using new materials, then you may need to look into the methods needed to fashion them into shape. To utilise what I have learned from years of developing wearables I use a cyclic method that I have developed to test and facilitate the progress of prototypes, which involves 'Identifying, Concluding, and Updating', this method is described in detail in Chapter 6 (p. 160).

Skirt construction

The skirt required a shape and cut that would not encroach on the electronics, but would flatter and support them. I chose a panelled A-line skirt pattern with a dropped waist. The panel shapes were big enough to allow them to be used as a canvas for the painted motif on the skirt. I researched suitable fabrics for the skirt, testing various swatches and weights of organza for how the fabric would fare when washing and ironing, and for the colour fastness/permanence of the fabric paints. I chose the final fabric for the skirt for its ability to diffuse light from four strips of RGB LED that were positioned underneath the fabric. This diffusion also gives the light a softer feel. The positioning of the apron matches up to the painted design on the skirt itself.

For the design on the skirt, I decided to use a weather/atmospheric theme and was inspired by Japanese ink and brush landscape paintings that depicted mountains, seas and natural elements. I wanted to give the skirt a more contemporary feel, in line with the usage of electronics, and so explored imagery and fan art, which draws on peoples' desires and familiarity of the console game, *Ōkami*. The images chosen were deities from the game, symbolising opposing weather conditions of high and low pressure. These were sun god Amaterasu, depicted as a wolf and the main character in the game, shown advancing through precipitous weather, and the cat deity, Kabegami, bathing in the rays of a red Japanese sun.

FIGURE 4.6: Painting the *Baroesque Barometric Skirt*, with a Japanese weather theme, inspired by the video game *Ōkami* (2012)

The design of the skirt also included what I have named an 'electronics apron' (Figure 4.7, p. 97). The purpose of the apron was to be a removable substrate upon which all the electronic components could be deployed. The apron was made of a light lining fabric, which was able to hold the weight of the electronic components, but not alter the shape of the skirt. It was held in place in the lining of the skirt by Velcro squares. The apron also shields the wearer from contact with the electronics and holds the components and the battery pack securely in a fitted pocket. The electronics apron is easily removed so the skirt can be washed, which makes the skirt long-wearing and more sustainable. If for whatever reason a new design or version of the skirt was required, the electronics apron could be appropriated and reused. The electronics apron also allows for the electronics to be taken out and viewed as a standalone piece of e-textile design.

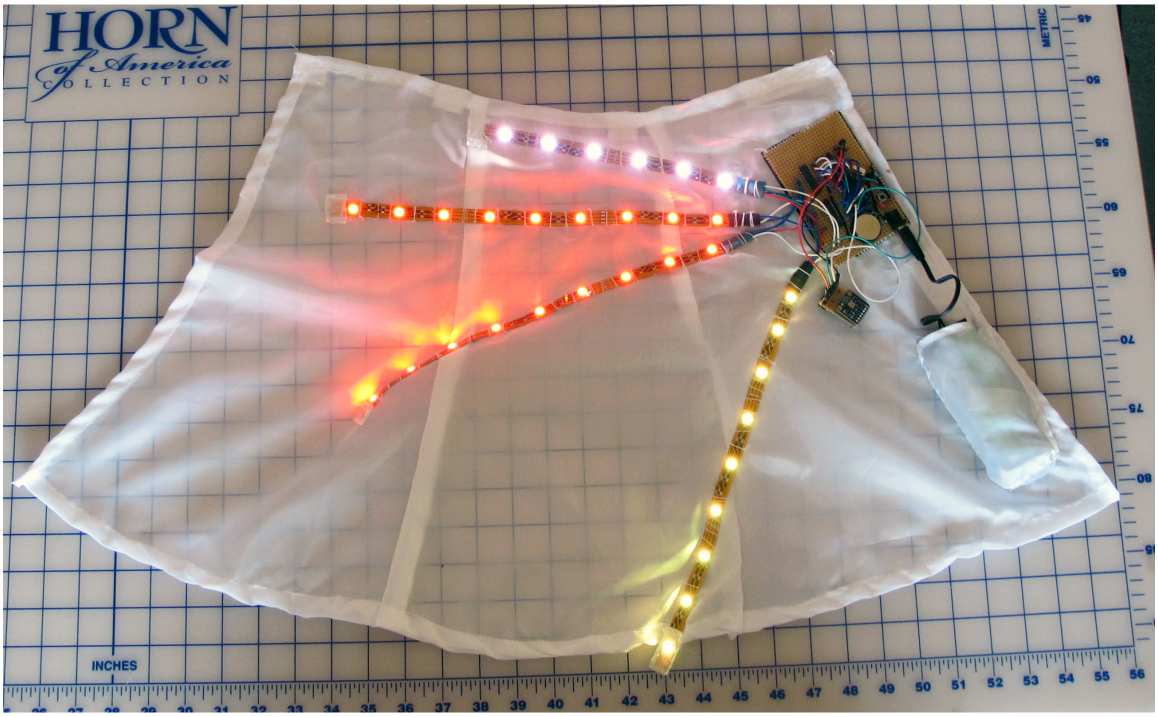


FIGURE 4.7: The *Baroesque Barometric Skirt's* removable electronics apron (2013)

Electronics

The design and construction of the electronic circuitry located inside the skirt was carefully considered as it is integral to the visualisation of data from the four sensors. The sensor data — ambient temperature, the wearer's temperature, pressure and altitude — was reflected on the four lengths of RGB LED strip. I chose the strip over individual LEDs as it is very flexible and moulds to the A-line shape of the skirt and can tolerate gentle bends whilst being worn. The strip was easier to sew into the substrate fabric of the electronics apron than individual LEDs with *conductive thread*. Also, because the RGB LED strip requires a 12V battery pack, coated wire was used instead of conductive thread because of resistivity issues. Another possible problem that helped me make the decision to use wire was that the fine conductive elements in the thread could overheat and singe the fabric.

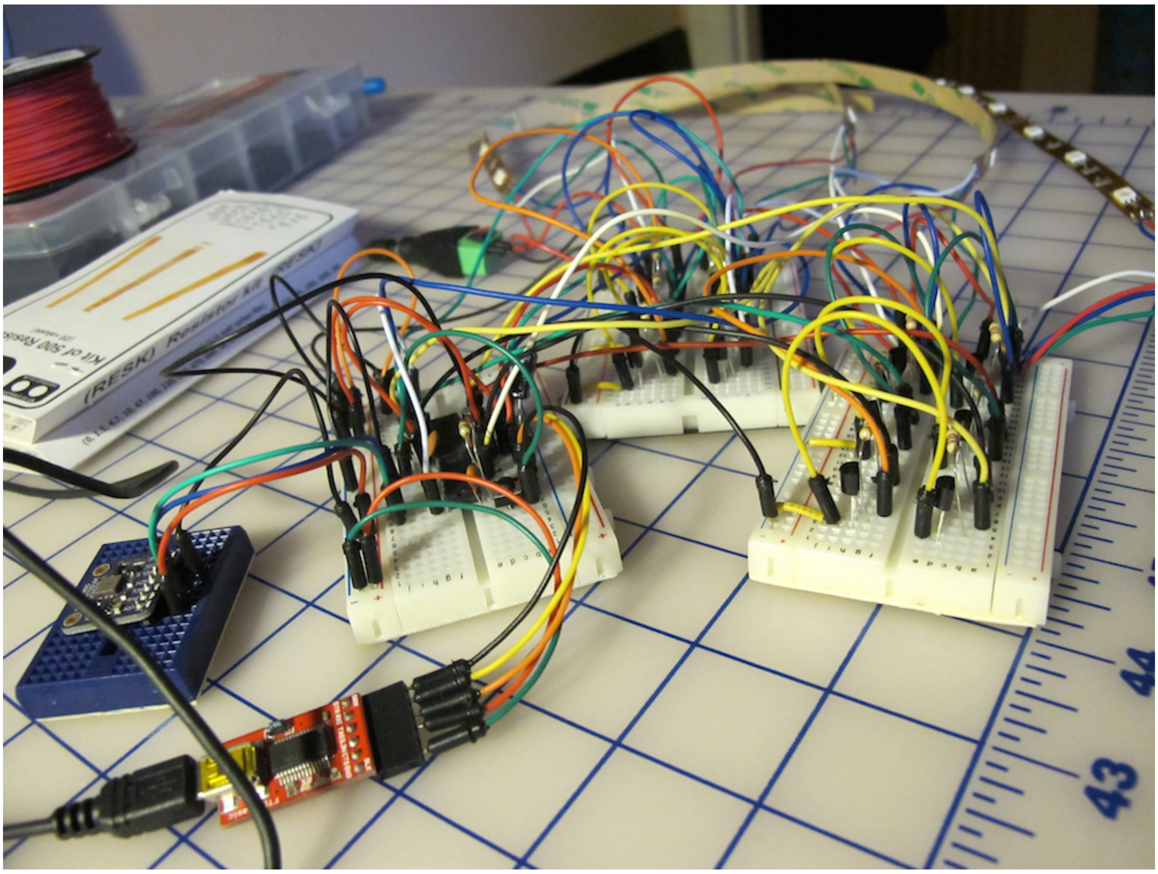


FIGURE 4.8: Complex electronic circuitry being tested on breadboard before shrinking down and soldering onto stripboard for the *Baroesque Barometric Skirt* (2012)

Before sewing or embedding components into any garment, the electronic circuitry needs to be temporarily built and tested as a separate entity on *breadboards* before any soldering is done (Figure 4.8, p. 98). For this project the prototyping was conducted on three breadboards and connected to an *Arduino Uno* microcontroller, which is a comparatively large compared to the microcontroller circuit that was eventually constructed for the skirt. The reason for using the larger *Arduino* microcontroller was that it has plug-in connections to the I/O input and outputs which do not require soldering. Using the breadboards and the Arduino Uno together means that components in the circuit can be moved around while experimenting and testing. Once this mass of wires and components was tested, it was simplified into a much neater circuit by using two *Darlington Pair ICs* (Integrated Circuits). The Darlington Pairs incorporated their own transistors, which made for a smaller, more elegant solution and meant that the circuit would then fit on one breadboard instead of on three.

Once this circuit had been tested it was scaled down to a much smaller circuit by replacing the Arduino Uno with a *Shrimp microcontroller kit*, which is comparable to the Arduino Uno and uses the same Atmel 328 microcontroller. The Shrimp kit is a low-cost alternative to pre-assembled microcontrollers and is purchased as a bag of components, which can be constructed in a much smaller area than the Arduino Uno, so is useful for saving space in a wearable garment's circuit.

After this new, smaller circuit was tested, the circuit was laid out on *stripboard* so it could be soldered together. To keep track of this, I needed to plan out my electronics, which required several iterative circuit board diagrams to be made (Figure 4.9, p. 100). The Shrimp microcontroller circuit, barometric sensor (ambient temperature, pressure and altitude) and physiological temperature sensor, are powered by a 3.3V coin cell battery. The RGB LED strip requires a bigger power source and the four strips run off a 12V battery pack.

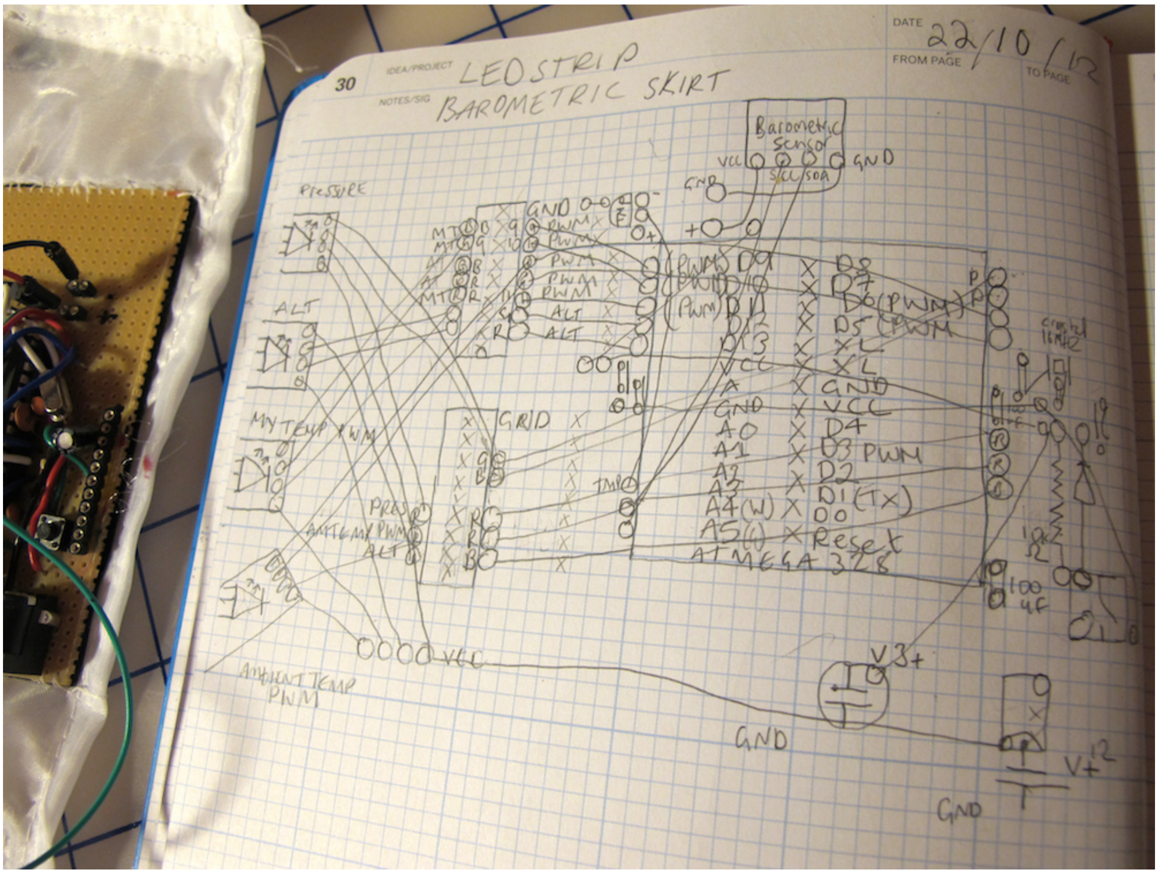


FIGURE 4.9: Bespoke circuit design for the *Baroesque Barometric Skirt* in my practice notebook (2012)

Approach to programming

```
main loop:
        read sensor(s) value
        compute scale value and compute colour
        set LED pins to appropriate colour
        wait 500 milliseconds
```

To help describe the processes of the program, this pseudocode shows an informal high-level description of the programming for the *Baroesque Barometric Skirt*. Full program code can be found in *Appendix C: Device Source Code* (p. 291).

This hardware is driven by code written in the *C programming language*. It additionally uses the *Wire* library and code library for the barometric sensor, which is responsible for calculations to convert readings from the individual sensors to °C (Celsius), Pa (Pascal) and m (metre). For getting an area-specific altitude reading it is required that the local mean sea level reading is entered into the code manually. This can be obtained from weather information websites and usually only needs doing once, unless the wearer is taking the skirt to be worn in different parts of the world.

To calculate how the data from the sensors is reflected in colours on the RGB LED strips, an algorithm is used that incorporates certain thresholds to reflect changes in the ranges of data coming in. The RGB LED strip visualises changes in incoming data from the lowest reading in a range, which will be shown as blue, which changes to cyan, green, yellow, white, magenta, to the colour for the highest reading in a range, indicated as red.

User experience

The skirt provides an easy-to-use interface between the wearer and their surroundings. In terms of the user experience, to start the skirt polling the environment for barometric and physiological temperature, the wearer need only insert the batteries. If the batteries need changing, the LEDs will pulse, informing the wearer to change them. It is simple to access the numerical data values from the skirt's sensors, one just needs to connect the skirt or the electronics apron to a laptop or tablet via USB. Also, data can be recorded on the microcontroller's *EEPROM* memory and retrieved later.

To summarise this section, I have introduced my multidisciplinary practice of developing responsive and emotive wearables and described how I have been inspired by the fusion of materials and electronics to create wearables. I then describe two early prototypes which were influential in how I later investigated nonverbal communication and created the *Baroesque Barometric Skirt*, whose construction I have described in full. In the next section I discuss my explorations into creating emotive wearables using EEG data.

Investigations into emotive wearables using EEG

This section discusses my practice through the usage of EEG. Firstly, I give a brief explanation of EEG and my reasons for using and choosing the technology that I did. The section then goes on to describe the iterative process that I worked through to create the *EEG Visualising Pendant*, which saw me create four different versions of the pendant before settling on the research prototype with which I conducted my focus groups and field tests.

A brief introduction to EEG

Electroencephalography is a method of recording the electrical activity of the brain from designated areas on the scalp. Fluctuations of voltage are measured from ionic current within the neurons of the brain. In most cases the recording of EEG, over periods of time, is non-invasive and uses electrodes placed on the scalp to glean data, which is then processed by diagnostic software (Niedermeyer and Lopes de Silva, 2004). Electrodes are usually situated based on the recommendations of the International Federation of Societies for Electroencephalography and Clinical Neurophysiology, and are known as the 10–20 system, which amounts to 18 electrodes and two reference electrodes (*World Congress of Medical Physics and Biomedical Engineering 2006*, 2006, p. 1076).

The history of EEG stretches back to 1870, when Eduard Hitzig and Gustav Fritsch applied electrical stimuli to a region of a dog's brain, which caused a limb on the opposite side of the body to move. In neurosurgery today, surgeons still use electrical stimulation to map the brains of conscious patients during procedures to identify areas where any damage could result in paralysis, or loss of sensation or linguistic ability (Wolpaw and Wolpaw, 2012, p. 15).

Impetus to use EEG in my practice

My reason for choosing EEG data for my research prototypes was because, in terms of nonverbal communication, it felt very compelling and stood out to me as the most subjective and challenging area of physiology for attempting to gain insights regarding what humans and animals were thinking and feeling. Idioms such as 'a penny for your thoughts' and scenarios in science fiction connected to 'mindreading' have always intrigued me, so access to BCI (brain–computer interfaces) was very attractive. "Reading thoughts" via EEG was first mentioned by the German psychiatrist Hans Berger, known as the inventor of EEG, in 1929, when he first speculated on the possibility of processing EEG waveforms using mathematical analysis (Zander et al., 2014). Berger's research showed how electrical impulses from the brain:

> "(...) changed dramatically if the subject simply shifts from sitting quietly with eyes closed (short or alpha waves) to sitting quietly with eyes open (long or beta waves). Furthermore, brain waves also changed when the subject sat quietly with eyes closed, 'focussing' on solving a math problem (beta waves).

That is, the electrical brain waves pattern shifts with attention" (Ben-Menahem, 2009).

In terms of my practice, I have chosen to use the NeuroSky MindWave Mobile headset. I have chosen this over other devices for two reasons. Firstly, ease of use in terms of one being able to comparatively quickly set the device up and put it on. It has one dry electrode, which does not require gels or tape, so this made it a good candidate for using for field tests where it was crucial to be able to get the device up and running quickly and without too much fuss or discomfort for the wearer. Secondly, the device outputs two distinct streams of data, which for my practice was enough, as I wanted at this stage to create fairly simple devices that gave a binary output that each could be easily distinguished from the other. This was because at this stage I did not wish to create overly complex devices for my practice and field tests and focus groups, which would take too long to set up.

The NeuroSky MindWave Mobile headset's technology is proprietary and not transparent, so I am not able to comment fully on the functionality of its eSense algorithm or the reliability of its output. For future practice and to explore experimentation I am eager to explore using other devices for collecting data and have purchased a *Muse* EEG headset[23], which has seven 'sensors' (three are reference), and an OpenBCI kit[24], which includes electrodes for sensing *ECG* (Electrocardiogram) and *EMG* (Electromyography) as well as EEG, which would be suitable for multi-sensing prototypes.

Description of the *EEG Visualising Pendant*

The *EEG Visualising Pendant* is an LED matrix encapsulated by a 3D printed frame, which hangs around the neck and has the appearance of a bespoke piece of jewellery. It was developed for use in social or formal interaction with others, or for personal observational use. The pendant visualises and broadcasts two packet streams of EEG data, which is sent from a NeuroSky MindWave Mobile headset (Neurosky, 2013). The *MindWave Mobile* is a standalone Bluetooth headset that detects electrical signals from the brain, which are accessed via a single, dry electrode on a protruding arm from the headband. The electrode makes contact via the wearer's forehead at the prefrontal cortex area, over the left eyebrow, where higher thinking states are dominant.

[23] Muse EEG headset http://www.choosemuse.com
[24] OpenBCI http://www.openbci.com/

The NeuroSky headset processes signals sent from the electrode with its on-board proprietary ThinkGear hardware and algorithm called eSense, which filters out background noise and muscle movement. The *MindWave* headset sends out two streams of data packets, usually once a second (NeuroSky, 2015*a*). One stream of data packets is named 'attention' and is concerned with concentration, and the other is named 'meditation', which refers to relaxation.

FIGURE 4.10: *EEG Visualising Pendant* showing live EEG data sent from a *MindWave Mobile* Bluetooth headset. The pendant is shown featuring one of a number of interchangeable 3D printed alumide frames (2013)

Purpose for creating the pendant

My reasons for creating this emotive wearable returns us to the opening ideas expressed in my abstract at the beginning of this thesis. It arises from my investigations into nonverbal communication during social and formal interaction, as I have previously described in my paragraph on nonverbal communication on p. 4. I developed the *EEG Visualising Pendant* (Figure 4.10, p. 104) to explore if it is possible to create an emotive wearable that can relay nonverbal communication between the wearer and observers of the pendant during interaction.

During social interaction the purpose of the pendant is to signal to those around the wearer whether they are concentrating on conversation or if their thoughts are drifting away. It is also intended to be used as a visual cue for the wearer to help monitor their social interactions and look for cues to modify their social behaviour if they are concerned that they are often distracted or unfocussed. Taking attention and meditation data and visualising it might seem like a very unsubtle way of communicating, but it is intended that this unique approach may be helpful in avoiding awkward social situations. This would transpire by giving observers of the pendant a visual cue when attention is drifting away and it is perhaps time to change the topic of conversation, let someone else talk for a while, or move on to speak with someone else.

Monitoring and broadcasting one's EEG data is an unusual and distinctive approach to feeding back to others in social situations, because it makes data available that is not normally open to others. Looking to the future, humans are constantly evolving and changing approaches in terms of etiquette in work and social areas. As wearable technology evolves and shapes itself, and is shaped by technological innovation and consumer trends, it will eventually change social norms and behaviours. For example, through the evolution of mobile phone peripherals, it has in recent years become acceptable to walk along the street or be in a public place while appearing to be talking to oneself. We now recognise this slightly bizarre act as someone having a mobile phone conversation via a clip-on microphone or combined mic/speaker device.

However, some of the changes required to social etiquette, in regard to normalising visualising our physiological data in public, may take some time. Wearables, such as *Google Glass*, have already caused us to question our attitudes to issues such as personal space, privacy, and ethics (Google, 2013). Other location-aware wearables such as GPS (Global Positioning System) tracking shoes or dog collars, can be viewed as either invaluable devices for monitoring the whereabouts of vulnerable loved ones or an invasion of privacy.

Development of the *EEG Visualising Pendant*

After previous experiments creating responsive and emotive wearables, the next logical step for my practice was to explore developing a small and easily worn functioning device that could bridge the gap between technology and personalised or aesthetically designed accessories. This device would allow user studies' participants to experience wearing an emotive wearable in social and formal situations. The pendant was developed in an iterative fashion by following a process of testing and investigating each element of the pendant using the aforementioned cyclic method of 'Identifying, Concluding, and Updating'.

Pendant prototype v.1

The first circuit prototype consisted of an Arduino Uno microcontroller connected via a breadboard to a Bluetooth dongle and an eight-bar LED bar graph. The code to drive this prototype was written in the C programming language. The *MAC* (Media Access Control) address, which uniquely identifies a device, in this case the NeuroSky MindWave Mobile, was used to make a 'pairing' connection to the Bluetooth dongle.

Data is supplied by the headset from NeuroSky's proprietary eSense algorithm on a scale of 0–100. NeuroSky's documentation (NeuroSky, 2011, pp. 13–14) states that:

- 1–20 is "strongly lowered" levels
- 20–40 indicates "reduced" levels
- 40–60 "neutral" and similar to "baselines that are established in conventional brainwave measurement techniques".
- The threshold of 60–80 is "slightly elevated"
- 80–100 is considered "elevated"

During this part of my research, I experimented with the NeuroSky eSense algorithm's suggested data thresholds using an empirical method of perceived concentration and relaxation experiments, and the possibility of personalising the data thresholds was investigated. This was in order to find a more meaningful understanding of the proprietary algorithm, which I could not access, so could not understand fully how it makes sense of the data it receives. I used a 10-bar LED bar graph firstly to take a look at my attention and meditation data as individual stream visualisations.

Later, I split the bar graph to concurrently show a 50/50 split of attention and meditation data, so I could look at them alongside each other and compare them. I found that thresholds of less than 40 and more than 60 seemed to be optimal for measuring and visualising changes in attention and meditation for my personal EEG measurements based on my activities. Although testing with other thresholds still worked fine, such as less than 20 and more than 70, though I found 50 with no neutral zone was more difficult for me to get the meditation signal to lower (which may have meant that I might have been getting tired/distracted by that point).

To summarise, this was an informal observational test, which would be interesting to repeat in a controlled space with specific tests to trigger and measure attention and meditation levels with those of others.

With the headset and the dongle paired to receive the headset data, a *Finite State Machine*[25] was used to read the data from the Bluetooth dongle. The packet processing state was checked for the quality of the packets of data concerning attention and meditation values and only updated if the quality of the data was good enough. The Arduino Uno microcontroller then ran an algorithm to convert the data for visualising the attention or meditation signals on the eight-bar LED bar graph. At this stage the prototype was only visualising one aspect of the EEG data at a time, i.e. attention or meditation data, mainly to show that the packet data from the headset was successfully being picked up by the Bluetooth dongle and processed by the microcontroller.

To help describe the processes of the program, the pseudocode below shows an informal high-level description of the programming for the *EEG Visualising Pendant*. Full program code can be found in *Appendix C: Device Source Code* (p. 291).

[25] A Finite State Machine is a mathematical model that can be applied to logic circuits or programming that can only be in one of a number of finite states at any one given time. An example of a Finite State Machine is a light switch – it can only be in one state at a time, on or off.

```
main loop:
        if button not pressed:
                if button was previously
                record that button is not pressed
                update display
        else:  // button is pressed:
                if button not pressed before:
                        record that button is pressed
                        record initial button press time
                        indicate that mode icon should be displayed
                if elapsed time since initial press > 2 seconds:
                        advance "next mode"
                show icon for "next mode"

        if data available from bluetooth module:
                update packet reading finite state machine
        if recording save value

update packet reading finite state machine:
        // uses supplied data to build an incoming packet of data
        if checksum read and valid:
                update data for display

update display:
        if elapsed time since last display type change > 5 seconds:
                advance display type
        if mode icon should be displayed:
                display mode icon
        else:
                use data to generate one of 3 patterns
```

FIGURE 4.11: To help describe the processes of the program, this pseudocode shows an informal high-level description of the programming for the *EEG Visualising Pendant*

Pendant prototype v.2

For the second prototype of the pendant, a more expressive way of visualising the data was desired and a square 8 x 8 LED matrix was chosen as this would give an extra dimension to the visualisation compared to the bar-graph prototype. This was because the square matrix would have enough room to visualise the attention and meditation data side by side. The dual data visualisation was achieved by adding new Adafruit code libraries (Adafruit, 2013) to the code for the LED matrix and the first attempt at this comprised of two hollow rectangles, visualising attention and meditation data next to each other on a green-coloured LED matrix (Figure 4.12, p. 109).

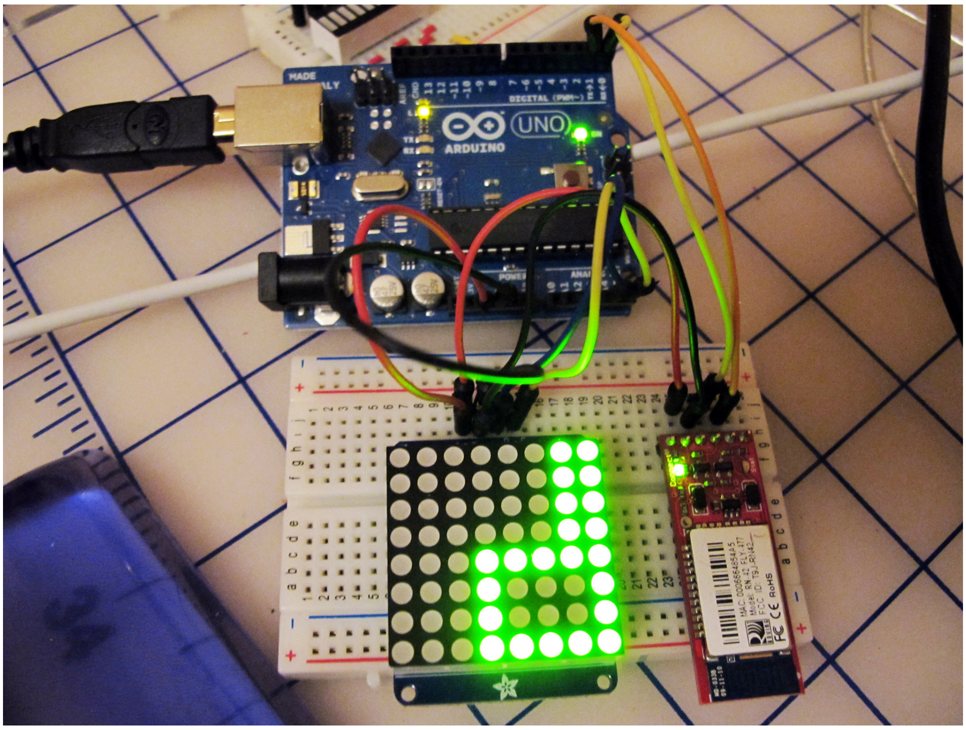


FIGURE 4.12: Breadboard prototyping of device using a green LED matrix to show attention and meditation data side by side (2013)

This worked well as one could compare the levels of attention and meditation data coming from the *MindWave* headset. Using the matrix achieved a good result, but it required a way of showing the distinction between the different levels for a more meaningful visualisation. The completely green LED matrix was exchanged for a 8 x 8 bi-colour LED matrix, which could be illuminated as red, green or yellow when the two sets of data overlapped. The C code was updated to display the attention data levels as red LED rectangles and meditation levels as green LED rectangles. These rectangles were split over two halves of the square matrix and they enlarged and contracted in accordance with the EEG data levels from the *MindWave Mobile* headset.

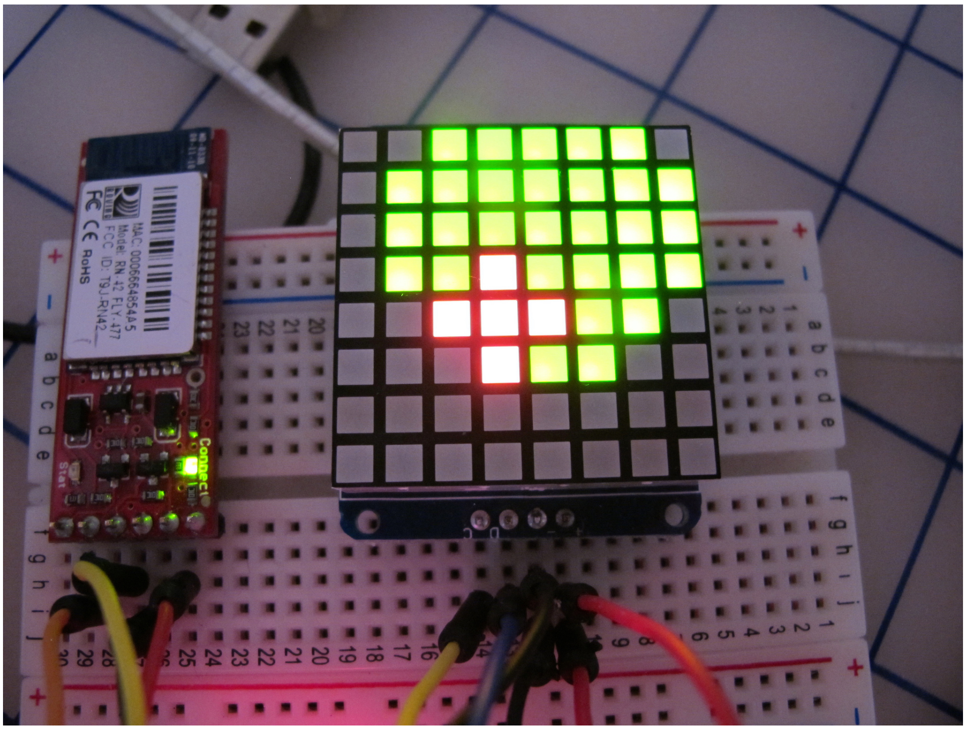


FIGURE 4.13: Breadboard prototyping of *EEG Visualising Pendant* using a bi-colour LED matrix to show attention (red) and meditation (green) data side by side as circles (2013)

The development of the pendant's data visualisation could have concluded at this point, but it was important to consider the design and aesthetic nature of this piece of wearable technology, from both the wearer's and the observers' points of view. Also, for onlookers and those who do not know what the shapes and patterns of the data relate to, it is important that the pendant appears as an innovative and unique piece of LED jewellery. Exploring how the EEG data can be creatively portrayed is a crucial part of the software and hardware evolution of the pendant. So bearing this in mind, the code was updated to add circular and diagonal data shape visualisations to the existing rectangle (Figure 4.13, p. 110). These shapes were shown as red for attention data and green for meditation data, and the visualisations cycled to the next shape at intervals of five seconds. The shapes were also now shown as filled blocks of colour, as this made the data levels easier to see and compare (Figure 4.14, p. 111).

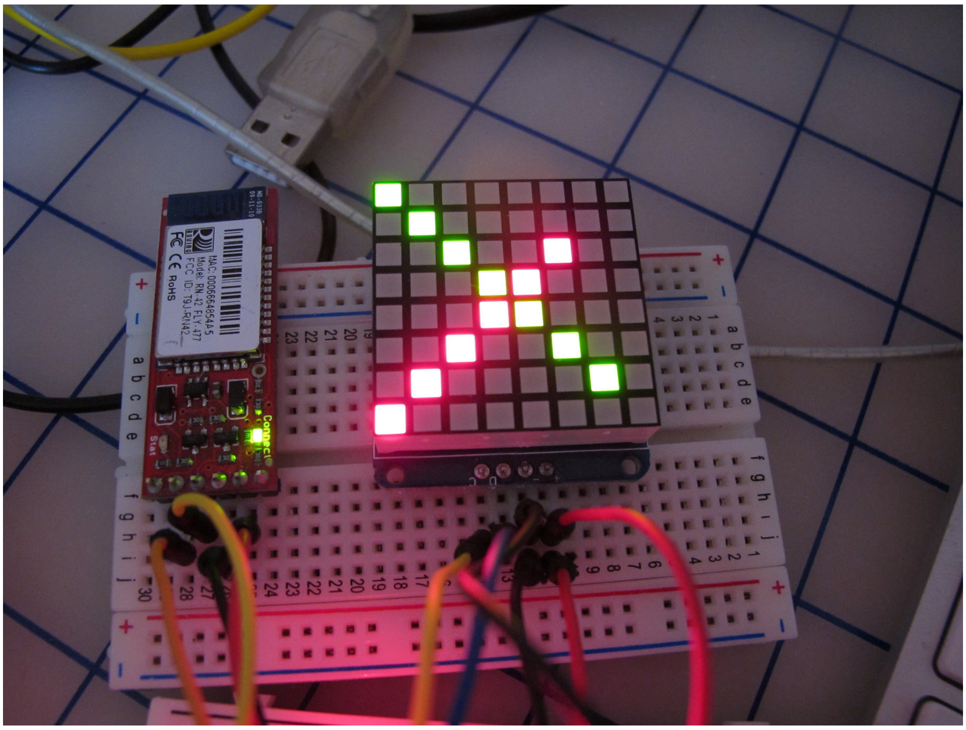


FIGURE 4.14: Breadboard prototyping of *EEG Visualising Pendant* using a bi-colour LED matrix to show attention (red) and meditation (green) data side by side as diagonals (2013)

Pendant prototype v.3

With the breadboard prototype and code now working with the *MindWave Mobile* headset, LED matrix, Arduino Uno and a Bluetooth dongle, it was time to consider and decide how the prototype could be made into a smaller and more compact microcontroller circuit for soldering onto stripboard. The Arduino Uno had worked well for the initial prototyping, but is somewhat bulky for an easily and comfortably worn piece of wearable technology. The Arduino Uno was replaced by a Shrimp (Figure 4.15, p. 112), a low cost microcontroller kit that was designed specifically for breadboard/stripboard prototyping and comes as a bag of loose components, which makes it fairly flexible in terms of putting it together as one can route the location of components to fit a specific board shape.

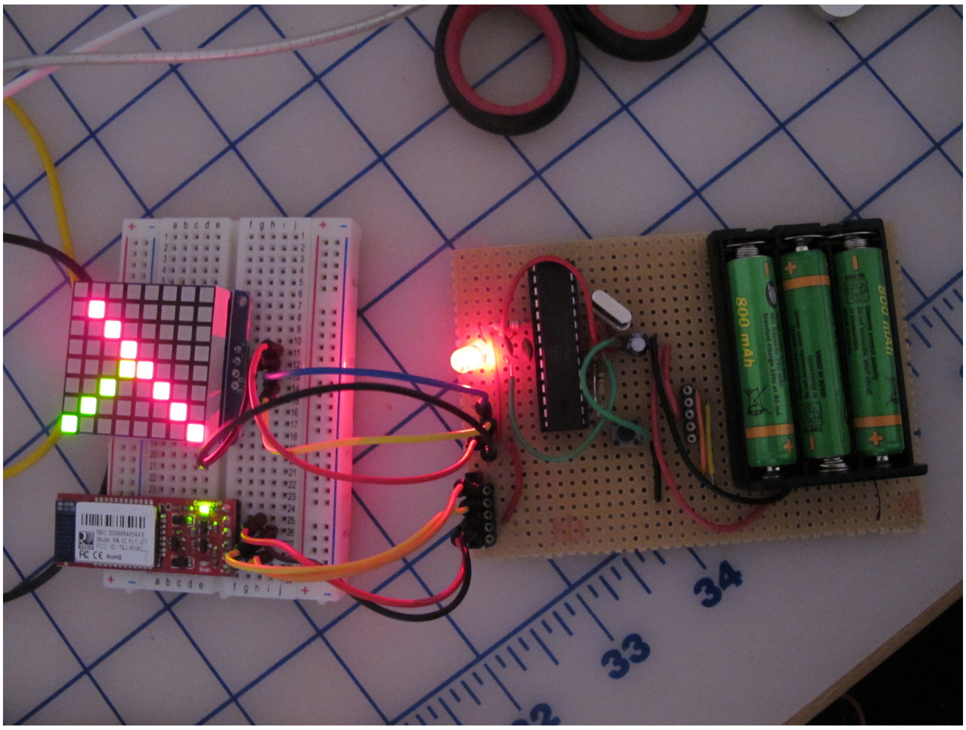


FIGURE 4.15: Breadboard testing of *EEG Visualising Pendant* electronics using a Shrimp microcontroller kit to save space (2013)

The Shrimp, as mentioned earlier in this and the hardware overview of the *Baroesque Barometric Skirt*, is based on the Arduino Uno and includes the same ATmega 328-PU microcontroller chip at its heart, so there was not a problem uploading the code and the libraries from the breadboard and Arduino Uno circuit. As the LED matrix, and Bluetooth dongle had already been tested on the *Arduino Uno*, it was simply a matter of putting the Shrimp kit together on a breadboard, uploading code and testing it for any problems, of which there were none. The next step was to test the circuit with appropriate batteries to ensure it could be powered as a standalone piece of wearable technology and not tethered to a laptop. It is important to do this testing when using multiple components — a Bluetooth dongle and an LED matrix in this case — as there are power draw considerations. Testing revealed three rechargeable AAA batteries sufficed to run the circuit and all its components.

Having tested the circuit, the schematic was then drawn out on a paper stripboard template to ensure the circuit and its components would fit neatly. An appropriate size of stripboard was cut, and tracks that needed to be cut to prevent short circuits were pinpointed. The components were then laid out for the circuit, double-checked for any errors in positioning and then soldered to the board. This version of the prototype worked well, but with the battery pack located and taking up a large amount of space on the stripboard it was not ideal and would require some thought as to how to make the overall size smaller. It was also time to consider the aesthetic presentation of the pendant in so far as it was worn simply as a plain LED matrix on a chain (Figure 4.16, p. 113).

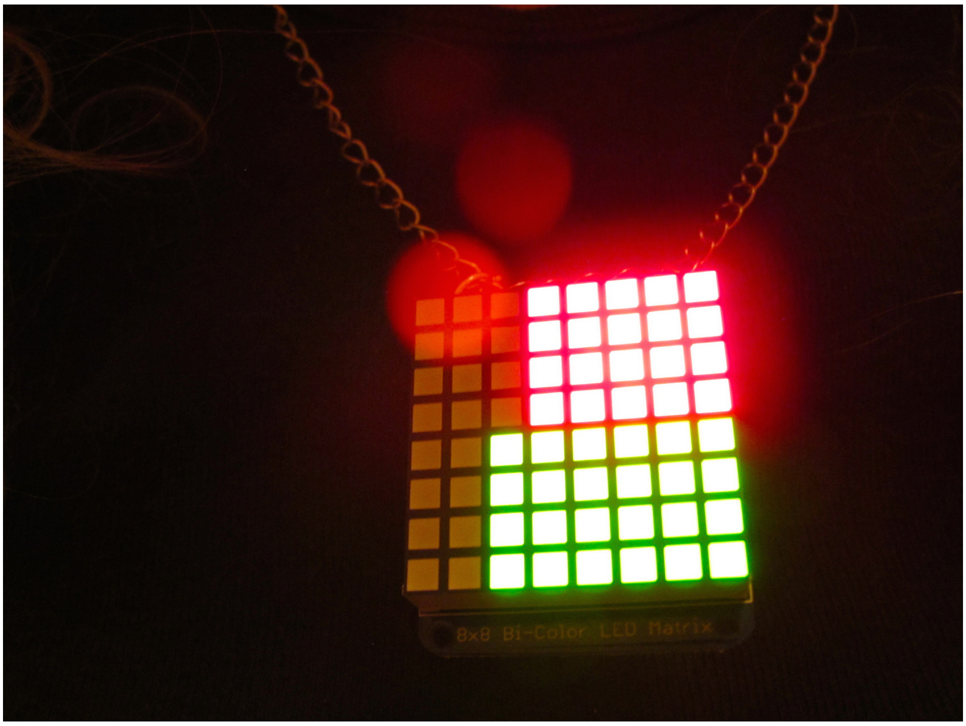


FIGURE 4.16: *EEG Visualising Pendant* before the addition of interchangeable and bespoke frames (2012)

Pendant prototype v.4

The *EEG Visualising Pendant* was developed further when I submitted an application for the prototype to be accepted for the ISWC 2013 Design Exhibition, to be held at ETH Zurich, Switzerland (ISWC, 2013). It was accepted, but as a static exhibit it would not be very interesting to view by the attendees of the exhibition. I decided this was a good opportunity to rethink the functionality, plus rebuild both the code and the external hardware for the pendant to fit into a smaller physical space. I considered how I could extend the functionality of the device and decided that the pendant would be more useful if it had multiple modes or uses. I had previously experimented with trying to control my own physiological data using various sensors, for example by monitoring my heart rate in varying situations with *You make my heart flutter* heart rate/proximity necklace, and also by trying to influence my EEG signals when using a *MindWave Mobile* headset. I considered how new modes could be incorporated into the pendant and how EEG data could be used to influence or manipulate social situations by what I call 'emotive engineering'. The other, less contentious, reason for having record and playback modes for the *EEG Visualising Pendant*, is for the wearer to be able to record and playback their data to view when they want to know when they're concentration levels are high or low. For example, for practising meditation or to explore at what time of the day they are most able to concentrate and are productive, as an aid to picking out times of the day when best to do tasks such as study.

To enable this new functionality, firstly the code was rewritten to add record and playback functions, this required accessing EEPROM memory on the microcontroller, which holds data when the device is turned off. The code was updated to allow the device to record live EEG data from the *MindWave Mobile* headset, record and store up to four minutes and then play it back at a later date.

The pendant's circuitry was also rebuilt, replacing the Shrimp circuit with an *Arduino Mini Pro* microcontroller, which fitted into a smaller space. The battery pack was relocated on the back on the stripboard, which allowed for the total circuitry surface area to be halved. The circuit then was able to fit into a small enclosure. It was then necessary to design an interface to switch between live, record and playback modes, this was done by adding a button to the circuit, which, when held down, would cycle through icons representing the modes on the pendant's LED matrix and allow the user to select the appropriate mode when the button was released (Figure 4.17, p. 115).

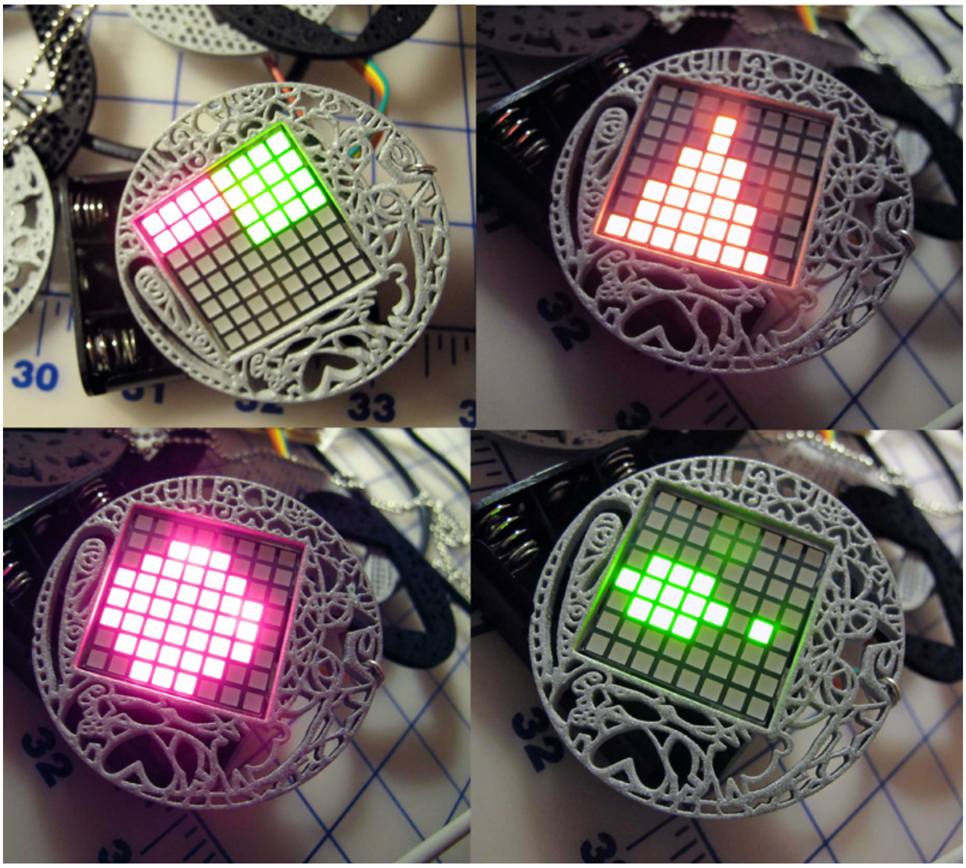


FIGURE 4.17: Pendant showing live data, icon for playback, record and live modes for *EEG Visualising Pendant* (L–R) (2013)

Aesthetic design of the pendant

In terms of aesthetic design, the LED matrix was chosen because of its small pendant-like size and shape and the compact setting for the LEDs. It is also very light, so will not weigh heavily on the neck or on the body if worn as either a pendant or a brooch (Figure 4.18, p. 116).

For the pendant's aesthetic look and feel, I used myself as a persona to create a selection of 'frames', which enclose the LED matrix. The frames have been created to take into account the style preferences and mood of the wearer (myself in this case) and to give the pendant a softer, less clinical look. In the first instance, I created a number of frames, in various shapes from *Fimo*, which is malleable clay that sets hard when oven-baked (Figure 4.18, p. 116).

The Fimo frames sufficed initially, though they had a 'homemade' look about them that I was not satisfied with and I felt it jarred somewhat with the clean sharp edges of the 8 x 8 LED matrix they were surrounding. Following some experimentation, I created a number of designs for 3D printed frames, which was a learning process as it was my first foray into 3D printing. My initial designs used geometric repeated patterns, but I later experimented with hand-drawn designs, which were more personal. These required some work to get the line/wall thickness correct to enable them to be selective laser sintered (SLS)[26] in nylon and polished *alumide* (nylon mixed with powdered aluminium) by a commercial 3D printing company. The 3D frames were much more aesthetically pleasing to look at, plus the polished finish gave them a more professional look. In focus groups and field tests of these frames, participants had varied views of how they would like such an accessory to be personalised.

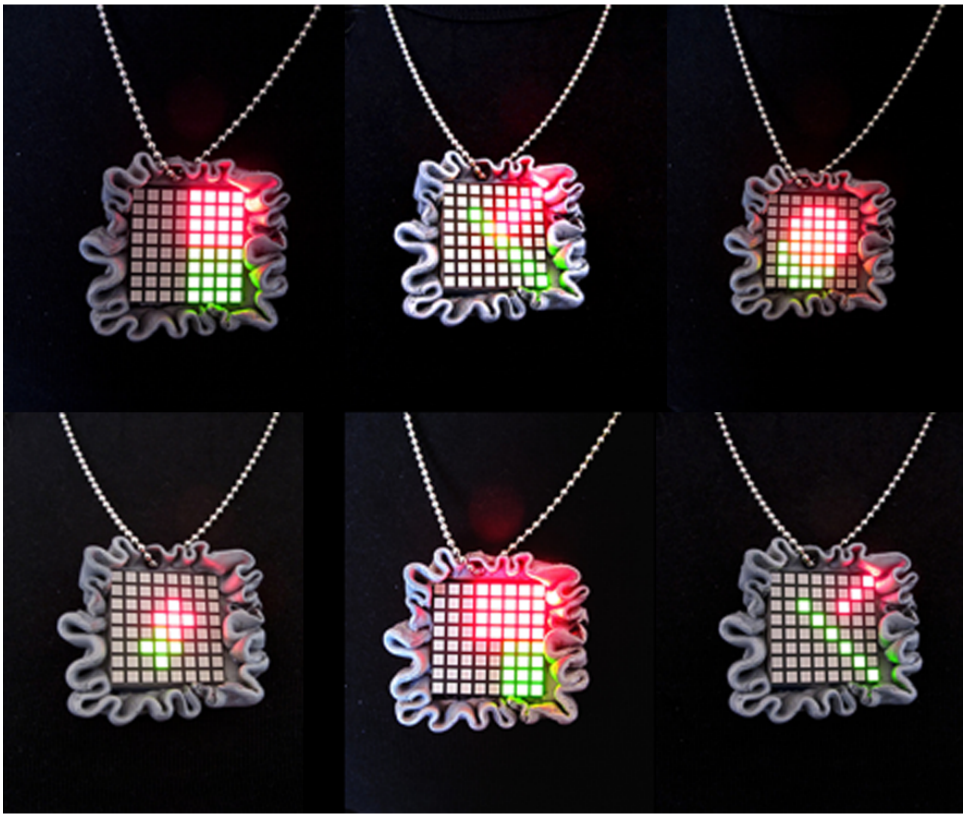


FIGURE 4.18: *EEG Visualising Pendant* showing live EEG data in rectangular, circular and diagonal shapes, featuring one of a number of interchangeable Fimo clay frames (2013)

Use of colour to symbolise EEG channels

The LED matrix displays both EEG data states simultaneously. It is constantly updated and changing with the arrival of new data packets. Red shows the 'attention' data, while green shows the 'meditation' data. Because colour has varied meanings and symbolism to

[26] Selective laser sintering is a technique that uses a laser to meld particles of plastics and other powdered materials such as glass and ceramics into a 3D shape. It's often used for small runs or creating prototypes from *CAD* files.

different cultures and religions (Dilloway, 2006), I opted to use what I feel is a Western interpretation of colour mapping akin to the theories of the German poet W. J. von Goethe in his 1810 book *The Theory of Colours* (Goethe, 2006, pp. 167–195) and 'colour extraction' of designer Claudia Cortes as discussed in *Mapping emotion to colour* (Nijdam, 2009, pp. 2–7). I feel red matches 'attention' as it echoes activity and enthusiasm, while I think green links to 'meditation' by suggesting 'calmness and neutrality'. I have used these colour choices as a constant throughout my practice with EEG devices.

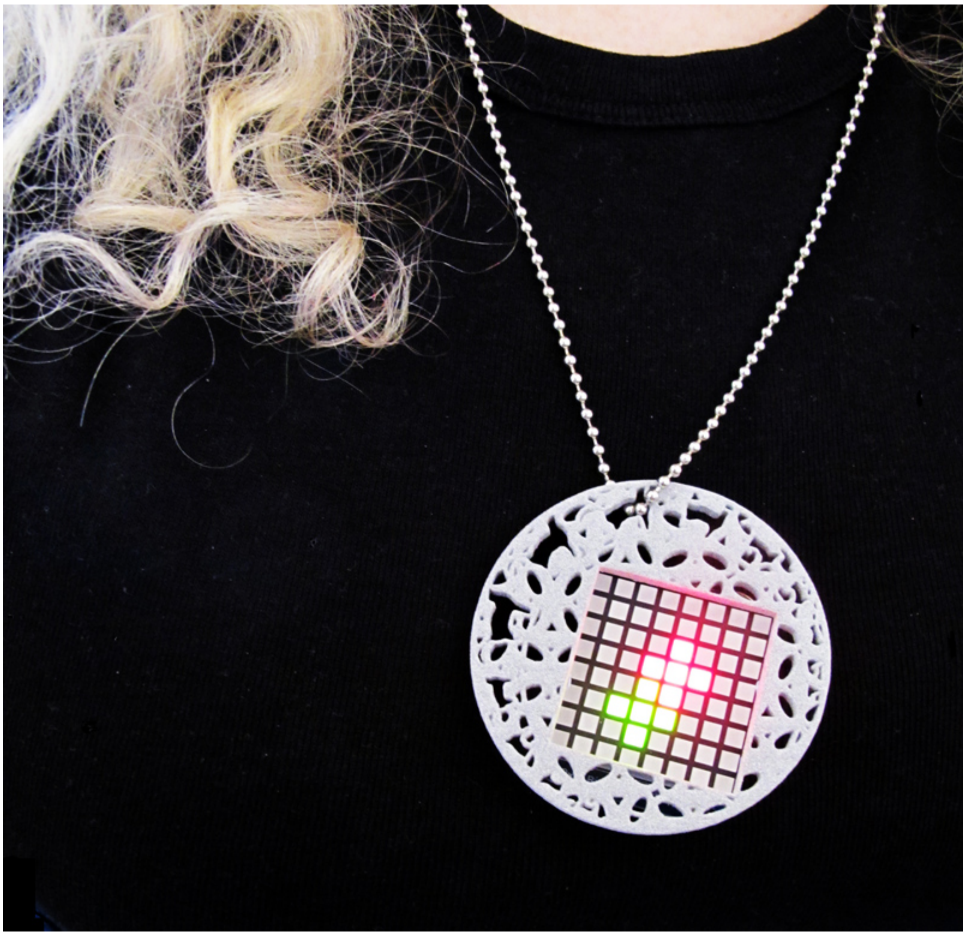


FIGURE 4.19: *EEG Visualising Pendant* with an example of a bespoke, laser sintered alumide frame (2013)

In this section I have given a brief introduction to electroencephalography and discussed my motivations for investigating this technology for use in wearables for nonverbal communication. I have outlined my processes for the design and build through four iterative versions of the *EEG Visualising Pendant*. I have also discussed the aesthetics around the pendant's design, for example the use of shapes and mapped light, also reasons for choosing certain colours to represent the EEG channels.

Conclusion

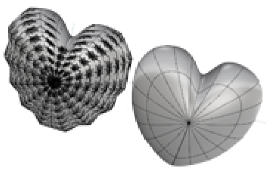
Through my practice I developed two key research prototypes, which led me to research ambient systems and responsive wearables embedded in everyday garments and accessories. Drawing on my use of the *EEG Visualising Pendant* I have gained insight into how a viable emotive wearable could be applied to research into nonverbal communication. I have built on this by using the pendant as an example of how an emotive wearable could be used in focus groups and field tests.

My iterative production process, 'Identifying, Concluding, and Updating', which I have developed specifically to facilitate progress in developing complex multidisciplinary wearables prototypes has been useful for prompting actions and decisions which have aided the progression of my practice. It has assisted me in keeping on top of issues related to the development of my research prototypes that require the exploration of new materials and designs, bespoke electronic components and code plus their libraries, to function together. However, to ensure that such a method benefits the prototype it requires effort from the user to keep track of changes and so cannot be viewed as an quick-fix solution. When developing complex projects one must have use a good method of version control, this is essential when programming for projects that require much testing and updating. Unless tweaks, additions and deletions are documented via versioning then it is very easy to lose previous solutions, fixes and discoveries.

The next chapter, *Chapter 5: Literature Review*, investigates themes that relate and support my research.

Chapter 5

Literature review



The literature review investigates themes that have had a significant impact on my research practice around emotive wearables. Accordingly, this review reflects, critiques, and underpins it. The review has enabled me to identify the gaps in the fields I have addressed to illustrate my contribution to knowledge. These are:

- In terms of context-awareness, responsive wearables fills a gap in which bespoke and personalised artefacts communicate beyond the wearer and device's screen using nonverbal cues in the form of visualising data outwards to also communicate with passing observers (p. 122).
- Issues that concern head-mounted displays and other headsets such as *Google Glass* connect with those I have found that surround the usage of the EEG headsets I have employed in my practice and studies (p. 172), which have led me to encounter a gap in the exploration of personalisation and the bespoke in order to make these functional and cumbersome devices more attractive and comfortable to confront issues around wearability (p. 184).
- Through the investigation of Erving Goffman's theory around 'fronts' I was compelled to explore a gap in the field in emotive wearables, in which these devices have the ability to record and play back physiological data for the purpose of manipulating or changing the outcome of a situation or its perspective to others, which I have termed emotive engineering (p. 147).

The review is divided into five themes, which are named as: evolving wearables, e-textiles: projects, integration and challenges, mobile technology for communication, human communication and emotional computing, and privacy and wearables.

In section one, *Evolving wearables*, examples of wearables from the late 1990s at MIT are discussed; in section two, *E-textiles projects and challenges*, looks at how designers, academics, and industry have been investigating, debating, and documenting e-textiles; section three, *Mobile technology for communication*, gives examples of mobile technologies used in wearables; section four, *Communication and emotions*, looks at the various forms of human communication that have been important to my research; and the fifth and final section is *Privacy and wearables*, which looks at data ownership.

Theme one: Evolving wearables

The first section, *Evolving wearables*, focusses on examples of wearables from the late 1990s at MIT, which were initially heavy and cumbersome and discusses the work of its students, Thad Starner and Steve Mann, who helped push forward the progress of wearables via their own practice. It looks at an evolving cyborgian aesthetic and contrasts this with Donna Haraway's feminist cyborg. This moves on to recognising the need for design to be incorporated into these systems, and how the void between engineers and designers needed to be bridged in order to move forward with design challenges, which is emphasised by Nicholas Negroponte. This leads to highlighting some of the early approaches to design that were discussed at ISWC in the late 1990s from researchers such as Gemperle et al.

Form factors: A heavy past

The idealised image of carrying a portable computer that could fit neatly into clothing defied the experience of graduate students and researchers in the 1990s who were carrying obtrusive and complex devices, such as tethered desktop computers. Dvorak (Dvorak, 2007, p. 10) reasons that the construction of these devices was focussed on pushing the envelope of technology and that ease of use and comfort was a low priority. This notion was confirmed by wearables pioneer, Steve Mann, who is often referred to as "the father of wearable computing" (Schofield, 2012). Mann (Mann, 1997) presented some of his findings on wearables at the first ISWC in 1997, which he described as evolving from "an awkward and cumbersome burden", in the late 1970s and 1980s, to smaller systems he described as being unobtrusive to become "a seamless extension of the body and mind" (Figure 5.1, p. 122). Moreover Mann's descriptions of his multimodal systems are of interest to my practice as they suggest they defined new forms of social interaction through enhanced abilities for self-expression.

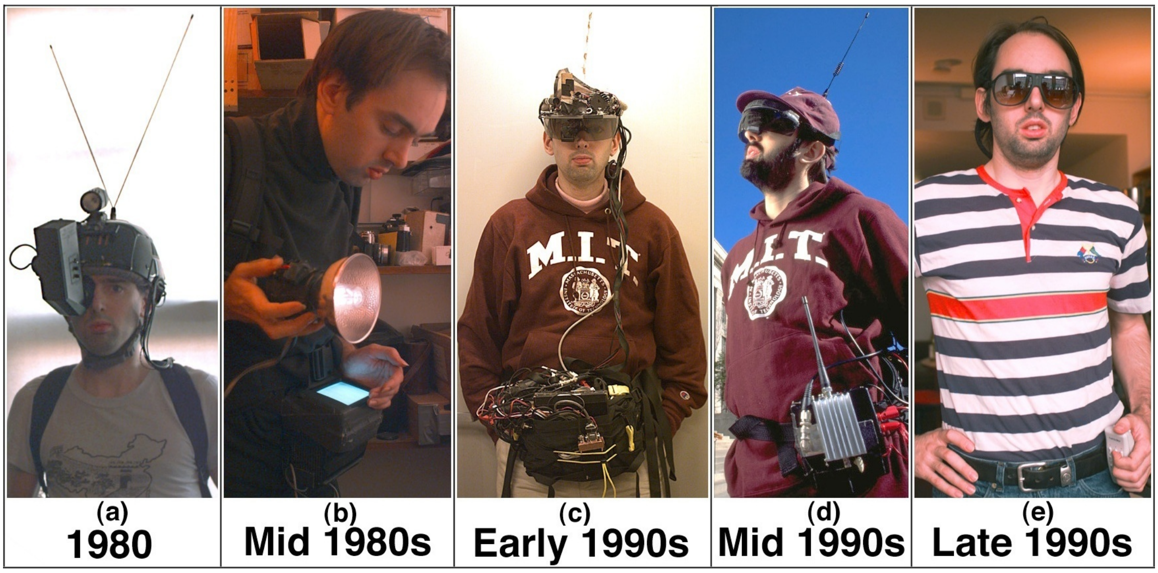


FIGURE 5.1: Steve Mann: Evolution of *Wearcomp* (CC BY-SA 3.0) (2004)

However, these wearables were designed with virtually no regard for their aesthetics. The heavy hardware components were not chosen for their looks, they were systems put together to realise an aim. Rather than look attractive or embed seamlessly into a garment, this resulted in electronics encapsulated in heavy backpacks and mounted on the body in rigid forms. The lack of bespoke components and hardware available was a limiting factor in what wearables students could build. This resulted in wearables being driven by extended desktop PCs and brought with it the issue of powering and portability. Dvorak (Dvorak, 2007, p. 12) highlights the *Lizzy*, developed in 1993 by Doug Platt and Thad Starner at MIT Media Lab, was one of the most widely adopted and adapted kits for wearables during these early years.

The Lizzy was intended as a general-purpose wearable computing system that provided the ability to investigate and test context-aware applications. Context-aware or awareness is used to describe when a wearable or mobile computer is aware of its user's state and surroundings, and then modifies its behaviour accordingly (Krause et al., 2003). Context types have been defined in multiple instances, for example, Schilit and Theimer first described "context as location, identities of nearby people and objects" (Schilit and Theimer, 1994, cited in Dey et al. (2001)). However, Dey et al.'s definition, which includes physical location, social environment, and emotional state (Dey et al., 1998), is closer to my practice artefacts and usage in responsive and emotive wearables. Starner's doctoral research hypothesised that wearables would be able to sense user context and " 'see' as the user sees and 'hear' as the user hears, provide a unique 'first-person' viewpoint of the user's environment" and stressed the importance of context in communication and interface in the areas such as physical environment, time of day, and mental state in order to process and convey critical information to and from a device (Starner, 1999, p. 24). This research connects to my research and practice, as it looks to a future where artefacts are used to sense and react to physical and environmental factors, although my practice fills a gap in which bespoke and personalised artefacts communicate beyond the wearer and device's screen to communicate not just with the user, but also to others via nonverbal cues in the form of visualising data outwards, rather than just towards the user.

Recognising the need for 'design' in systems design

Although size and weight were perhaps a trade-off for computational power, the advantages of making design tweaks to change perceptions so a device was thought to be aesthetically pleasing soon became apparent. Since 1993, MIT Wearable Computing Project students had been incorporating wearable computing into their everyday lives, engaging in "a living experiment". An insight on this, from Thad Starner, recorded painting the usually white Lizzy 'Private Eye', a monocular visual readout device for heads-up displays[27], black. In doing this, to be less obtrusive and match his clothing, it affected how the wearable was perceived by others. He recalled how a fellow Media Lab student had surprised him by exclaiming, "Hey Thad, I see you got a new display! I bet this one is much better, with it being smaller and looking nicer" (Starner, T. et al., 1999). This was a pivotal moment, as this was a conversation between engineers, rather than designers, whose goal had been to develop hardware rather than an artefact's design properties. The impact of the change to one component of the device, and reaction through an informal exchange, was an epiphany to Starner, which led to him recognising a missing link between hardware and design.

Multi-component prototype systems such as the Lizzy are large compared to recent innovations, which are much smaller and compact heads-up displays. An example is *Google Glass*, an *OHMD* (Optical Head Mounted Display), described in detail on p. 127, which dispensed with the need for a keyboard or interface such as a Twiddler, a one-handed chorded keyboard, made by HandyKey in 1992 [28]. Starner's knowledge and experience of working with the design of heads-up systems led him to become the Technical Lead on *Google Glass* (Georgia Tech, 2017). It was first made available to developers through

[27] The Private Eye was created in 1989 by a company called Reflection Technology in Massachusetts, US.
[28] http://twiddler.tekgear.com

its Explorer early adopter programme in the US in April 2013 for $1,500, and then to the public in May 2014. In January 2015, it was announced by Google that it would stop producing the *Google Glass* prototype, but would move on to the next phase of the project. The device was beleaguered by controversy regarding privacy, ethics, and security issues, which led to it being banned in various facilities and public places. *Google Glass* was also criticised for being expensive and out of the budgets of many people (Google, 2013). The concerns that have surrounded this device are of interest to my research and practice, as although my research prototypes do not raise issues around the recording of video and photographs, they may cause concern due to their recording and visualising of physiological data.

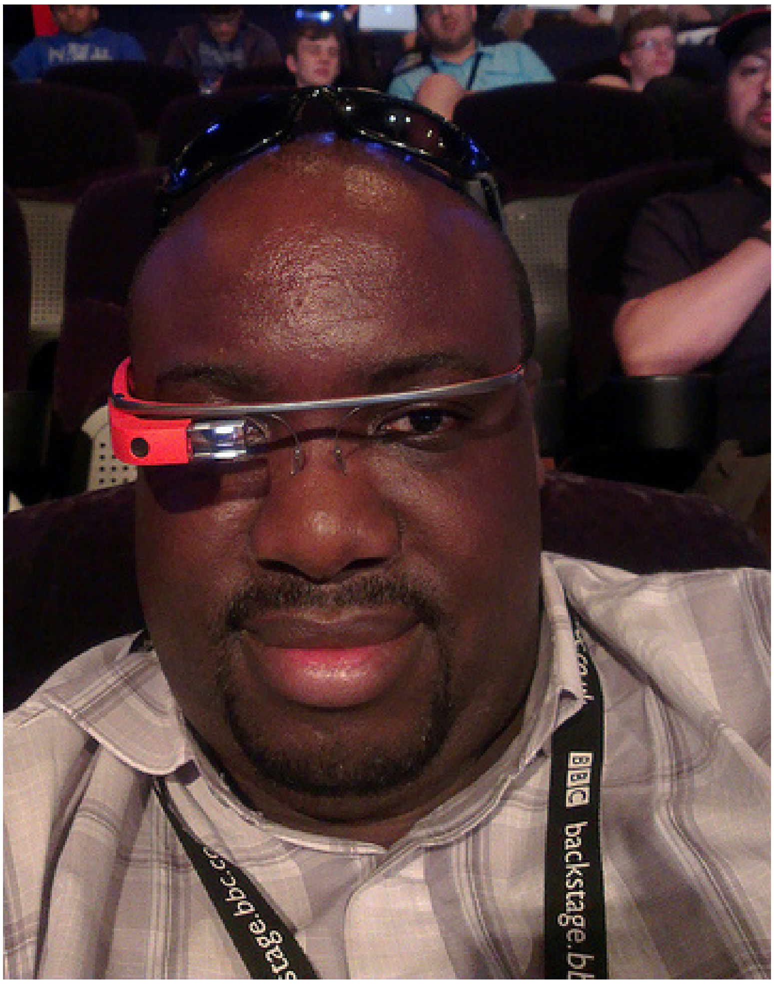


FIGURE 5.2: *Google Glass* (2013)

Function and form

In 1996, Starner and Mann's wearables group at MIT's Media Lab comprised a dozen undergraduates and graduates and was self-funded. They became known as the 'Borg Lab', a reference to the TV series *Star Trek's* hive mind collective of beings (Ryan, 2014, p. 70). A cyborgian aesthetic prevailed from within the group, this is illustrated at the time by an iconic photograph[29] of some of the Borg Lab members, all male, wearing various heads-up display configurations and boxy hardware on their backs and tied to their hips. The group included Steve Mann on one end of the group wearing an iteration of his WearComp system and Thad Starner at the other wearing a Lizzy system and holding a Twiddler controller. The members of the group are all standing upright, their bodies extended via large chunks of technology; they almost look folksy, like a group of cyborgian misfits or superheroes. The image is brash, nerdy, and clunky; it therefore clashes with feminist theorist Donna Haraway's (Haraway, 1990, pp. 149–181) more sophisticatedly drawn, but still raw and anarchic, feminist cyborg, detailed in her essay *A Cyborg Manifesto*.

The cyborg aesthetic is still relevant today as the wearing of technology on the head or face in public, as is the case with heads-up displays or EEG headsets, allows the wearer to publicly endorse technology as part of their persona. The MIT Borg's defiant pose says they are comfortable and proud of their technology, whereas Donna Haraway in her manifesto worries about women rejecting technology and encourages feminists to look beyond naturalist ideals of the time which might cause them to reject technology. This notion connects to my practice as I am exploring whether women's interest in using technology, such as emotive wearables, is bolstered by personalisation and the bespoke.

With the advent of cyborgian-looking wearables brings the risk of not fitting in with perceived notions of normal or acceptable attire. It's not unfeasible to imagine how objections could develop and be directed at those who wear obvious or unconventional-looking wearables, or indeed identify as cyborgs, especially bearing in mind the critical reception of *Google Glass* (p. 123). As we have seen with reactions in the recent history of wearables to *Google Glass*, inciting derogatory comments such as 'Glassholes' and the alleged assault on Steve Mann when he was questioned about his head-mounted *Eyetap* in a Paris restaurant (Bartkewicz, 2012), the public is perhaps not yet ready to embrace a cyborgian aesthetic and may feel intimidated by it. This connects to how one might identify oneself when wearing wearables, which I explore further in my user studies which describe the 'awkward factor' of wearing an EEG headset in public, which I state in my contributions to knowledge (p. 16).

[29]View *SafetyNet* image http://n1nlf-1.eecg.toronto.edu/personaltechnologies/fig8.gif (Mann, 1996)

When Steve Mann presented at the first ISWC in 1997, he gave an historical account of his *Wearcomp* and *Wearcam* inventions and laid out his decision to follow technology for wearables, rather than fashion:

> "This early effort pointed toward a later effort of the mid 1980s when I was to make an attempt at making wearable computing fashionable, and be represented through two modeling agencies. By 1985, I had established a following in certain parts of the fashion industry. However, after various fashion shows and the like, I decided that function was more important than form, and changed my focus from design back to art and science." (Mann, 1997)

Despite Mann not allowing his work to be compromised or driven by fashion, images of his eyewear shrinking and compacting to the stage where it was almost able to be embedded into a pair of sunglasses frames (p. 121), could easily be mistaken for having a styled aesthetic or fashionable look to them as the boundaries between fashion and functionality perhaps begin to blur. His development of technology for heads-up displays also helped pave the way for future wearables such as *Google Glass*, but also his fascination with privacy and surveillance brought forth many questions around the ethics of recording, storing, and broadcasting data, which I discuss further in this chapter in the section on privacy (p. 152).

Bridging the void between engineers and designers

The gap between technology and fashion design was glaring in the early days of wearables, Ryan (Ryan, 2014, p. 74) frames the confrontation at MIT Media Lab in the 1990s as "between the 'serious' pursuit of cybernetics-derived and machine-based *augmented reality*, a world of looking and working, and the 'frivolous' world of fashion, a spectacle of glamour and dressing, and the experience of being looked at". A shift in attitude towards fashion and uses of technology was required to make wearables pertinent and attractive to designers, who might then present it in an aesthetic form to those outside academia. Relevant to this and the design of wearables, Ryan cites (p. 75) a 1995 *Wired* magazine article, in which the then director of the MIT Media Lab, Nicholas Negroponte, reveals the significance of melding technology with the materials and garments that we wear on our bodies and thrust his thoughts into the view of engineers and designers.

Negroponte (Negroponte and Gershenfeld, 1995) gave examples that provided a provocation to those who had not yet grasped how important this fusion was going to be. His vision of the future was, "Your shoe computer can talk to a wrist display and keyboard and heads-up glasses. Activating your body means that everything you touch is potentially digital." He was adamant that the path that needed to be taken towards making wearables accessible was through considering how they could be embedded in fashionable items that we might wear on a daily basis. His vision was important because he could see a future for wearables in mass consumption. Conversely, he warned that they so far lacked inoperability and would "be useless if you have to walk around looking like the back of your desk" (Negroponte and Gershenfeld, 1995).

Negroponte did not forget to include his prominent students, Steve Mann and Thad Starner, addressing them as the "Cyborgs that are already here", he discussed the uncanny experience of teaching the students who were using their technologically extended bodies to take notes, film lectures and send media backwards and forwards. He also predicted that the "digital headdress", referring to their heads-up displays, would become more common. He compared the rise of wearables to behavioural changes that other technologies have influenced, such as the mobile web revolutionising publishing and multimedia CD-ROMs allowing us to view media in many different formats.

Ryan suggested that Negroponte's article was prophetic in its timing and may have reflected discussion at MIT Media Lab at that time, as during the same year students from the Media Lab were involved in a breakthrough collaboration with students and the faculty of the Parisian design school, Créapole École de Creation, culminating in a runway show at the Pompidou Centre in Paris, in 1997. Ryan (p. 75) documents that such was the interest in the merging of garments and tech, that another show of wearable-computers-as-fashion-design was included in conjunction with the first ISWC conference in 1997. Titled *Beauty and the Bits*, it involved MIT students, such as Thad Starner, who was also an ISWC co-founder, and Maggie Orth, whose work looked at the then emerging new area of e-textiles, which forged routes into aesthetics, garment design, interfaces, and conductive embroidery (Post and Orth, 1997, pp. 1–8).

The fall and rise of the 'digital headdress'

Heads-up displays failed to take off in the way Negroponte predicted, due to factors such as size, weight and discomfort. Almost twenty years after Negroponte's prediction, there was great interest in the aforementioned *Google Glass*. However, as discussed earlier the controversies regarding the privacy concerns connected with the device and issues such as price, availability, and battery life may have resulted in the project being put on the back-burner before it could make it to mainstream consumers. Thus the *Explorer* edition of *Google Glass* that was designed for the masses was halted in 2015 before long-term use by consumers could be observed, but the device has demonstrated that with the shrinking of technology, the opportunity to design smaller, lighter, and more discrete circuits and ergonomic enclosures has arisen.

In the summer of 2017 it was revealed that although *Google Glass* had not been a success with the public, over the two years since the design of the consumer version had stopped, the device had found a usefulness in other areas, such as speeding up the quality checking process in industry and entering medical data. Levy (Levy, 2017) revealed in a *Wired* magazine article that Google's parent company, Alphabet, had commissioned a version for workplace use named *Glass Enterprise Edition*. The new version reportedly had improved on some of the Explorer's bugbears, that battery life has been improved, a faster processor and more reliable WiFi and rigorous security standards, and in terms of improving privacy, a green light illuminates when video recording is in use. On why this version has been successful in private settings where it failed in public, Levy said that "because in the enterprise world, *Google Glass* is not an outgrowth of the intrusive and distracting smartphone, but a tool for getting work done and nothing else". Naughton (Naughton, 2017) reflected that the unexpected repurposing and success of *Google Glass* is one of a long line of initial technology failures that have become successful through a side-project or unintended usage success. Issues around headsets such as *Google Glass* connect with those I have found that surround the usage of EEG headsets used in my practice. Finding a gap in the discussion of personalisation and the bespoke in order to make them more attractive, I have raised this in my user studies. I reveal feedback on the experience of wearing them together in my contribution to knowledge on p. 184.

Dynamic design for wearables

A contrasting approach from the early MIT Media Lab examples that I describe in the first paragraphs of this chapter, which began to scrutinise the component parts of the design of a wearable, was revealed at the second ISWC in 1998. Gemperle et al. (Gemperle et al., 1998) explored the concept of *'dynamic wearability'*, or wearables that work in synchronicity with the body, through design research. They understood at that time that trends around computing were consistent with a societal and an historical momentum to evolve a technology into something more portable, mobile, and wearable than simply shrinking hardware into 'mini PCs'. This research is relevant to my practice as it emphasises the importance of testing differing variables or component parts to create bespoke wearables for the individual, for example including diversity in body shape and size. It has impacted on my thoughts in areas such as sizing, proxemics, and placement on the body. I discuss placement on the body in my user studies methods (p. 163), and also in my results and discussion and contribution to knowledge (p. 196).

Gemperle et al.'s investigation produced a thirteen-point set of design guidelines, which took into consideration issues such as the placement and affectations of the embodiment of wearables. The aim being to "thoroughly reflect design guidelines and define the ideal three-dimensional envelope where forms can exist on the human body in motion". Applying the first six of their guidelines[30], as the remaining seven[31] were not easily generalisable and were dependent on specific design problems, they set about creating a set of forms to attach to the body and then test them to find the most unobtrusive and suitable areas to wear them. This included ensuring the forms adhered to a 'humanistic form language' to ensure a comfortable and stable fit to the body, which included choosing subjects who were diverse in body shape and size. The design of the forms also had to bear in mind that they might be required to contain other materials that were not confined to electronic components, but also food or water.

At ISWC 2017, Zeagler updated these guidelines with further and emerging examples of on-body location technologies such as proxemics and physiological sensors (Zeagler, 2017, pp. 150–157), but there were still gaps regarding areas that could be investigated and he would extend these principles further with the current requirements for wearables.

[30]Gemperle et al.'s first six guidelines, listed in an order of simple to complex were: Placement (where on the body it should go); 2. Form Language (defining the shape); 3. Human Movement (consider the dynamic structure); 4. Proxemics (human perception of space); 5. Sizing (for body size diversity); and 6. Attachment (fixing forms to the body) (Gemperle et al., 1998).

[31]Gemperle et al.'s second group of seven guidelines, listed were: 7. Containment (considering what's inside the form); 8. Weight (as its spread across the human body); 9. Accessibility (physical access to the forms); 10. Sensory Interaction (for passive or active input); 11. Thermal (issues of heat next to the body); 12. Aesthetics (perceptual appropriateness); and 13. Long-term Use (effects on the body and mind) (Gemperle et al., 1998)

These would include guidelines on the suitability of various materials for embedding and enclosing electronics and for carrying objects and their placement on the body, including how such forms would be created, for example the use of fused filament 3D printing, selective laser sintering (SLS), laser cutting, and injection moulding. Additionally, the guidelines would cover their manufacture if it is decided to develop them past research prototypes, for example costings, shipping, sales, and then post-sales issues such as maintenance.

Whilst Gemperle et al.'s guidelines make points about design issues pertaining to the wearability of the artefact, Dvorak (Dvorak, 2007, pp. 81–82) in contrast draws attention to the usability needs of the consumer and what could hinder them from being able to use a device for its intended purpose via what he calls 'Operational inertia'. He prompts us to consider user experiences of everyday technology including, for example, inconvenient, annoying or time-wasting functionality. Such devices provide the user with an underwhelming experience of the primary task that the technology was set to deliver. This could be a wearable that becomes uncomfortable to wear over time. Examples from my own experiences include EEG headsets that rub or pinch and clip-on fitness trackers that jab into the body when sitting down.

This section has explored how form and design has evolved for wearables through the early days of MIT Media Lab and its prominent students, which has led me to contrast MIT's Borg wearables group with Donna Haraway's feminist cyborg. Next this section moves on to recognising how the void between engineers and designers needed to be bridged in order to move forward with design challenges, which was emphasised by Nicholas Negroponte. I discuss gaps in the field that my research fills in terms of methods of communication, personalisation and guidelines for wearables. The section ends by highlighting some of the early approaches to design that were discussed at ISWC in the late 1990s from researchers such as Gemperle et al., which leads me in the next section to discuss e-textiles projects and their challenges.

Theme two: E–textiles projects and challenges

As a continuation from my investigations into wearables design in the previous paragraphs, this section considers more contemporary projects and their challenges and limitations, such as sustainability and the problems created by the lack of bespoke hardware that is suitable for garments. Also discussed is E-Fibre, an e-textiles project, which brought together practitioners, artists and industry in 2014, which led me to investigate literature concerning projects including CuteCircuit's designs and examples of Philips' SKIN Probes project. Philips' projects are of particular interest as they concern using sensors to sample physiological data. Looking beyond prototyping, due to manufacturing limitations and issues such as sustainability, garments embedded with technology are often bespoke, or have short or limited runs. CuteCircuit, interviewed by Sandy Black in 2010, discuss integrating technology into garments and sustainability. They warn of polluting the world with discarded wearables and making positive decisions for creating washable and recyclable wearable designs, such as the *Twirkle* top (Black, 2015, pp. 105–120). Launched in 2010, the garment reacted to the wearer's movements by illuminating micro-LEDs. The rechargeable by computer USB electronics were patented and developed to be washable at 30°C (CuteCircuit, 2010*c*).

CuteCircuit have gone on to design fashion as spectacle, such as creating outfits for celebrities such as the American singer Katy Perry, who commissioned CuteCircuit to create a couture gown in silk chiffon containing over 3000 full colour MicroLEDs for New York's Met Costume Institute Gala, a yearly event in the US fashion calendar (CuteCircuit, 2010*a*). The composition of the dress is not detailed in CuteCircuit's report to discern if/how the *Met Gala Dress* is washable or if any of the components are removable for recycling. However, their website states that they have a "designed for sustainability" product cycle, which includes "recycling and repurposing" though it is not stated which garments this covers (CuteCircuit, 2017).

FIGURE 5.3: Ryan Genz and Francesca Rosella of CuteCircuit, with *Galaxy Dress* slide, at E-Fibre Making Connection workshop, C4CC, London (2014)

The E–fibre project

The *Twirkle* top and other e-textiles garments such as the *Galaxy Dress* (Figure 5.3, p. 132) were presented by CuteCircuit at *E-fibre: From Invention to Consumption: electronic textiles*, an AHRC (The Arts and Humanities Research Council) funded project set up to conduct research and to build a network around electronic textiles[32]. I joined the community by giving a presentation on my *Baroesque Barometric Skirt*.

Relevant to my practice was Clive van Heerden's[33] presentation on Philips Design's research into wearables. He discussed sensor driven textiles such as the *Bubelle Dress* (2006), created under the Philips Design SKIN Probes programme, which explored human skin's reactions to stimulus (Figure 5.4, p. 134). The dress, an early example of an emotive wearable, resembled a bell-shaped transparent pupae of light and colour and was said to "'digitize' physical responses of the human skin and display them in spectacular, fascialized form" (Ryan, 2014, p. 121). The dress was made of two layers, one layer equipped with heart rate and galvanic skin response (GSR) sensors, from which data was gathered to

[32]The first of three workshops, *Making Connection*, was held at the Centre for Creative Collaboration (C4CC) in Kings Cross, London, UK, in May 2014. The workshop built on the findings of CAST (Creative and Social Technologies) exploring how wearables are changing how we understand ourselves and others and featured presentations from prominent practitioners and technologists. It mixed presentations and discussion on industry led research with research prototyping and e-textiles that had gone into production with textile art projects.

[33]www:vhmdesignfutures.com

simulate a blush skin colouration in response to emotion or anxiety projected from LEDs onto the outer layer of the garment.

The *Bubelle Dress'* construction was of interest to investigations I had made into e-textiles for the *Baroesque Barometric Skirt*. I had experimented with a two-layer construction of e-textiles, which had three purposes: to allow for the skirt's electronics to be removed so the garment could be washed, shield the skin from electronics and to project and dissipate the coloured light which was a response to personal and environmental sensor data. Considering the delicate nature of the *Bubelle Dress*, it is unlikely that its construction would allow for it to be washed.

The SKIN Probes collection and collaboration between Nancy Tilbury (who went on to launch wearables company Studio XO), Lucy McRae (who now describes herself as a "body architect") and Rachel Wingfield (who founded responsive environmental laboratory, Loop.pH) contrasted skin surfaces and light-emitting biometric sensor technology, but the motives behind Philips' promotion of the SKIN Probes pieces Ryan describes as "pure prototypes, impractical and photogenic, garnering extensive media coverage, which was their main purpose" (p. 119). However, the *Bubelle Dress* and other SKIN Probes pieces such as *Frisson* (2006) are performative pieces, perfect for social media, websites and coffee table books — what Ryan describes as "the perfect internet spectacle". *Frisson* is a catsuit with a copper wire construction that imitates goosebumps or horripilation (which the *Taiknam Hat* (2007) also seeks to reproduce using feathers (p. 151), whose LEDs are illuminated by air passing over its sensors, such as from someone blowing over them. It was featured on the cover of Sabine Seymour's wearables book *Fashionable Technology*.

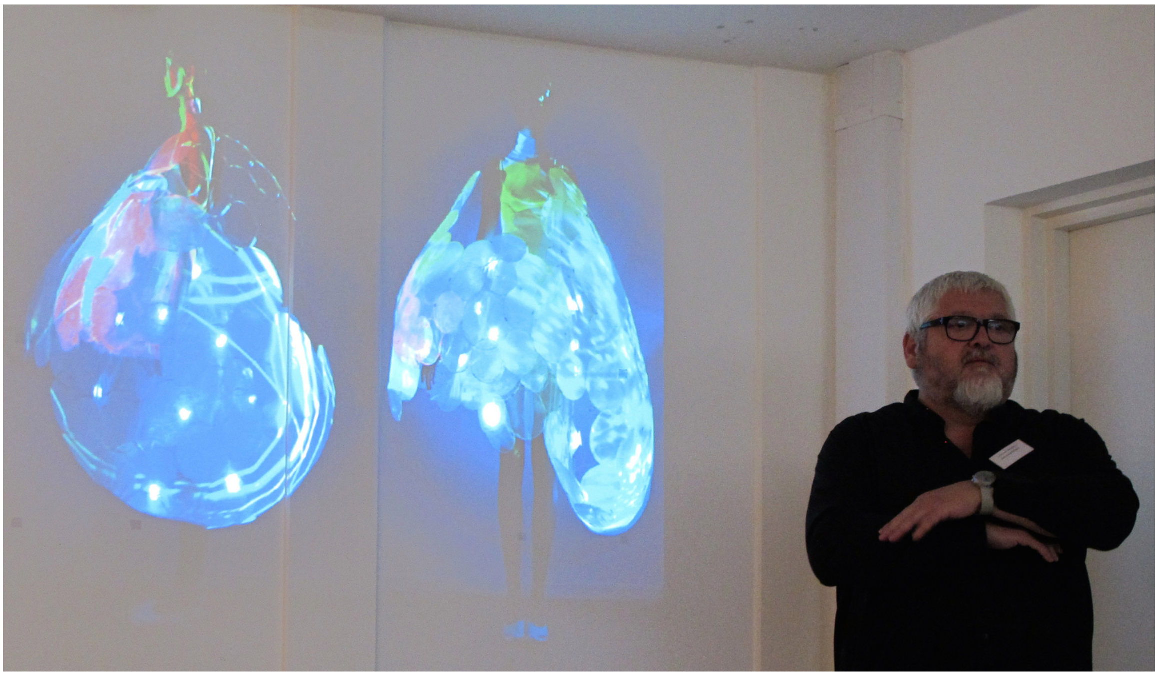


FIGURE 5.4: Clive van Heerden discussing the *Bubelle Dress* at E-Fibre Making Connection workshop, C4CC, London (2014)

The *E-Fibre* project published a report that contained the many themes and summary details that emerged from the workshops. It listed outcomes such as the recognition that e-textiles lack a presence in the 'public imaginary', the acknowledgement that markets for e-textiles tend to be restricted (such as defence, health, and high-fashion), and the wider acceptance of the possibilities for and problems with e-textiles. From a community point of view, the project had created a functioning network and created a website and blog (E-Fibre, 2014), which was a relevant source of information for e-textiles areas of my practice.

Moving from an e-textiles community to two practitioners, the experiences of the designer and technologist partnership between Elizabeth Bigger and Luis Fraguada is relevant to the discussion of e-textiles, from the perspective of sourcing and integrating electronics. *Programmable Plaid: The Search For Seamless Integration In Fashion And Technology*, exhibited at the ISWC 2016 Design Exhibition (Figure 5.5, p. 136), discusses the lack of purpose-made electronic components in textiles such as lightweight batteries and in particular issues around textile light-emitting capabilities. It highlights the problem that off-the-shelf electronic components are not designed for embedding in textiles and are unsuitable to be worn on a daily basis. Bigger and Fraguada argue that this has led to the emergence of an unwanted aesthetic of pixelated digital textiles. They have addressed this by developing a new tartan pattern and fabrication technique, using fibre optic filament to add programmable light-emitting properties to textiles. It mixes wool fibres and fibre optic threads in both warp and weft directions. Their methods led them to evolve a traditional craft textile, tartan, with the use of embedded technology. This novel approach to a light-emitting textile, is controlled by a mobile device camera and software app, fashioned into a dress for the exhibition (Bigger and Fraguada, 2016, pp. 464–469). This research relates to my experimentation with fibre optic filament in constructing the *ThinkerBelle EEG Amplifying Dress* (p. 210). I have found a drawback to using fibre optic filament to be that low levels of illumination generated results in the garment's data visualising properties only becoming significantly visible in dark conditions.

Whilst the situation with electronics components is improving all the time, it is still difficult to embed many types of electronic components into clothing as, for example, they do not wash well. This impacts on the designers of wearables because although ideas and prototypes that have commercial appeal are possible to realise, they do not transform into marketable goods well enough for them to be easily used by potential customers.

FIGURE 5.5: Elizabeth Bigger and Luis Fraguada's *Programmable Plaid* dress at the ISWC Design Exhibition, 2016, Heidelberg, Germany (2016)

This section began by looking at e-textiles and garments that have approached issues of sustainability. It then moved on to describe how designers, academics and industry were brought together by the E-Fibre project and how this has increased awareness of e-textiles research, but also the challenges it faces. Clive van Heerden's presentation on Philips SKIN Probes, led me to examine the literature on their work in detail, as it relates to the design of early emotive wearables, but also because it looks at the design and presentation of such garments, which continues from investigations in the previous section. In the next section, I discuss mobile technology that has been an enabler to wearables including smartphones and mobile technologies.

Theme three: Mobile technology for communication

In examining the desirable functionality of current technology for wearables, I have explored some of the mobile technologies practitioners have investigated for wearables usage in social interaction and nonverbal communication. I consider the use of smartphones with wearables and discuss three examples of garments which blur the boundaries between mobiles, portables and wearables, followed by discussing two examples which use smartphones as a conduit for nonverbal communication. This section ends by looking at wireless communications technologies for wearables and in particular Bluetooth which I have used in many of my practice pieces.

Smartphones and wearables

In the past there has been confusion surrounding the definition or role of smartphones as wearables. This is because they were carried on the body, in pockets for instance, rather than worn on the body. However, smartphones are now considered 'portables', in the same category as personal music players, tablets and laptops as they have become mini-computers and communications devices. Moreover, they are often used as the engines that can process data from wearables, due to their increasingly large memory, data processing power and online and data sharing access. They have become useful for doing the processing work of wearables that have less computing power, due to physical size requirements, which restrict them from being able to process their own data. An example of this in my practice has been experimenting with *near-field communication* (NFC) as a trigger for my smartphone to carry out tasks related to nonverbal communication.

Smartwatches illustrate an example where convenience of access to smartphone data and alerts has resulted in a market for watch form factor wearables with small viewing screens to see data. The smaller screen is also appealing because it gives the wearer access to information and alerts discretely, rather than them having to take out their phone to view them. This could be of value in instances where gathering physiological data for medical care is necessary. For example, a study by Årsand et al., found that it was quicker to enter blood glucose measurements into a Diabetes Diary app on a Pebble smartwatch than finding and entering it on a smartphone, which was helpful to diabetes patients (Årsand et al., 2015, pp. 556–563).

CuteCircuit took the idea of a smartphone as a wearable a step further by blurring the boundaries of portables and wearables with the *M-Dress* (2010). It was designed to solve an observed problem that phone calls are often missed because mobile phones can be awkward to carry. It was specifically aimed at women because their garments were perceived to be designed with small or no pockets in which a phone can be stored. The dress was a simple, form-fitting design which only required a SIM card to be inserted into the *M-Dress* to begin using its functionality. Arm gestures and gesture recognition software was used to control answering and ending calls. The phone element that was not immediately visible lent a covertness to the garment (CuteCircuit, 2010*b*).

The *M-Dress* was not the first vision of a mobile phone secreted into a garment. Whilst research prototyping, such as heads-up displays and affective wearables (p. 58), was going on in academia at MIT, over in Europe one particular company in the private sector was focussing on the development of specific industrial prototypes. In 1995, Philips Electronics, launched its *Vision of the Future* initiative to "propose ideas and solutions that will enhance people's lives" (Lambourne et al., 1997, cited in Ryan (2014), p. 112). The project used design methodologies and creative multidisciplinary workshops to identify user needs, make technology forecasts and develop strategies.

Following the *Vision of the Future* initiative, Philips published a book, *New Nomads: an exploration of wearable electronics by Philips*, in which a set of aspirational ideas and a collection of garments were laid out, emphasising how clothing would empower, save time and enhance the young, tech-inspired and trend-setting audience's work and leisure time. The book opened with a passionate standfirst: "The quest for power, comfort and freedom" (Philips Electronics, 2000, p. 4), by Stefano Marzano who was chief design officer and CEO of Philips Design at the time, which sounds like a battle cry for the right to wearables.

The first of the aspirational profiles, labelled *Perform: digital suits for professionals*, was a dark grey work suit, *Nomadic Working*, fitted with mobile phone technology in the form of an earpiece, a 'speech device' was embedded into a detachable 'button' on the inside of the jacket and a 'fabric keypad' that unfolded from the jacket's cuff, "providing overall physical control" of the devices embedded into the suit (Philips Electronics, 2000, p. 28). The Philips fabric keypad is similar to the embroidered capacitive keypad that featured as an interface on former MIT Media Lab's Maggie Orth et al.'s *Musical Jacket* in 1997, which was exhibited at the MIT Media Lab's "Wearable Computing Fashion Show", part of the first ISWC in 1997 (Orth et al., 1998, pp. 331–332).

Smartphone as an interface and engine

For wearables with very small or no screens, smartphone capacitive touch screens are useful to act as easily accessible interfaces. To give an example, graphical user interfaces for wearables can be designed to fit into a phone screen, using familiar icons and control metaphors, which help users navigate the controls, such as stop, start and pause. An example of a smartphone-controlled wearable is Elizabeth Bigger and Luis Fraguada's aforementioned *Programmable Plaid* research (p. 134), which uses a smartphone as an interface to control colour mapping of fibre optic filaments woven into the dress's fabric (Bigger and Fraguada (2016, pp. 464–469), see also Figure 5.5 (p. 136)). Using a smartphone to control the garment via Bluetooth wireless technology means the dress does not need to be tethered to a computer via a USB cable, which was how many wearables were controlled in the past and made movement difficult and cumbersome. Controlling the dress by a smartphone means the technology and process can be hidden, disguised or only revealed when necessary.

A responsive wearable that incorporates mobile phone usage to generate a form of nonverbal communication, using environmental conditions, is Ricardo O'Nascimento, Ebru Kurbak and Fabiana Shizue's *Taiknam Hat* (2007). The hat's large feathers, meant to reference elegant women's hats from periods of history, are animated according to changes in surrounding radio frequencies, to alert the wearer and those around of increasing levels of electromagnetic radiation pollution in the environment affecting humans and animals, which the designers of the garment call "electrosmog". The hat is controlled by a mobile phone, which initiates the sensing and movement of the feathers, emulating horripilation: the erection, self-display, and signalling via hairs or feathers in various species under irritation and stress (Ryan, 2009, pp. 114–116). The hat uses horripilation as a metaphor, in order to express the human body's supposed irritation towards electromagnetic radiation, although it's not clear on the project's website what the biological effects are and how measurements from the system relate to this. The hat is used to create a visual and tactile signage of the existence of this pollution for observers and is operated by a motor that is activated by a medium-wave detection system (Nascimento, 2007).

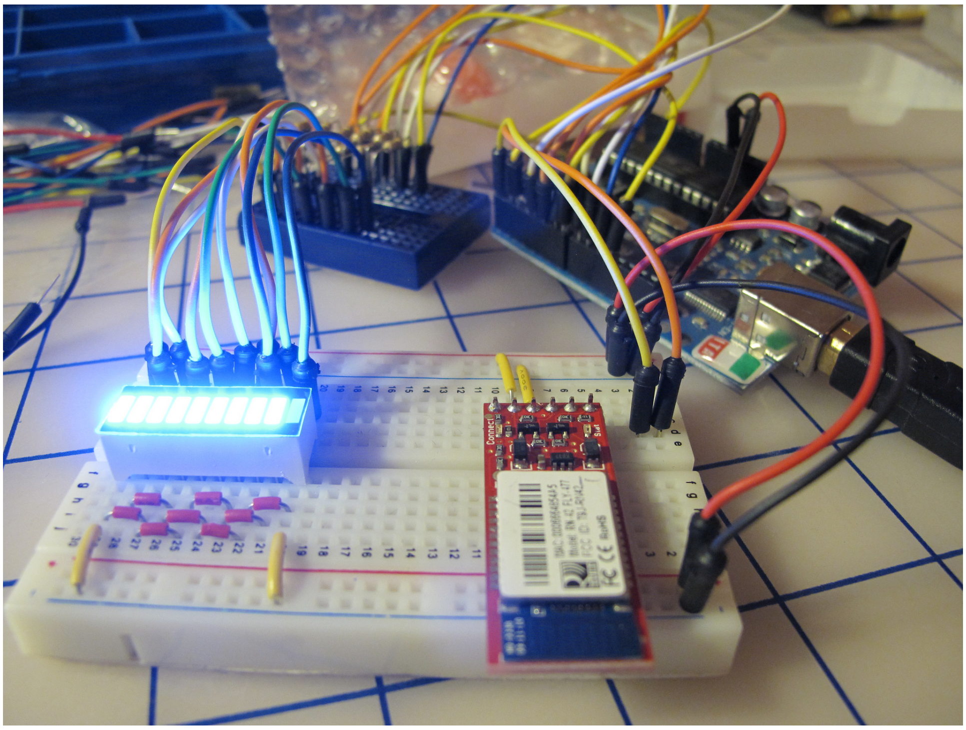


FIGURE 5.6: Breadboard experimentation to get a *BlueSMiRF Silver* Bluetooth dongle working with an Arduino microcontroller to receive and process EEG data (2012)

Data transfer technologies for wearables

Wireless communications technologies such as Bluetooth, *ZigBee*, and near-field communication (NFC) have become valuable for transferring data between wearable devices and smartphones for processing and vice versa. They have boosted the connectivity and transfer of data for many wearables, and have become valuable for designers and artists as well as commercial developers of smartwatches and sports devices. Bluetooth, an open standard for short-range radio frequency communication (Padgette et al., 2017), has also been used as a conduit for social interaction. For example, at ISWC 2011, Tri Do et al., showed via a new probabilistic relational model that they could infer different interaction types from the Bluetooth proximity data set, to reveal participants of groups and their social contexts (Do and Gatica-Perez, 2011, pp. 21–28). This contrasted with earlier uses of Bluetooth as a proximity sensor, such as in the context of measuring people flow, presented at Ubicomp in 2006 by O'Neill et al. (O'Neill et al., 2006, pp. 315–332). As Bluetooth is an enabler of my practice, for example with my EEG-driven wearables, as well as for breadboard prototyping and testing (Figure 5.6, p. 140), to discover the research on using Bluetooth as a sensor in social interaction was informative to my work.

CuteCircuit's *Hug Shirt* (2004), is an early example of a wearable that used Bluetooth combined with mobile phone technology. The garment was a Bluetooth-enabled hoodie, which when paired with a second shirt, could exchange nonverbal, emotive and spacial field data between a caller and a receiver via a mobile phone. It relates to my prototypes in that they also seek to convey nonverbal data that says something about the wearer to another person. The shirt, which can also be triggered by SMS message, delivers a hug to the receiver by applying pressure to areas of the body. The *Hug Shirt* utilises the instant nature of mobile communication technology over distance to deliver a physical and nonverbal communicated feeling of comfort and physicality that people miss when they are talking to loved ones over distance (Ryan, 2014, p. 176).

Bluetooth has been an important technology for my practice in terms of wireless connectivity for transferring data from sensors, though there is a limitation in terms of distance to consider. For example, the connectivity range between devices for Bluetooth 'Classic', which is used by NeuroSky MindWave Mobile headsets for my three practice EEG pieces and user studies, is a distance of up to 30 metres (Bluetooth low energy (BLE) is 15–30 metres). This compares with hundreds of metres for ZigBee technology, which is used for creating wireless personal area networks (Omre, 2010). Though distance is not such an issue if the data is being collected or sent to a nearby wearable, computer or smartphone. With this in mind, choice of wireless connectivity for specific devices needs to be carefully considered, for example if the wearer requires the freedom to physically move away from the device collecting data. An example of where this would be a consideration is with medical technology, where longer connectivity ranges would be beneficial to potential users, who are mobile.

Security is an issue to be aware of when using Bluetooth and users need to be vigilant and secure their devices using the strongest security mode available. This is because Bluetooth devices are susceptible to threats such as eavesdropping, message modification and man-in-the-middle attacks, to name a few. Also, improperly secured Bluetooth implementations can provide unauthorised access to sensitive information and access to devices and the systems and networks that they are connected to (Padgette et al., 2017).

In this section I looked at some of the mobile technologies used in wearables for social interaction and nonverbal communication. I discussed this via a number of wearables examples that use smartphones as engines, interfaces, to aid nonverbal communication and which blur the boundaries between garments and mobiles. The section closes by looking at mobile communications technologies for wearables and in particular the *affordances* of Bluetooth. In the next section I examine human communication and emotional computing.

Theme four: Communication and emotions

Through the development of my research and practice prototypes I have aimed to create new forms of nonverbal communication. I have mentioned some of the non-spoken cues which contribute to human communication in the opening to this thesis (p. 4). But to understand nonverbal communication further it has been necessary to investigate other forms and theories around human communication, which have in turn impacted on my research, influencing and directing methods of communication. Through my research and this thesis I have defined my own interpretation of nonverbal communication via the use of technology and in the form of wearables. I have achieved this by exploring methods to capture and visualise physiological data, which signal hidden aspects of the wearer, and also by inviting observers to interpret the data visualisations.

I begin with an introduction to nonverbal communication, looking at statements starting with Knapp and Harrison. Next I investigate some of the definitions of emotions, what they are and how moods are different by looking at early theories, such as James–Lange theory and Canon-Bard theory, which is a criticism of the aforementioned theory. I then look at Irving Goffman's writing on how, in social or professional situations, humans participate in a set of practices akin to performing. The section then looks at proxemics and how Edward Hall's theories get us to contemplate the social spaces we create.

Introduction to nonverbal communication

When communicating with individuals or groups, it is understood that we communicate verbally (overtly) via speech, or nonverbally (covertly) via certain signals, consciously or unconsciously. Verbal communication is shared and open, explicit, unambiguous and clear, whereas nonverbal communication is seen as hidden, implicit, covert, or unexplained, which is often not obvious and can be seen to be misleading (Eklund and Tenenbaum, 2014, p. 304). There exist various definitions of nonverbal communication, for example, Harper et al. (Harper et al., 1978, pp. 1–4) gave an overview of studies and methodologies spanning from relatively simple explanations to the complex, but there is no consensus of an exact definition in the field, due in part to a lack of agreement on the boundary between verbal and nonverbal, and the distinction between communicative or non-communicative behaviour. Harper et al. compared statements such as by Knapp (Knapp, 1972, pp. 57–71), who described it thus: "Nonverbal communication designates all those human responses which are not described as overtly manifested words (either spoken or written)", with similar but wider and more poetic approaches to the theories from Harrison, who expanded on the description of nonverbal communication as:

> "(...) a broad range of phenomena: everything from facial expression and gesture to fashion and status symbol, from dance and drama to music and mime, from flow of affect to flow of traffic, from the territoriality of animals to the protocol of diplomats, from extrasensory perception to analog computers, from the rhetoric of violence to the rhetoric of topless dancers." (Harrison, 1973, pp. 93–115)

Furthermore, Harper et al. presented opposing ideas of Wiener et al. (Wiener et al., 1972, pp. 185–214) who viewed nonverbal behaviour, which is communicative, as a subset of the larger domain of specifiable nonverbal acts. This contrasted with Barker and Collins (Barker and Collins, 1970, pp. 343–371), whose broad view of nonverbal communication, which included 18 forms from animal and insect to time, stated that there had been a tendency to use the term nonverbal communication synonymously with the term nonverbal behaviour. They went on to argue that nonverbal communication is much broader than nonverbal behaviour: "a room devoid of behaving, living things communicates atmosphere and function. Static clothing communicates the personality of the wearer".

Nonverbal communication, emotion and space

Exploring emotive wearables required investigating theories to explain the terms of 'emotion' and 'mood'. The word emotion is believed to have been in use since 1579 and the origin of the word is attributed to the French term 'emouvoir', meaning to 'stir up' and also from the Latin term 'emovēre', 'to remove, displace', and from 'movēre', 'to move' (Merriam-Webster Dictionary, 2017).

Various interpretations and explanations of emotions exist such as by Fox:

> "Emotions have been described as discrete and consistent responses to internal or external events that have a particular significance for the organism. Emotions are brief in duration and consist of a coordinated set of responses, which may include verbal, physiological, behavioural, and neural mechanisms." (Fox, 2008, pp. 16–17)

Emotion has been described as "one of the most central and pervasive aspects of human experience" (Ortony, 1990, p. 3) and is an area for which it is hard to find an agreed definition. For example, there were 92 definitions and nine sceptical statements listed in *A Categorized List of Emotion Definitions, with Suggestions for a Consensual Definition* (Kleinginna and Kleinginna, 1981).

The James–Lange theory is one of the earliest theories to consider the origin of emotions. Philosopher and psychologist William James and physician Carl Lange independently came up with similar theories to explain that emotion is not caused by perception, but by physiological arousal to an event, that results in an emotive response, such as fear. To give an example, this might happen if the heart starts to race and palms become sweaty in reaction to a potentially dangerous situation, signalling to the brain that one is experiencing fear. In 1884, William James described this experience in *What is Emotion?*: "the bodily changes follow directly the PERCEPTION of the exciting fact, and that our feeling of the same changes as they occur IS the emotion" (James, 1884, p. 190).

The James–Lange theory was heavily criticised by psychologist Walter Cannon and his doctoral student Philip Bard, who argued that different emotions, such as happiness, anger and fear, could have quite similar physiological responses such as increased heart rate and respiration, and so they questioned how the body could distinguish between which emotion was being experienced. Cannon and Bard went on to suggest another theory in response to the James–Lange theory, named the Cannon–Bard theory, in 1934. It suggested that emotion is cognitive and is enhanced by physiological reactions to cause a simultaneously cognitive and physiological reaction, so if one was in a terrifying situation, the mind and the body would recognise at once the need to run away (Parker, 2007, pp. 329–331).

Cannon's criticisms of the James–Lange theory are pertinent, as the apportioning of data to a specific emotion is an aspect that I have considered when constructing emotive wearable devices. Although in my own practice, I have been careful to point this out when using single sensors, such as heart rate or temperature in my work. In these cases, I ask for the viewer or wearer to consider using the exported physiological data or visualisation in an interpretive or subjective manner based on their knowledge of the person(s) they are interacting with.

Making use of the effects that emotions have on the physiology of the body could be useful. For example, if fear is triggering sweating, and intensifying heart rate and breathing, the rapid changes in physiology could be followed and identified using multiple sensors on the body as a kind of telemetry. This detection might prove useful for keeping tabs on and organising how those working in dangerous environments, such as fire fighters, police or military personnel, approach their work, or identify if they are getting into trouble. On a personal level, such technology could help people working in high-stress environments to track and identify stress triggers over a period of time. This would be an example of how emotive wearables could approach the treatment of stress by combining multiple sensors to track stress triggers.

In some cultures there is social stigma around the appropriateness of showing emotion in social situations, for example some believe that expressing emotion is a sign of weakness. However, for others, regulating emotion is a way of maintaining composure and cognitive performance under stressful circumstances: "Western culture is decidedly ambivalent about emotions. On the one hand, emotions are seen as wanton marauders that supplant good judgment with primitive, immature, and destructive thoughts and impulses", but are also regarded as how we deal with interfacing with life on a day-to-day basis (Richards and Gross, 2000, p. 1).

The suppression of emotion in different cultures is discussed by Emily A. Butler et al. (Butler et al., 2007), in which research the authors found that there were significant differences between Western and Asian participants, finding, for example that, when in the company of others, women with "Asian values, as compared to those with European values, suppression may be more automatized", meaning that the researchers felt these women would begin to suppress their emotions without considering doing so in an automatic or habitual way. While it might be unsurprising that different cultures might have different learned values attached to emotion, it seems odd that some reactions might be considered 'automatized', as the term has a robotic, mechanical, and unemotional feel to it.

When considering emotion, we should also recognise the influence of body language or expressions on emotions. Gestures, such as hand-waving, can relate to many things and can be learnt or controlled, and culturally influenced, but the voice and facial expressions are reactive and directly relate to emotions. In *The Expression of Emotion in Man and Animals*, Charles Darwin claimed that our expressions of emotions are innate and are a product of our evolution, rather than learned, and that non-human animals have some similar emotions and expressions. The psychologist Ekman points out in his introduction to Darwin's third edition of the book (the first was published in 1872) that Darwin has had many challengers such as the anthropologist Margaret Mead, who claimed that facial expressions differ, as do languages and customs, and so some may well be unique to certain cultures (Ekman, 2006, p. xxiii).

Not to be confused with emotions are 'moods'. Thayer deduces what defines 'moods' from investigating a number of theories such as Thayer's characterisation "as a background feeling that persists over time" and Watson and Clark's definition: "a transient episode of feeling or effect" (Thayer, 1996, Watson and Clark, 1994, cited in Payne and Cooper (2001)) to infer that: In *Emotions at Work: Theory, Research and Applications for Management*, 'mood' is described to:

> "(...) typically involve feeling states of mild to moderate intensity that wax and wane gradually over time; unlike emotions, they usually cannot be linked to a specific precipitating event or experience, but rather reflect the cumulative effect of multiple inputs (including both internal endogenous processes and external events)." (Payne and Cooper, 2001, p. 27)

Social interaction as a performance

The process of consuming and wearing wearables is not confined to the act of useful devices serving us, or the data - there is an element of the performative.

The Canadian sociologist Erving Goffman (Goffman, 1959, p. 32) compared the act of engaging with others in public to performance, he discusses how in social or professional situations, Western populations participate in a set of practices akin to performing. Goffman claimed the 'actor' or individual performs to the observer by putting on a 'front', which is "the expressive equipment of a standard kind intentionally or unwittingly employed by the individual during his performance". The 'front' is a set of actions in which an individual presents themselves to manipulate a situation and/or be seen in a certain way to others. The front could include facts about the individual, the 'setting' or location and props, the 'appearance' to refer to those stimuli that function at the time to tell us of the performer's social statuses (p. 34). An important element of the performance according to Goffman is the 'dramatic realization', which occurs when the 'actor' emphasises what he or she wants to communicate to the audience in their performance to create an 'idealized' situation to convey the individual and their agenda in a favourable way to cause admiration.

The theories of Erving Goffman have inspired me to consider and develop new forms of social interaction in the context of my practice. I have been influenced by Goffman's theory of 'fronts' to develop an activity I have named emotive engineering, in which wearables broadcast pre-recorded physiological data to manipulate or change a situation or perspective to others and which represents a gap in the field. I discussed this in *Chapter 2: Communicating Via Wearable Technology*, (p. 38).

Emotional interaction and personal space

Personal space has been an important theme for my practice and exploring studies concerned with proxemics and social space by the cultural anthropologist, Edward T. Hall, has helped in positioning these ideas further. Contemplating the effects of social space also helped conceptualise other practice pieces, for example artefacts that visualise fluctuations in physiological data in response to social interaction such as my EEG pieces.

Hall (Hall, 1966, p. 1) introduced the term 'proxemics' in 1963, which is one of a number of subcategories of nonverbal communication, to describe: "The interrelated observations and theories of man's use of space as a specialized elaboration of culture". Through his investigation into 'space' his intention was to help people communicate both socially and culturally; his studies look in depth at different cultures and their relationship with space. His aim was also to provide city planners with a reference for incorporating space into architecture and city planning, and this work encourages us to think about the spaces we create, and put ourselves and others into. His investigations led him to chart four "distance zones", which he saw as "invisible bubbles" (p. 128), compiled from "observations and interviews with non-contact, middle-class, healthy adults, mainly natives of the northeastern seaboard of the United States". He also stated that these were mainly men and women, either professional or 'intellectuals'. His four distances included near and far phases, and were labelled intimate distance, personal distance, social distance, and public distance.

Using Hall's guidelines, I have created an image to reflect upon these distances or 'bubbles' as he called them, which show radius in feet and metres (p. 117, see also Chart 5.1 (p. 148)).

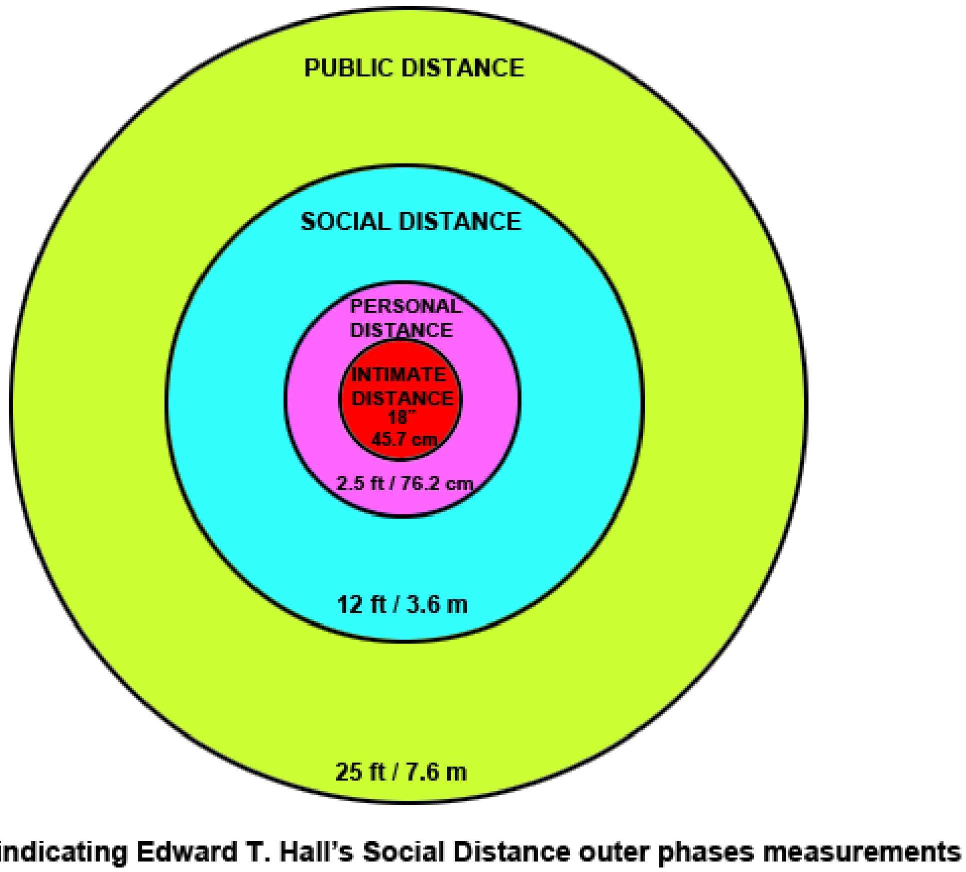


CHART 5.1: Diagram created using Edward T. Hall's outer distance phases for social interaction (2015)

Two examples of practitioners who have engaged with proxemics and similar themes to emotive wearables are Anouk Wipprecht and Sarah Kettley. Wipprecht's *Spider Dress* (2014) tackles social interaction from a defensive viewpoint, but relates to my practice via it's use of proximity and physiological data to measure a response to those entering the space of the wearer. The futuristic selective laser sintered (SLS) cocktail dress hosts a robotic, moving set of spider legs served by 20 servos which sit on the wearer's shoulders and react to invasions of personal space via proximity sensors. The spider limbs move autonomously, but also react to sensors reacting to stress levels in the body from respiration sensors. Wipprecht describes how the dress reacts: "when approached at an aggressive pace, the system answers in a territorial attack mode", she said. "But when you walk up to the dress in a more cautious, friendly symbiotic way, you can almost get the dress to invite you closer, as if to 'dance' with you" (Kaplan, 2015).

Sarah Kettley's (Kettley, 2007) proximity sensing friendship jewellery presents a different usage of proximity to the *Spider Dress*. Kettley's doctoral research exploration of 'authentic' wearables connects with my research via a shared interest in a bespoke and personal wearable for everyday usage. She investigated inter-personal human connections through experiments with a women's friendship group and from these created a suite of wirelessly networked jewellery in the form of neckpieces. The research prototypes combined traditional craft techniques with technology in the form of sensor nodes, using materials such as light emissive polymers and precious metal clays with enamel and had a hand-crafted, organic look to them. Each of the sensor nodes were able to locate and identify others within the group within a range of approximately 20 metres and reflected three social distances in the flashing frequency of the LEDs. The three social distances, which had come about from an ambiguous approach to identity and proximity information regarding greeting distances, had a remarkable commonality with proxemics social distance research by Hall.

Wipprecht and Kettley's projects illustrate two very different approaches to proximity: one based on the defensive self and the other through lasting friendships. I have used proxemics in my practice to indicate physiological changes when someone wanders close into the wearer's space, but also to reveal during an extended period of interaction how the wearer's physiological response, for which they might not have any control over, changes. The two examples illustrate how proxemics can be used in different ways to illustrate movement in social space. They differ with my own use of proxemics because the visualised information shared can only be decoded if the wearer has shared knowledge of what the visualisations mean with the viewer. Through the generation of my practice pieces I have seen how proximity touches not only on social etiquette and awkwardness, but also issues of comfort around others and privacy.

This section explored communication and emotion, it began by discussing verbal and non-verbal communication, with examples of various interpretations. The section then investigated some of the definitions of emotions, comparing and contrasting different theories. Following this I discussed Erving Goffman's theories on social interaction, which focus on how humans behave in public in a manner akin to performance. The section then looks at proxemics and how Edward Hall's theories contemplate the social spaces we create, including giving examples of wearables which use proximity, which also reflect how we feel about social space and our privacy. In the next section I discuss issues around privacy and wearables.

Theme 5: Privacy and wearables

In this section I discuss considerations for wearables in and around privacy. These issues are connected to my research because they will shape how we use wearables in the future. My research prototypes do not share data, but because they have the functionality to do so it is important to recognise and reflect on the possible implications. Issues include the ownership of data and how companies collect consumer and personal data through fitness trackers to sell on to other companies. This section then discusses how clothing company Sisley caused ethical concern by wanting to use RFID tags to track the movements of garments. I look at lifelogging and how building up vast amounts of personal data may be beneficial, but also cause problems. Lastly, I discuss the controversy *Google Glass* caused in relation to privacy and the reaction it received from the 'Stop The Cyborgs' pressure group to halt its usage.

Data and ownership

Where one's data resides, and who has access to it, should be an important question for anybody considering using a device that records their data. The discussion around self-tracking, remote monitoring for health reasons and uploading data has caused a certain amount of ethical concern around who owns data and what happens to it once it is uploaded to the 'cloud'. The wearables market has been steadily growing in recent years, business research and advisory company, Gartner, Inc. (Gartner, 2017) forecasted that that 310.4 million wearable devices would be sold worldwide in 2017, which they stated is an increase of 16.7% from 2016 and in monetary terms sales of wearable devices will generate revenue of $30.5 billion in 2017.

Many of the above sales will be health and fitness trackers and due to the plethora of sensors, devices and apps for uploading and tracking data each device or application will have its own terms and conditions in regard to its data policy and sharing. These documents are long and hard to understand, but it is left up to the user to read these carefully and decide if the usefulness of the device or application outweighs the possible consequences of handing over personal data. Empirical studies have shown that users do not read these acceptance of end-user license agreements (EULAs) and suggest users quickly click through consent dialogue boxes when they install software or upon license agreements on their devices. This means users do not fully understand what they are consenting to with regard to issues such as who has access to their data and where it might be stored (Böhme and Köpsell, 2010, pp. 2403–2406). Piwek et al. looked at a number of concerns regarding consumers not owning their data even though they have bought their device, as it is collected and stored by the manufacturer. In other cases, consumers may pay a monthly fee for access to their own raw data that is often sold on to third-party organisations. They also found that companies share personal data that includes a users' location, age, sex, email, height, weight, or 'anonymised' Global Positioning System (GPS)-tracked activities (Venkataramanan, 2014, Strava Labs, 2017, cited in Piwek et al. (2016)).

There is also the issue to consider of whether data from wellbeing and activity trackers will have implications for the wearer. For example, if it is used for medical insurance validity, workplace fitness schemes, or other methods of reflecting on the wearer/user of a device. Nissenbaum et al. (Nissenbaum and Patterson, 2016, pp. 79–100) finds worrisome the possibility of workplace discrimination if an employer speculates that an employee may develop an impairment that will affect their performance at work or drive up healthcare costs. Also if eating habits or weight gain will be interpreted as a worker having a perceived lack of discipline that would not be desirable in the workplace. However, perceived threats to privacy do not only manifest from devices used and worn by oneself, but also from those belonging to others, such as those that could record us in public places (Goldsmiths, 2013, p. 4). These include body-worn cameras (BWCs) such as lifelogging devices and those worn by police which are increasingly used in law enforcement to record evidence during incidents (Ariel et al., 2017). Not everyone wants to record or be recorded going about their daily business and in reaction privacy worries Stop The Cyborgs, an online campaign group, was set up in 2013 to protest against the use of *Google Glass* and similar devices by encouraging the banning of them in public places such as bars and cafes (Figure 5.7, p. 152).

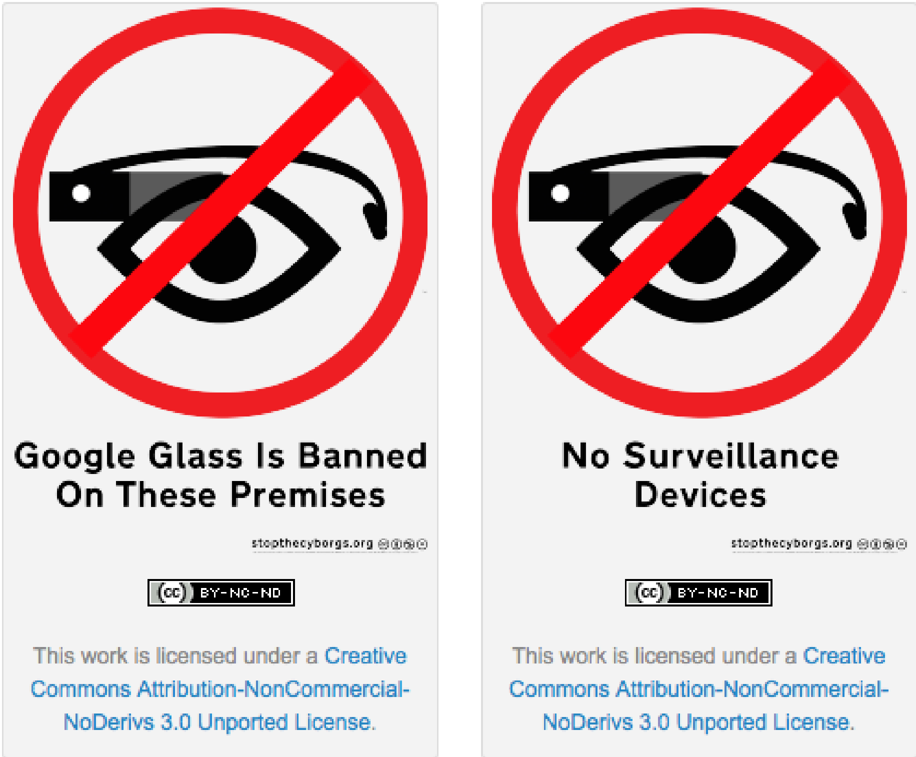


FIGURE 5.7: *Google Glass* ban signs from Stop The Cyborgs website (CC BY-NC-ND 3.0) (2013)

Privacy and lifelogging

Google Glass, which has already been mentioned in this thesis, is one of a number of wearable devices that have been used for 'lifelogging' which is the practice of recording one's life constantly. The recordings can be done using virtually any medium, with digital media, such as images and video, being popular, while email and physiological data are other methods used (O'Hara et al., 2008, p. 156).

Examples of wearable cameras such as the *Narrative Clip* (Narrative, 2015) and Microsoft's *SenseCam* (Microsoft, 2013) have settings for automatically taking photos, which can, for example, be set to every 30 seconds or by trigger sensors such as temperature and movement (Figure 5.8, p. 153). However, 'lifelogging' is not a new practice; the aforementioned Steve Mann, Thad Starner and their colleagues at MIT Media Lab, began experimenting with transmitting and recording their lives 24/7, via video in the 1990s.

The constant and regular act of recording means these devices soon build up a large amount of data to store and sift through. The recording and compiling of data by these devices has incurred privacy and ethical concerns, and worries regarding consent. For example, there are questions of control and what happens to footage from those captured in photographs or video. O'Hara et al., (O'Hara et al., 2008, p. 157) offers a contrast to these concerns, and states that in a world where so much of our data is taken from us, through surrender to commerce, marketing social media, government, travel, and security, lifelogging has the potential to be empowering, and can allow us to reaffirm control over our identities, not only that but facilitate a constructed identity that outweighs the others by weight of evidence. However, Allen points out that although lifelogging can be helpful for reminders of important conversations, it can also dredge up the past and extend the longevity of personal misfortune or error (Allen, 2008, pp. 47–74).

Whilst a number of my practice prototypes that use EEG data, such as the *EEG Visualising Pendant* (p. 103), have record and playback functionality, they only currently store one instance of recorded data, though it is possible to transfer and store this data on to a drive. The data could be stored for lifelogging purposes as particular moments could be replayed and reflected upon at a later date.

FIGURE 5.8: Mann, S: *Evolution of the lifelogging lanyard camera. From left to right: Mann (1998); Microsoft (2004); Mann, Fung, Lo (2006); Memoto (2013)* (CC BY-SA) (2013)

Monitoring through the lifecycle of a garment

One should not assume that the tracking of a person and their data will be limited to health and wellbeing devices. Bradley Quinn (Quinn, 2010, p. 22) discusses the clothing brand Sisley's intention in 2003 to embed an RFID chip into the label of all new garments. Companies who claimed that they needed to track the journey of a garment through its production cycle to identify defects to improve quality control are challenged by consumer organisation *CASPIAN* (Consumers Against Supermarket Privacy Invasion and Numbering) which is concerned that the embedding of such chips into clothing would enable retailers to track consumers by their purchases and link this to their credit card details to find out names and other information. Quinn states, "Embedded chips also raise issues of ownership. The chips embedded in bank cards remain the property of banks at all times, irrespective of being held by the consumer" (p. 22). As RFID tags are increasingly used in products, devices and services, the problem of privacy and security becomes a challenge to all.

Contrastingly, a project endeavouring to aid the wearer rather than the manufacturer was presented at the ISWC Doctoral School in 2012 by Michele A. Burton. It focussed on developing wearables to make clothing accessible to those with visual impairments by replacing traditional clothing tags with washable wireless technology tags that convey information to smartphones (Burton, 2012, pp. 55–56).

Technologies that transmit data highlight ethical implications around privacy that need to be followed to ensure that no personal data is inadvertently collected or distributed such as the wearer's location. As I mentioned earlier in this chapter (p. 141), wireless technologies passing data between wearables and smartphones or other devices are susceptible to being breached in a number of ways, and so the highest security settings for apps should always be used.

This section looked at issues surrounding privacy in relation to wearables. In particular, it looked at data ownership and how manufacturers of devices such as fitness trackers have access to their users' personal data and sell it to third party companies, who wish to know more about people's habits and lifestyles. This section also discussed how concerns around privacy have hampered acceptance of devices for lifelogging, and finished by looking at how one company set out to monitor the lifecycle of a garment, prompting privacy concerns.

Conclusion

This Literature Review examined five themes under five sections that have had a significant impact on my research practice around emotive wearables. To summarise, these were: *Evolving wearables*, *e-textiles: projects, integration and challenges*, *Mobile technology for communication*, *Human Communication and emotional computing* and *Privacy* *and wearables*. These themes have informed my research and aided in identifying gaps that will help form my contribution to knowledge.

In the first section, *Evolving wearables*, I looked at the development of wearables as an emerging technology at MIT Media Lab and how they lacked design input. This was due to suitable components being hard to come by, but also because achieving functionality would be a priority over aesthetics. This resulted in a cyborgian aesthetic emerging which I compare with Donna Haraway's feminist cyborg. Gemperle et al., probed the ergonomics of wearables on the body through space, shape and size, which progressed the recognition of design issues, impacting on the ISWC community, along with other designers. Discussion of head-mounted displays brought *Google Glass* into view, which is of interest due to my investigating reactions wearables in my user studies. There is a connection between people and events that ties together with the evolution of wearables at MIT and my main academic community, ISWC, and it was important to understand how and why wearables had evolved around these factors. This has led me to investigate and address themes around aesthetics and design by exploring the opinions and requirements of potential users through user studies.

The next section referenced the second theme, *E-textiles projects and challenges*, which gathered practitioners' various approaches and concerns around e-textiles, including examples from the E-Fibre community which have connected with the construction of my research prototypes. In joining the E-Fibre project, not only was I given a platform to discuss my practice and demonstrate my *Baroesque Barometric Skirt*, it also gave me another academic and industry community to learn from and share research with. For example, I was prompted to look at literature concerning the history of the Philips Design lab, which included the *New Nomads* project that explored a future through embedded mobile technology, and highlighted the aspirational, but was impractical in terms of aspects such as washability. Philips SKIN Probes research was of more interest due to its futuristic exploration of physiological data, but again it wasn't practical as everyday wearables. My practice addresses issues discussed in this section by ensuring that during the design phase my prototypes consider issues of practicality and sustainability, such as washability and also the ability to upgrade and repurpose hardware and materials elements, including the use of rechargeable batteries.

The third section and third theme, *Mobile technology for communication*, was undertaken to be informative for the development of my research prototypes in regards to the selection of technology for prototyping. But also to investigate how mobile technologies have been used as interfaces, drivers, and engines to wearables. Investigating mobile technologies has highlighted security issues addressing privacy and data control which have arisen in user studies. It also allowed for the investigation of previous design artefacts and research prototypes which honed in on (at the time) predicted trends for wearables, such as embedded mobile technologies that would transform clothing into communications hubs.

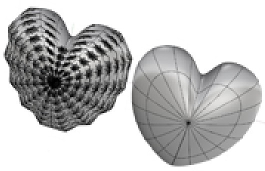
The fourth section and fourth theme, *Communication and emotions*, focusses on examining theories that have enlightened my research to the diverse opinions in the fields of nonverbal communication and emotions. The investigation revealed that there is no exact definition of the field of nonverbal communication due to a lack of agreement on the boundaries between verbal and nonverbal behaviour. Theories around emotion are also in abundance and steeped in disagreement around the physiological process that triggers them. This lack in consensus indicates that there are still opportunities to define these areas and add further theories and knowledge to the field. Erving Goffman's theories on the performative aspects of communication have helped me contemplate how my practice prototypes could be used and was an inspiration for a contribution to knowledge, emotive engineering. Discovering Edward T. Hall's theories on proxemics have been useful for my practice in terms of giving me a frame of reference for personal space and also for considering the work of other practitioners in the field of wearables.

In the fifth and final section and theme, *Privacy and wearables*, I discuss some of the issues that accompany the recording and sharing of our personal data, such as ownership. Privacy is an important ethical area for wearables as many of wearables record and share personal data, which might seem like a small tradeoff for steps or sleep pattern analysis, but long-term data logging may have future implications, for example in areas such as health insurance and job applications. There are also issues to consider around others invading our privacy by recording us knowingly or unknowingly via body-worn cameras and lifelogging devices. Investigating this area has helped me consider and address issues for my user studies and emotive wearables generally.

The next chapter is *Chapter 6: Methodology and Methods*, where I reveal the methodologies and methods that I've used in my research, including user studies.

Chapter 6

Methods and methodologies



In this chapter, I describe the methods and methodologies for my research which I have used to answer my research questions and how they can be reproduced by the reader. The chapter begins by situating my research in autoethnography, action research, reflective practice and rhizomatic methodologies and describes how these have shaped my research. This is followed by research methods that includes the development and testing of the artefacts I have produced in section two. The third section addresses ISWC peer research methods that have impacted on my own. Finally, I discuss how the focus groups, field tests, and surveys, were carried out to with potential users of emotive wearables. Feedback from ISWC and Quantified Self research communities provide further evidence of research distinctiveness.

Methodologies

In this section I situate and discuss my choices and usage of methodologies in the pursuit of my practice and research.

Autoethnography

Autobiographical notes, images and videos, together with empirical experimentation are central to my research methods. As Ellis describes in The *Ethnographic I: A Methodological Novel About Autoethnography*, the focus falls on the "research, writing, story, and method that connect the autobiographical and personal to the cultural, social, and political" (Ellis, 2004, p. xix). This approach has assisted me in describing and relating my own individual experiences, through the use of the "I" and also the dynamics of my research and practice. An example is the descriptions of the evolution of my practice prototypes which I describe in detail in Chapter 4 (p. 89).

Action research

As well as using autoethnography to convey my journey, my research has led me to gather various other methodologies to investigate my practice. For example, the processes underpinning 'action research', which in Kurt Lewin's model, uses "a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of action" (Lewin, 1946, pp. 34–36). Insights from an action are used to understand, inform and then improve, which is a suitable methodology for my iterative approach to practice, which requires constant research, note-taking, testing and updating to help make critical decisions during the evolution of a prototype.

Reflective practice

Another important methodology to my research is Donald Schön's concept of 'reflective practice', as the ability to reflect on action so as to engage in a process of continuous learning (Schön, 1983). It relates particularly to my approach to developing work because there is a continuous learning process when approaching researching and bringing together electronics, code, aesthetics and other disciplines in the process of my practice, which each require differing specialist knowledge.

Rhizomatic

Due to the multidisciplinary nature of my practice, my prototypes have evolved from the intersecting of concepts, media and processes, which is akin to a *rhizomatic* approach. A *rhizome*, also known as a *creeping rootstick* or *rootstock* is an underground stem of a plant that grows new shoots from its nodes and if broken up into separate pieces is able to grow into a new plant. French philosophers Gilles Deleuze and Félix Guattari used the terms *rhizome* and *rhizomatic* as a concept to describe theories and research that have "no beginning or end; it is always in the middle, between things, interbeing, *intermezzo*" (Deleuze and Guattari, 1988, p. 25). I am using a rhizomatic approach in the context of my practice as a metaphor to describe how my ideas iterate, grow and intertwine with each other as necessary. This occurs as my thoughts weave, bud and grow away from each other, but then reconnect as they pass each other by in the iterative structure of their development. For example, due to my practice having several experimental components developing at any given time, such as code, electronics and design, their evolution and final outcome depends on the outcomes of the development of each component part. Thinking about my practice, using 'rhizome' as a metaphor has helped me visualise where ideas and concepts cross over, and how my work is constructed in a multidisciplinary way. It has also shown how one can draw paths between different disciplines and the specifics of a piece of work (Chart 6.1, p. 160).

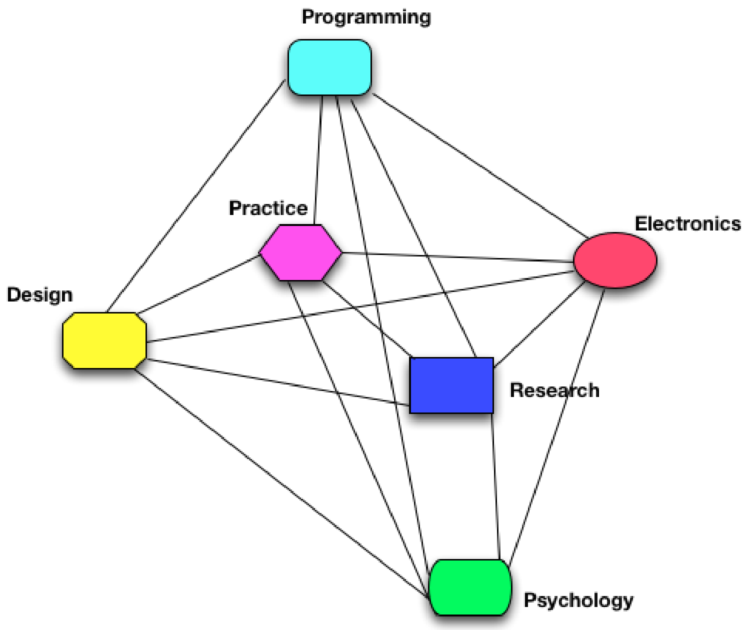


CHART 6.1: Rhizomatic of multidisciplinary practice and research

In this section I have discussed the methodologies that I have used in my research. These have included autoethnography, which has helped achieve focus and make connections within the personal, societal and cultural aspects of my studies. In my quest to understand, inform and then improve my work, I have found action research and reflective practice useful for working in an iterative manner. A rhizomatic approach to my practice has helped me to solve problems and progress with multidisciplinary artefacts. In the next section I discuss my methods for user studies.

Methods

In this section I discuss the methods I have used in my practice. In the first section I describe a method that I have developed from my multidisciplinary practice to manage and help advance the progress of wearables research prototypes. The section goes on to describe how I have learned from methods created by my peers in the ISWC community.

A method for creating multidisciplinary wearables

I have taken an aspect of Deleuze and Guattari's aforementioned rhizomatic approach to research; that theories and projects are in a state of continual evolution, which seems appropriate for my multidisciplinary practice. I have also applied aspects of other methodologies as mentioned earlier in this chapter, such as Lewin's 'spiral of steps' and Schön's reflective practice and have proceeded to create a method which I have used to facilitate the development and progress of my practice artefacts, which operates via cyclic method of 'Identifying, Concluding, and Updating'.

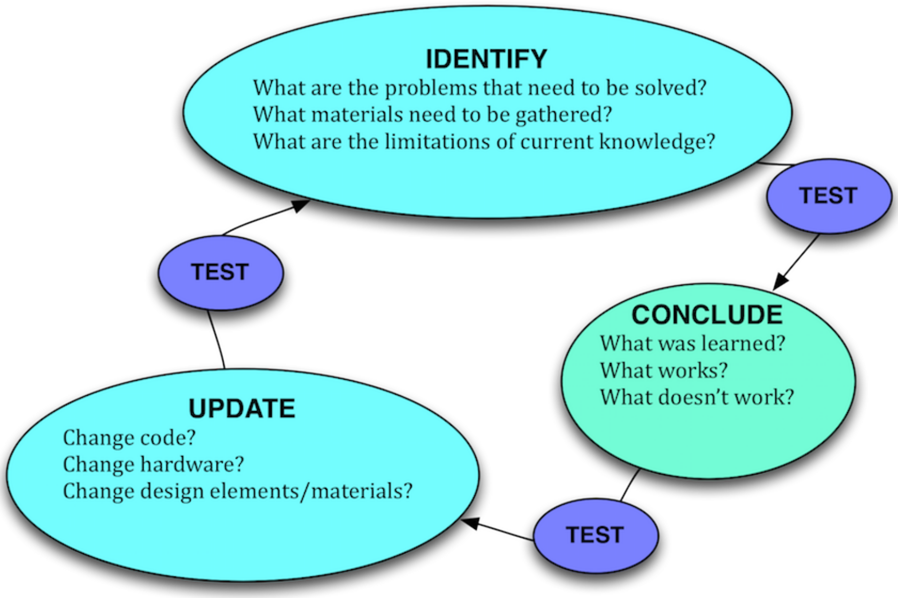


CHART 6.2: 'Identifying, Concluding, and Updating', a method for developing multidisciplinary wearable prototypes (2017)

The above chart (Chart 6.2, p. 161) illustrates the cyclic, repetitive and iterative nature of the method, which recognises three major stages that are used to question the current state of the project, these are:

Identify: *What are the problems that need to be solved? What materials need to be gathered? What are the limitations of current knowledge?*

Conclude: *What was learned? What works? What doesn't work?*

Update: *Change code? Change hardware? Change design elements/materials?*

The method requires that the elements of the project are tested in between each stage to assess if progress has been made and whether the components i.e. code, hardware or design elements such as enclosures or materials are operating together successfully. Typically my practice involves elements of code, electronics and design, and each of these have their own stages or elements as they evolve through the process of prototyping. For example programming for an artefact will incur several layers of planning and testing, and within this it will be required to implement other items such as code libraries to import to drive specific areas related to the workings of the electronics, such as a library for a sensor, a servo or to map colour to a display made of LEDs. This is illustrated in the chart below which contains typical elements that are brought together and require testing in the process of creating a prototype (Chart 6.3, p. 162).

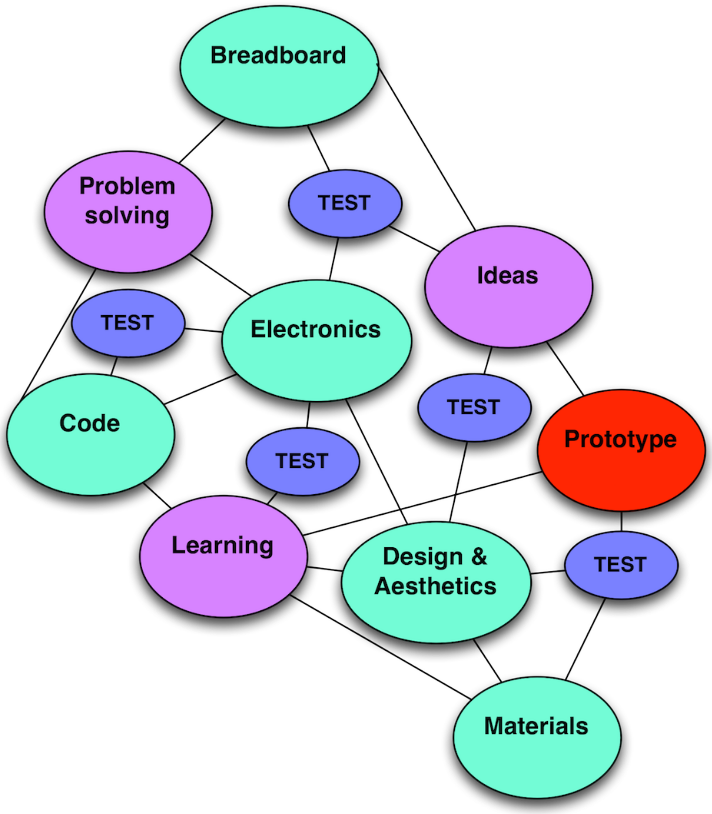


CHART 6.3: Mapping components that represent a typical evolving prototype (2017)

By using the method of continual testing, identifying, evaluation and updating, the progress of the individual elements that make up my multidisciplinary prototypes are pushed forwards towards realising their goals.

Methods of interest from my peers

While my research has grown and matured during the exchange of ideas and approaches with my colleagues in the field, I have found the rigorous approach of the ISWC community has had an especially direct and positive influence. Through participating and contributing my research to the ISWC community, plus learning from peers sharing their research ideas at its Doctoral School, I have been introduced to new perspectives, projects and processes, plus I have been able to ask questions and give and feedback on the research that I have witnessed develop.

In the case of methods for research, ISWC doctoral student Halley Profita et al. (2013) examined the societal perceptions of a user interacting with the textile interface in the form of an e-textile 'jogwheel' (a circular controller, see Figure 6.1 (p. 164)) on different on-body locations via video demonstration (Profita et al., 2013, pp. 89–96). The methods in this study were helpful to reflect upon when considering approaches for my user studies. When designing my own studies, I demonstrated the functionality of the *EEG Visualising Pendant* prototype to the focus groups by wearing the device to exhibit the device's real-time data visualisations, before handing it to participants to inspect and experience. Conversely, in the field tests, I recruited participants to experience the device by wearing it in social and formal situations. It was necessary for participants to interact with the device as both user and observer to understand how it worked, make comments on aesthetics and to give functionality and user experience opinions.

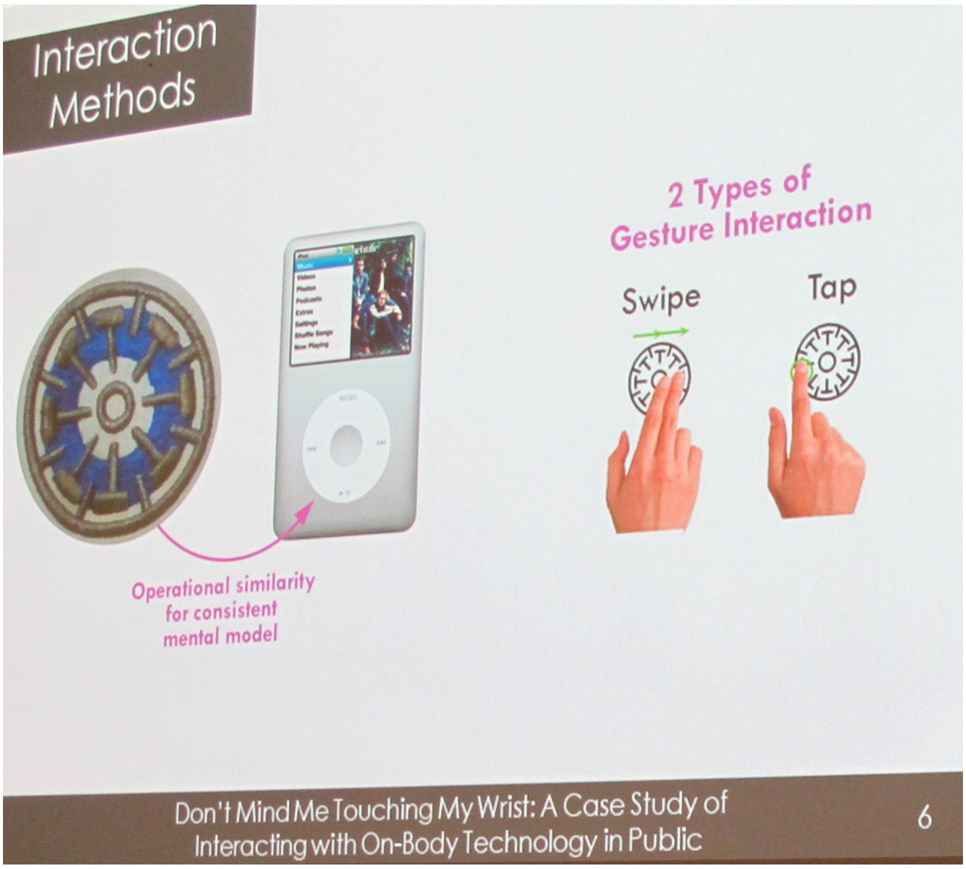


FIGURE 6.1: Jogwheel slide from presentation of *Don't Mind Me Touching My Wrist: A Case Study of. Interacting with On-Body Technology in Public*, by Profita et al., at *Touch and on-body* session, ISWC, Zurich, Switzerland, 2013 (2013)

In this section I discussed how I have used aspects of various methodologies to create a method for developing prototypes. I have also discussed how I have found the investigations of peers in the community of ISWC useful for contemplating methods for user studies. In the following section I discuss in detail my various methods for user studies.

Focus groups, field tests, and surveys

In this section I will discuss in detail my methods for focus groups, field tests, and surveys which have allowed me to answer my research questions. Firstly I discuss focus groups which outlines the purpose of the studies, how I went about recruiting participants and the locations I chose. This is followed by the settings and methods used to conduct the studies and how data was collected. Next I discuss methods for running field tests with the *EEG Visualising Pendant*. This includes the context of the field tests and recruitment of participants, including information about participants such as their gender and vocation. The section then looks at setting the scene of the field tests, how they were organised, setting up the participants with the pendant and how the field tests were executed and feedback collected.

Following on from field tests, I discuss how I invited attendees of the ISWC Design Exhibition, 2016, to give feedback on my *AnemoneStarHeart* prototype, whose design was informed by user studies participants. The section then goes on to inform the reader how the participants were recruited and then outlines the survey. Finally I discuss my methods for data analysis. Firstly, I investigated three common approaches to research in the form of qualitative, quantitative and mixed methods, and briefly described each. I then discuss my rationale for approaching data analysis and why I discounted Grounded Theory or computer-assisted software in favour of examining and reflecting on the contents of the transcripts to stay true to the context of my enquiry.

Focus groups

I chose to use focus groups, which were comprised of informal feedback sessions and design critiques, to inform my research as they provided a useful method for people to meet, interact and discuss emotive wearables in a social context. Kitzinger and Barbour's (1999) description of focus groups fits well with my aims as they describe them as "ideal for exploring people's experiences, opinions, wishes and concerns" and that they enable researchers to "examine people's different perspectives as they operate within a social network" (Barbour and Kitzinger, 1999, pp. 1–20).

Through focus groups, I aimed to discover potential users of wearable technology, particularly in the form of emotive wearables. This included investigating their preferences for these devices in terms of aesthetics and functionality. The discussion probed participants' thoughts on various aspects of these artefacts such as: how they might choose to interact with such technology, what they feel is taboo or appropriate in the area of analysing physiological data and how they feel about amplifying it to others. Due to increased awareness of personal privacy in regards to data, it was also pertinent to investigate what issues potential users had, if any, with areas around data privacy. An example being the collection of data by wearables such as fitness trackers, which request the uploading of user data for processing and visualising. I especially wanted to hear participant feedback on making personal data public by using wearables that visualised their physiological data.

For the scope of my research, I chose two distinct participant groups for the focus groups, one being women in London, UK. This was because my personal and professional experiences with technology led me to believe that women had been overlooked when it came to the design of technology devices and so wanted to hear opinions on emotive wearables from women (p. 19). The second focus group was carried out in Amsterdam, Netherlands, comprised of members of the Quantified Self movement, a community that I am part of and mentioned earlier on p. 80, and in particular attendees of the Quantified Self Europe conference (QSEU)[34]. This group was made up of men and women of various ages, nationalities and backgrounds.

Recruitment

In conducting my research, it was necessary to get ethical clearance for all participants of my studies. This is an obligation and requirement to protect study participants, whether human or other species, by ensuring that they are not put through any experiences or procedures that might cause them harm, discomfort or distress. It is also a responsibility to ensure their interests, such as privacy are not compromised by following steps to store data safely. Ethics and integrity clearance is determined through a series of questions that check, for example, that consent is properly obtained and participants are fully informed of how the studies will be performed[35].

After receiving confirmation of clearance from the ethics and integrity committee, I began organising the focus groups. During April and May 2014, participants for the three all-women focus groups were recruited via various means: from posters on notice boards, doors, lifts and communal areas in Goldsmiths buildings, to email invites, social media, such as *Twitter* and Facebook, and word of mouth. I chose these methods of recruitment as I believed they would attract responses from a diverse group of potential participants outside of my own social and professional circle.

[34] QSEU14 was the third European Quantified Self Europe Conference. The first was held in 2011 and attracted over 200 attendees, and the second in 2013. All were held at the Hotel Casa 400 in Amsterdam, Netherlands. Since 2011, a yearly conference also has been held in San Francisco, US, where the Quantified Self movement began `http:quantifiedself.com`. The conference was run, as described on the website, in the style of a "carefully curated *unconference*" (Carmichael, 2011), where attendees presented talks and sessions themselves.

[35] Further information on Goldsmiths research ethics and integrity policies can be found on http://www.gold.ac.uk/research/ethics/

The recruitment posters specifically asked for participants who were users of, or had opinions on, wearable technology, the posters also carried photos of the *EEG Visualising Pendant*, and informed the reader that they would be asked to evaluate this after a demonstration and discussion of it, which meant they had the potential to be a future user of emotive wearables and this was suitability enough to evaluate the *EEG Visualising Pendant*.

There are differing opinions on focus group participant numbers and focus group duration, for example, Powell and Single (1996) suggest 6 to 10 strangers for inhibited discussion lasting 90–120 minutes (Powell and Single, 1996, pp. 499–504), whereas Kitzinger (1995) suggests between 4 and 8 participants of a "naturally occurring" group, such as co-workers, or brought together specifically, with the session lasting between 1 to 2 hours (Kitzinger, 1995, p. 299). I originally hoped that each focus group would be comprised of six participants, a number I believed would create a small enough environment for people to speak freely among strangers and also to be able to get their voices heard without anyone shrinking into the background if there were too many people speaking at once.

Recruitment was not straightforward, but instead rather complex. This was partly to do with recruiting participants with an interest in a fairly new subject area, which was highlighted by receiving enquiries about how much subject knowledge was required. This would probably not be such a problem in 2018 as interest in wearables has expanded and many people are now familiar with devices such as activity trackers. I also encountered problems with participants dropping out during the run-up to the focus groups, which was reportedly due to a combination of work and social engagements arising. With hindsight, I would do things differently in that I would invite the potential attendees to use a web-based event scheduling calendar, such as Doodle[36], that would allow for consensus to find the best time and date to meet. In the end, each group had four participants, which was intimate enough for people to have a stimulating discussion, but also not feel left out or retract into the background.

For the session at the Quantified Self Europe Conference in Amsterdam, participants were recruited via the conference programme and by the event's forum. Because there was such a rich choice of talks and sessions to attend for each time slot on the conference programme, the organisers decided to create a section for the conference on the Quantified

[36]https://doodle.com

Self website forum (Quantified Self, 2014). This gave those running sessions the opportunity to compose a description of their sessions to help attendees decide which to choose and also ask questions. To attract attendees to my session I wrote a short paragraph describing my research, the *EEG Visualising Pendant*, what would happen at the session and my intentions for any data gathered.

Location and participants

The focus groups took place in London, UK and Amsterdam, Netherlands, during 2014. The three small focus groups with women were held in London at the Centre for Creative Collaboration (C4CC), Kings Cross and Goldsmiths, University of London, New Cross. The Amsterdam focus group comprised a different, mixed-gender demographic and was made up of attendees recruited from the aforementioned Quantified Self Europe Conference (Quantified Self, 2014).

The women in the London focus groups were recruited for three age groups: 18–24, 25–35 and 36 and over. The age ranges were chosen to investigate the differences in opinion across generations towards emotive wearables and to probe who might be interested in using the *EEG Visualising Pendant*.

It was not a requirement to be a technology expert, but all participants needed to have an interest and opinions on wearables, nearly half were owners of various activity trackers or fitness watches. They were all everyday users of technology and some worked with technology. This set of interests qualified them as potential users of emotive wearables and able to evaluate and comment on this technology. The participants included: two undergraduate students, four masters students, one PhD student and recently completed PhD student, a freelance photographer and maker, a fashion expert, and a computer engineer. The participants were from various backgrounds, countries, cultures and educations, and included both working and student participants. Together they formed a diverse international and ethnic group. Each and every one of the participants entered into an informal dialogue with me via email to discuss their interests and suitability to take part. Not every woman who answered my recruitment flyer decided to take part, this was for a variety of reasons, including dates and availability, I did not reject anyone who wanted to take part.

To compare and contrast against opinions from the three groups of women participants in London, I sought the opinions of Quantified Self Europe conference attendees as most participants would be very familiar with the latest, emerging and experimental wearable technology products and prototypes for self-tracking. This did not mean their feedback was more important, but gave a slightly different potential user perspective. The conference also attracted attendees who were researchers, start-ups and individuals who had experience of constructing their own devices. Having a contrasting focus group would give me further insight into potential users, through feedback on what might attract or repel them from wearing such a device, and perhaps highlight new and different concerns around areas such as functionality or aesthetics.

The Quantified Self focus group comprised 10 participants, who were visiting the conference from various countries and cultures, were of mixed ages and gender, so were also a diverse group. There were two extra participants who wanted to take part though could not attend due to session clashes, but with whom I discussed the *EEG Visualising Pendant* during a more informal demonstration of the pendant. These participants could not take part in the group discussion, but were able to give feedback to specific questions also posed to the group.

Setting the scene and capturing data

The focus groups took place in May and June 2014. I endeavoured to ensure that everyone felt relaxed by arranging the chairs in advance for all the focus groups into a semi-circle so everyone could see each other and communicate easily. At the London focus groups, space allowed me to position seating around a table and I provided soft drinks and snacks as participants arrived as suggested by Powell and Single (1996), as a means of allowing informal conversation and introductions (Powell and Single, 1996, p. 502). Having the table allowed me to sit down with the participants and pass around the *EEG Visualising Pendant*, it also allowed me to use a voice recorder on the table. I used a video recorder for audio back-up in case of any technical problems. Having small groups of four participants made transcribing the session slightly easier to follow conversation. However, there was some difficulty when people talked over each other.

In Amsterdam, as I was addressing a bigger group of ten participants, I stood at the front for the whole session whilst wearing the pendant. Drinks and snacks were freely available in the common areas of the venue, so I did not need to supply them. As mentioned before, I was mainly interested in recording the audio, so although I used a video camera it was not pointing directly at the participants as I was using it as a back-up. This ties in with my declaration in the recruitment materials that all focus group participants would remain anonymous and their identities not revealed. This approach allowed the participants to feel more relaxed about revealing their opinions, especially those who had public-facing jobs, for example in academia or for high-profile technology companies.

Having audio recording devices meant that I did not have to take notes and so could concentrate on the conversation, although the bigger group did make it more difficult to follow conversations when transcribing. Barbour (2008) reports that when accessing narratives, focus groups may not be the first choice for gathering individuals' stories. This is due to participants competing to tell their stories that would produce 'noise' that would make ordering and attributing speakers difficult (Barbour, 2008, p. 18). Although I was not specifically asking for protracted individual stories, I did want to hear their opinions and experiences in some detail. On reflection, if I had recruited someone to help by taking notes, during the focus groups, it would have made deciphering the audio recordings at a later date an easier task.

Even though this was a bigger group of attendees, I was not aware of anyone feeling any apprehension or lack of confidence when discussing their views on wearable technology or the *EEG Visualising Pendant* in front of others. This may have been because local Quantified Self meet-ups are very open events and there is much discussion. Also, the conference slot was during the last afternoon of the conference, and so most attendees were very relaxed and used to speaking openly.

Presentation to participants

All of the focus group sessions consisted of a slide talk, which gave an introduction to responsive and emotive wearables. I also spoke about my practice, and how it was situated in the aforementioned wearables fields and connected to my research. Finally, I gave an in-depth presentation on the *EEG Visualising Pendant*. The final slide presented the participants with some topics and questions that I asked them to contemplate ready for the discussion part of the session (Figure 6.2, p. 171).

FIGURE 6.2: Final slide from focus groups presentation: Questions for contemplation (2014)

Participant survey

I concluded the sessions by asking the participants to fill in a survey that contained questions about their opinions on emotive wearables and feedback about the *EEG Visualising Pendant*. The questionnaire included text box areas for the participants to handwrite their responses. The survey was added to give extended feedback and an opportunity to analyse responses of participants as a collective. Conducting the survey at the end of the session gave the participants a chance to reflect on their opinions on the pendant and emotive wearables. The surveys extended the live discussion and revealed further participant opinions that there was no time for or had not be elaborated on in the discussion. The data from the surveys is presented in Chapter 7 (p. 184)

Methods for field tests

Purpose of the field tests

A field test is the process of testing a procedure or product in situations that reflect its intended use (Merriam-Webster, 2017*a*). Also known as field studies, they are defined by their taking place in "the real world" instead of being set in a laboratory. Their advantages include increased realism and control, disadvantages have been noted as limited control of experiments and complicated data collection, compared to, for example, laboratory settings (Kjeldskov and Graham, 2003).

The purpose of the field tests in the case of this research, was to gauge reactions and gather information via the experiences of participants who wore the *EEG Visualising Pendant* prototype. This was carried out in social and work situations and was especially interested in investigating how the pendant affected interaction between the wearer and observers.

I sought to discover through the field tests how the user became aware of visualising and broadcasting their physiological data via the *EEG Visualising Pendant*. This included feedback on how the experience affected them, for example did they feel comfortable or awkward wearing the device and what happened when they engaged with others. A key aim was to investigate how participants felt about the aesthetics, design and functionality of the pendant, and how they might change or improve on it to suit their requirements. It was also of interest to discover where they would wear the device on the body, and how it would look. The pendant could not be tested without seeking feedback on the experience of wearing the NeuroSky MindWave Mobile EEG headset, which sends EEG data to the pendant. This is because the headset is worn in a prominent position placed on the head, which has implications for how observers see the wearer and how the wearer feels the headset alters and affects their look. There is also the physical comfort of the user to evaluate in terms of the headset's weight and fit.

It was also pertinent to discuss the NeuroSky headset as at the time of testing there was much discussion in the wearable technology field of another headset, albeit one not collecting EEG data, which was *Google Glass* (p. 127). It was important to find out how highly visible wearable technology, rather than hidden or discreet technology, would impact on the wearer to gauge if it would put them off wearing it. For example, if such wearables would increase self-consciousness, make the wearer feel awkward or would be comfortable to wear (Figure 6.3, p. 173).

FIGURE 6.3: Experiencing *Google Glass*, CERN (2014)

Research context and recruitment

The field tests took place in London and Brighton, UK, during November and December 2014. After sending plans to the appropriate ethics committee at Goldsmiths and gaining approval, the recruitment of participants could begin. In planning the field tests, It was decided that the participant could choose where to conduct the field test (Figure 6.4, p. 174), this was to obtain experiences of wearing the pendant in as many situations as possible. All the participants were to be over 18 years of age and it would be a mixed gender group. It was not a pre-requisite to have experience with emotive wearables specifically, but an interest in wearable technology was necessary.

FIGURE 6.4: A field test participant wearing the *EEG Visualising Pendant* in a cafe

The field tests had far more respondents than all the focus groups put together and far fewer cancellations. Recruitment did not prove as labour intensive or frustrating as compared to the focus groups. I believe that this was because of two factors: visiting the participants at a time and place convenient for them, rather than asking them to visit me at a specific date and venue. The other factor was the invitation to wear the *EEG Visualising Pendant*, which seemed to pique a lot of curiosity and attracted many enquiries.

Recruitment was conducted via social media, email invitation, personal recommendation and word of mouth, and I spoke to every potential participant about their interests and how the field test would run. All participants were interested in wearables, with many owning fitness trackers. They were all interested in finding out more about themselves via technology and agreeable to testing and evaluating the *EEG Visualising Pendant*. The majority worked in technology or were studying a form of technology, so many could be viewed as leaning toward being technology experts. These combined factors suggested that they would be possible users of emotive wearables and whose opinions and evaluation of the *EEG Visualising Pendant* would be of interest.

Participants

I recruited 22 participants of different genders, who were aged from 20 to 60-plus years of age. Of those, 19 completed the survey forms, directly after wearing the pendant. Three participants who took forms away to fill in later did not return them, reminders were sent, but the survey forms were never received back. Reflecting on this, if conducting field tests in the future, I would ask participants to ensure they had enough time to stay and fill in survey forms before leaving. The participants who completed their forms included three musicians/performers, one shop owner, one research fellow, two software engineers (same company, different departments), two MA students (different universities), one senior lecturer, one engineer, four PhD students (not all from the same university), three interactive producers (different companies), one interaction designer and one marketing consultant. This mix of participants gave a variety of opportunities for trying the pendant in various social and formal situations, with participants of differing knowledge and attitudes to wearables.

FIGURE 6.5: A user study participant taking part in a field test during a lunch break in a cafe wearing the *EEG Visualising Pendant*, London (2014)

Locations and setting the scene

The field tests were typically organised with the participants as follows: after responding to recruitment the potential participant would be sent an email giving a description of the *EEG Visualising Pendant*, an explanation of the research and what would happen at the field tests. The participants were free to ask any questions they might have and also suggest convenient times and suitable places in which they would be happy to wear the *EEG Visualising Pendant*. After agreeing where and when to meet, I would visit the participants with the pendant. I ensured participants knew they were under no obligation to take part and could withdraw from taking part at any time. Participants experienced the pendant in a number of locations of their choice, consisting of places of work, such as offices, classrooms and shops, and performance venues. Others chose to wear the pendant at regular lunchtime work eateries and places of social engagement, such as pubs and restaurants. A number were visited in semi-formal environments of education (Figure 6.5, p. 176).

Visiting participants and setting up the pendant

The pendant is quick to set up. It hangs on a chain around the wearer's neck, so putting it on is simple and is not intrusive. It runs on batteries and does not need to be plugged into a computer or electrical socket. As only one pendant prototype existed at the time of testing, schedule constraints and the risk that the pendant might get lost or broken, it was decided that field tests via post were not practical. It was regrettable that a number of offers from potential participants who requested that the pendant was posted to them had to be turned down. Instead, it was decided that the field tests were best carried out where the pendant and surveys could be delivered in person.

Visiting the participants in person ensured that the pendant was set up correctly during the field tests and that the surveys were received. The field tests took place around London and Brighton, all in areas that I could easily travel to and from in a day, including enough time to conduct the field test. As the field tests were self-funded, expenses were a challenge, so London and Brighton were affordable areas to travel to.

A risk of travelling to meet participants was relying on public transport. One field test had to be abandoned due to unexpected travel delays when trying to meet a participant at a drinks reception before they attended a lecture. Unfortunately, the participant was visiting London and did not have time to reschedule the field test so the opportunity was lost.

FIGURE 6.6: A field test participant speaking to an observer at a theatre (2014)

Execution of field tests

Each field test, with the participant wearing the *EEG Visualising Pendant* and NeuroSky MindWave Mobile headset, ran for approximately 15 minutes. It was decided that this would be the optimal duration as it would give enough time for the participants to relax, interact with others and complete tasks, hopefully before the pendant or headset became bothersome. Also, as some of the sessions interrupted work, performances or social situations, I did not wish to disturb participants for too long. Some sessions lasted a little longer than 15 minutes, usually because participants were enjoying wearing the devices and were not watching the time. I ensured participants knew they could halt the field test at any time and asked each participant after the 15 minutes had lapsed if they were ready to finish. I also checked that they were not uncomfortable, as the Alice-band style headset can pinch a little when worn for long periods, this is because it needs to fit snugly to the head to keep its electrodes in place.

I chose not to ask participants to test the pendant in laboratory conditions because it was important to discover how experiences unfolded in real-life situations when they interacted with friends, family, colleagues and onlookers. It was also desirable to conduct tests outside of the laboratory to observe what might happen if a chance meeting occurred.

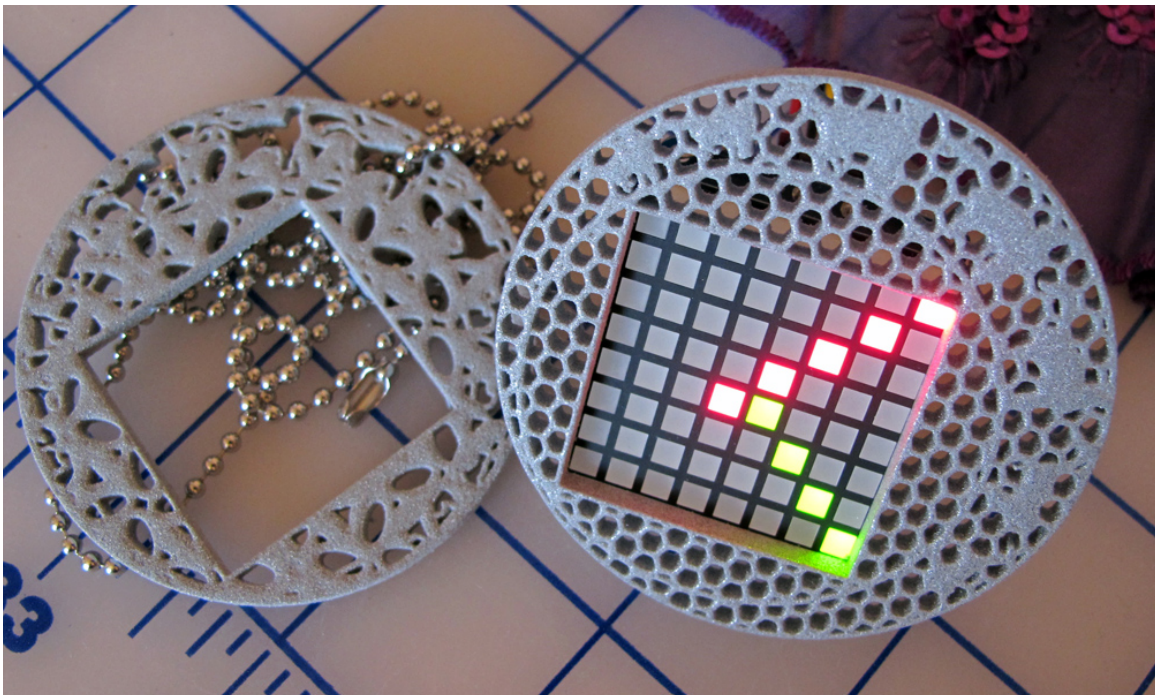


FIGURE 6.7: *EEG Visualising Pendant*, as used in focus groups and field tests (2013)

Collection of data

Because the *EEG Visualising Pendant* and NeuroSky MindWave Mobile EEG headset were already very noticeable devices, rather than hidden accessories, I decided not to draw further attention to the participants by filming them while they were wearing the device in public. This was so they might be able to relax and engage in more natural interaction with others during the time they were wearing the pendant.

I asked the field test participants to complete a survey on the experience of wearing the *EEG Visualising Pendant*. Information from the surveys was used to identify issues and concerns regarding the participants experiences and also for design and functionality decisions for future iterations of the *EEG Visualising Pendant* and other new emotive wearables projects. The survey was two pages long and took 5–10 minutes to complete.

ISWC 2016 Design Exhibition feedback

At ISWC 2016 in Heidelberg, I invited attendees to give feedback on the research prototype *AnemoneStarHeart*. This was carried out at the Design Exhibition in an informal way to tap into their opinions as experts in the field of wearables.

Participants and recruitment

Feedback was obtained in an informal manner by approaching attendees in the vicinity of the *AnemoneStarHeart* exhibit and asking if they would be happy to take part in my research. There were several positive aspects of acquiring feedback in this way, such as making use of access to attendees who had specialist knowledge in wearables, being able to present a live demonstration of the exhibit's functionality, and giving attendees the opportunity to ask questions and examine the device. However, there were some aspects that hindered conducting survey research in this way, including only being able to explain the device and survey to one or two people at a time. Also, because attendees visited the exhibition at various times, such as during conference receptions, break times and whilst skipping scheduled sessions, it was not always possible to be at the exhibit to invite people to take part. Another factor was that attendees did not always feel inclined to fill in surveys, especially if they were carrying drinks and eating food, or were networking/socialising.

In hindsight, if I was to conduct research in this way again, it would be helpful to prepare feedback area signage and instructions, to make participation easier, but this would only be appropriate if exhibition space and curators' permit. One alternative option would be an online survey, although from past experience, I have found that event attendees do not follow up by giving feedback after they have gone home. Feedback and opinions from participants is discussed in Chapter 8 (p. 213), and can be found represented by theme in Appendices (p. 283).

Data analysis

Eight hours of recorded audio discussion from the focus groups was transcribed using the Express Scribe software[37] (full transcripts can be found in Appendices (p. 236). It took a considerable amount of time to do this because of participants speaking over each other and having to rewind the recordings to try to understand accents and intonation. Data was also generated from by survey, which was taken by all participants.

Research decisions

I considered the three common approaches to research, which were: qualitative, quantitative and mixed methods. The difference between qualitative and quantitative research is often outlined by describing qualitative data in terms of outputting texts and quantitative as giving a numerical result. Also, using open-ended questions in qualitative interview

[37]http://www.expressscribe.co.uk

questions instead of closed-ended quantitative hypotheses. Mixed methods research sits in the middle of qualitative and quantitative approaches as it incorporates components of each (Creswell, 2013, pp. 3–4). Although the original plan was to present a mixed approach of analysis of both qualitative and quantitative output, on reflection the quantitative data yielded samples that were too small for analysis, so the decision was made to leave these results out.

Analysis decisions

I investigated qualitative methods for analysing the data, including Grounded Theory, which was developed by American sociologists Glaser and Strauss in 1967 as a way of arriving at a theory suited to its supposed uses by comparative analysis (Glaser and Strauss, 1967, p. 1). Grounded Theory provides guidelines on how to form categories by coding data generated by participants, in the form of descriptive labels. This then allows the researcher to make links and relationships to understand the subject of investigation (Barbour, 2008, p. 119).

On reflection, I decided Grounded Theory was not the best method of analysis for my data. This was because during the lead up to the focus groups, through researching emotive wearables and noting themes emerging for my literature review, it became obvious what some of the themes would be. I used these initial themes and questions as a starting point for participants to consider their thoughts on emotive wearables. They were also useful prompts for restarting discussion if there were any pauses, but largely the pace and direction of the discussion was influenced by the participants. I believe that this approach uncovered interesting themes and points of view that may not have otherwise surfaced. In going through the responses from the focus groups, there were issues that came up in the analysis that were unexpected and led to new areas of discussion that became relevant and important in communicating the findings.

There was also the possibility that I could have used computer-assisted software to help in the analysis of my data, such as NVivo[38], but this required a learning curve and time to investigate its features, which I felt was not an efficient use of time. Instead I decided that it would be more productive to examine the transcripts and draw my own conclusions from the links and connections from the data to ensure the context was not lost. I discuss my

[38] http://www.qsrinternational.com/product

findings from the focus groups, field tests, ISWC 2015 and 2016 surveys in Chapter 7 (p. 184).

Conclusion

I began this chapter by describing the various methodologies used in my research. Autoethnography has been a practical way of approaching my qualitative studies because it allowed me to reflect and examine my personal research experiences and document them. I have used autoethnography in conjunction with other methodologies such as action research, reflective practice and a rhizomatic perspective, which have been complementary for addressing the investigation and progress of practice pieces, including aiding the formulation of a bespoke method for working with multidisciplinary wearables prototypes, with which I was able to critically appraise prototypes at various stages of their development.

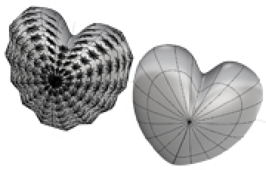
In terms of methods, my previous experiences of user testing interactive media at a UK public service broadcaster were useful for considering approaches to user studies. However, I found the processes of peers, such as examples shared via the Doctoral School at ISWC and Ubicomp, particularly useful for considering methods for conducting studies in an academic context. These examples inspired the exploration of strategies for creating user study methods that focussed on my research questions, aims and objectives. This led me to devise distinctive approaches that were useful for eliciting feedback on my research prototype, such as giving detailed device demonstrations during focus groups and allowing participants to examine component parts of the prototype.

In summary, the research methods have provided a mechanism for accumulating answers to my research questions by directing a process for recruiting and gathering potential users of emotive wearables together, in groups or individually, to answer questions and to discuss their opinions, concerns and requirements on this field and give a critical evaluation of the research prototype presented. I have explained how I have made decisions at each step of the way during the organisation of these studies, which includes the methods chosen to collect data and their analysis.

The next chapter, *Chapter 7: Results and discussion*, presents the results of user studies and discusses the results in relation to my research questions, which have investigated emotive wearables and the potential users of this technology.

Chapter 7

Results and discussion



This chapter represents qualitative data gathered from user studies carried out between 2014 and 2016, which were conducted in order to answer my research questions investigating the possibility of creating new forms of nonverbal communication. In the following sections I lay out responses by theme. These responses represent the views of a diverse group of 43 participants (this number excludes those who did not return surveys) from different backgrounds, nationalities, genders and ages. The participants were recruited to input their ideas, opinions and feedback via focus groups, field tests and surveys between 2014 and 2016. Details of their recruitment and organisation of these studies can be found in the previous chapter (p. 158).

Themes and discussion of findings

The following section discusses key findings from user studies participants' feedback on the prospect of wearing emotive wearables, which include design critiques of the *EEG Visualising Pendant* research prototype. The themes are Theme one: *Wearing emotive wearables in public*; Theme 2: *Placement on the body and form factors*; Theme three: *Aesthetics and personalisation*; Theme four: *Functionality*; and Theme five: *Privacy and data*. The full transcripts of the focus groups can be found in Appendix B.1 (p. 241).

Theme one: Wearing emotive wearables in public

This section represents discussion and feedback on wearing emotive wearables in public. It is split into two sections to make the distinction between expectations, i.e. how focus group participants felt, and experiences, i.e. the actual experiences recalled by field test participants of wearing the device (Figure 7.1, p. 185).

FIGURE 7.1: A participant of the field tests wearing the *EEG Visualising Pendant* (2014)

Expectations about wearing emotive wearables

In the first of three focus groups with women of different ages on the topic of visualising and revealing one's physiological data to others, one participant in the women's 18–24 age group was concerned that broadcasting their physiological data might lead to their 'front' being uncovered:

> "I've been to so many job interviews where at the end they say 'oh you seem really confident', like I am confident, but I am wracked with self-doubt at every point of my life, but I can hide it quite well. I put on this front of being confident, so if I had this thing on (the pendant) that actually showed that I was freaking out, it would ruin my front that I'd taken so long to perfect."

This reaction is suggestive of Goffman's theories around social fronts, discussed in Chapter 5 (p. 146). Another participant from this group brought up the subject of social awkwardness in wearing an emotive wearable in public:

> "I think I'd be a bit self-conscious to wear it (in public), especially at first as you'd have to explain it every time and it does put you in such a vulnerable position, and it's definitely something you'd have to get used to. I'd wear it around people I already trusted and already knew."

Visible or prominently positioned wearables on the body are subject to the wearer being comfortable with the connotations of being seen wearing such artefacts. For example, being perceived to be "geeky", or suspicions as to what the technology is doing, and how that changes others' perceptions of them, were concerns expressed by participants. In order to soften the appearance of such devices and to make them more appealing suggests that they might suit a bespoke or personalised treatment. This would allow the user to choose to wear a device that was personal, but also tailored to their level of comfort regarding attributes such as form factor, size and brightness of display. Outside of my studies the need for personalisation and aesthetics in wearables was part of the discussion and resulting agenda developed for on-skin technologies at the UnderWare: Aesthetic, Expressive, and Functional On-Skin Technologies workshop at ISWC 2016, discussed in Chapter 3 (p. 77).

The conversation then moved on to a thought-provoking insight regarding using the device, or a modified device, to show whether the wearer felt comfortable or uncomfortable in the context of being 'hit upon' and how the pendant might signal to the observer to go away:

> "There's quite a lot of discussion about casual sexual harassment, and a lot of guys don't realise it's classed as sexual harassment, like when they come up to you in a club and start hitting on you. If they could see that you're uncomfortable with that, they would maybe realise more that you don't want to talk to them, as they're assuming you want to talk to them. I don't know how you'd do that, maybe heart rate or something, but I wouldn't mind broadcasting that I was uncomfortable in a situation."

On a different note, in the women's 25–35 age group, there was speculation on how groups of people might use the device. Opinions were raised around how the device could be used in, for example, loud environments as an aid to discern if friends were being left out of conversations. The feedback from my field tests into this resulted in useful examples (p. 192).

> "It's a thing I could see in a group setting like in a pub or something and it's particularly loud and you could see if people were getting left out if they weren't paying attention if they weren't in the conversation - actually I'd say

> that'd be pretty useful. In a conference or an interview I'd want a lot more control over who could see it, so I probably wouldn't wear something like that in that situation."

Similar to the 18—24 women's age group, the 25—35 age group was less enthusiastic about wearing the device in formal situations, such as at a conference. They were also less enthusiastic about being able to control what could be seen or shared, which, alongside the aforementioned example regarding women's safety, upholds the need for data to be visualised in a form or cue that can only be read by those invited to do so. The women felt that the idea of having a secret language or code and "Having something that you know what that [the pendant] was saying but no one else does" could prove useful.

> "I can see its potential and it's not so relevant to the individual, it becomes a generic and consensual visualisation of how someone or groups are feeling. I think on a personal level, having the choice of if you're among your friends you'd want them to see your new gadget, but if you were at a conference presenting then I probably don't want people to see it or be aware of it."

Still on the topic of group visualisations, but on a larger scale, the women's 25–35 age group discussed how visualising emotive data could be used in concerts and movies as a form of feedback for research or marketing purposes:

> "I'm just thinking if it's more fun if more people have it at same time so data comes at the same time for example it is a movie and the audience can express themselves — like I think it's fun. Or dating or meeting each other — I think it helps communication."

Studio XO's wristbands, which were created to be used to gauge audience's responses to a show reel, highlights another possible use for emotive wearables as an aid to marketing research, and is discussed in Chapter 2 (p. 50).

The discussions at the Quantified Self workshop also brought up that there are occasions when we do not want data to be made public to others. For example, when revealing physiological data might not have a positive effect on social or formal situations.

> "Well it seems it would lead to increased self-monitoring; in that situation you'd be very careful to kind of maybe control yourself in some ways so the negative emotions don't come out. And then if I were interacting with you, I would be constantly paying attention to the pendant and thinking 'oh she's getting bored!'"

How we might try to compensate for wearing physiologically revealing devices in public is an aspect to consider and also what other ways we might find to manipulate our data or appearance, such as by emotive engineering (p. 38). The Quantified Self discussion went on to question how emotive wearables would be able to discern the nuances between emotions and how situations might become confusing for the observer trying to read between the actions of the wearer and what the pendant was reflecting via its LED matrix:

> "Maybe she looks bored or this thing [the pendant] says she's bored, or not paying attention to what you're saying — so maybe I'm boring her, but maybe she has just learned two hours ago that her mother is seriously ill."

The discussion continued with one participant pointing out to the group that the observer can always ask the wearer of the device for clarification on how they're feeling if they're concerned. This drew agreement, although another participant added that the pendant draws attention to how the viewer is making assumptions about the wearer's emotive state. This prompted one participant to think ahead to the future and how emotive wearables might be used, which envisaged a partnership between body language and the device:

> "Just the first phase, in the far future when it would be normal for everyone to wear it and then it would kind of normalise, maybe. So that it would just incorporate with all the other interactions and body language that you have."

One of Quantified Self participants, a neuroscience post-doc researcher, brought up the need to gain context from the situation to interpret the data visualisations from the *EEG Visualising Pendant*, which is how I envisage the device to be used. He described how knowing the person whose data is being studied is key to making interpretations:

> "The responsibility still rests on the person interpreting what they're seeing."

Even though the shapes, patterns and colours convey a certain amount of meaning, the data visualised is still open to interpretation, depending on the situation and person wearing the device.

Experiences of wearing an emotive wearable

The objective of the field tests was to gather evidence from potential users of emotive wearables by gathering their experiences of wearing the *EEG Visualising Pendant* in their everyday situations, such as working and socialising. This differs from the above feedback from focus groups in which the participants discussed their opinions about the possibility of wearing the pendant. To highlight this difference I have split the section into two areas.

A short but succinct observation of wearing the pendant and headset during a lunch break with a colleague in London came from a male participant who conveyed in a few stark words his experience of wearing the pendant:

> "Curious. Slightly uncomfortable, exposed."

Feeling uncomfortable wearing the pendant and headset was an issue that came up more than once. The headset, the pendant, and the data it displayed were all potential sources of discomfort.

On two separate occasions, participants decided after arriving for the field test that they were not comfortable wearing the headset and pendant in their choice of venue, leading to the field test being abandoned. However, in both cases the test was either relocated or rescheduled to suit them. This awkwardness pinpointed that certain public areas or situations that were anticipated as acceptable to participants become unacceptable based on, for example, how busy a location was and who might observe them. It highlighted that it was not easy to predict where one would feel comfortable wearing the pendant and headset until they were in situ. For example, one of the aforementioned participants reported that she was much happier once we had relocated to a location that was more familiar to her:

> "I first donned the headset in a falafel cafe but felt too self-conscious to continue there. I felt more comfortable in a juice bar (frequented by colleagues). Wearing it was fun."

Fortunately, it wasn't a problem to move to the juice bar and the comfort of the participant was always more important than running the session in a space they were unhappy in.

A recurring observation was that many of the participants remarked how, after a short while, they forgot they were wearing the pendant. They also mentioned that because it was resting on their chests they could not see it. A major usability discovery from the sessions was that the participants expected and would prefer to be able to see what the pendant was visualising, without having to tilt the pendant upwards. This was because they wanted to corroborate/discover their attention and meditation levels and to monitor what was being amplified to others.

In a discussion about engaging with strangers, one participant brought up that wearing the pendant could become very uncomfortable if it would cause strangers to stare at her chest, even if she did think it was a natural place to wear it:

> "What if they weren't talking to you but staring at your chest looking at your pendant and you just think, y'know, that could be really uncomfortable too."

Another participant told me she owned a *Google Glass* headset, so was not disconcerted at all by wearing the headset and pendant, even though she could not see what the pendant was visualising:

> "Wearing the pendant felt pretty natural for me, it didn't feel like much more than a necklace, because I could not see it when I was talking to someone. I did have a few thoughts while people were saying things that I should keep paying attention, or else they would know that I wasn't paying attention to what they were saying."

Another observation, this time from a field test participant was as follows:

> "Wore it as a pendant which was not ideal as I couldn't see it without a mirror. Somehow I didn't feel comfortable 'broadcasting' my state if I could not see what I was sending out."

A participant who wore the pendant while chatting to one of her colleagues reported that:

> "Physically, the fit of the NeuroSky unit wasn't ideal so I was very conscious of making sure I didn't hit my head and cause it to slip. Mentally, I found I forgot about the pendant while chatting to my colleague unless attention was drawn to it. I didn't feel conscious about wearing my (brain)waves on my sleeve so to speak."

Although this participant struggled with the fit of the headset initially, it was good to hear that she did not feel conscious of wearing the pendant, although as it is an unusual device featuring a bright LED matrix, it wasn't surprising that during the field tests many of the participants' conversations included discussing the pendant. The following quotes are very typical of the interactions reported:

> "My colleague knew about the device so the subject matter was the pendant at times. A few questions about the data displayed but I didn't find it too distracting possibly because I couldn't see the pendant myself. I think the interaction was quite natural and the subject matter was engaging enough to hold attention."

Even though I witnessed much of the interaction between the wearer and the observer from a distance, there were many conversations that I wasn't close enough to hear. I probed all the participants to describe how their conversations fared, for example a participant's remarks on her colleague's reactions:

> "Positive interactions, teasing about the level of concentration I displayed or didn't."

Some observers, such as clientele and waiting staff in a busy London restaurant were not so sure what to make of the ensemble when this participant wore it to lunch with her mother:

> "Many people in our surroundings asked what it was because it intrigued them, but once they found out it was a brainwave reading device they seemed intimidated and confused."

I noted several customers and staff observing the headset and the pendant. It was not surprising that people asking about it seemed to be taken aback by the information that the devices were linked to 'a brainwave reading device'.

FIGURE 7.2: The *EEG Visualising Pendant* being worn by a participant with a group of friends at a Christmas get-together in a pub

To discover how groups of people reacted to the pendant as a comparison to expectations of the focus groups, I sought out evidence of interaction in groups. The following describes three different occasions when the pendant was worn in a large group of people, starting with the feedback from two performers/musicians who wore the pendant during two musical shows attended by about 100 people in Brighton. One of the performers described the reaction of audience members to her wearing the pendant:

> "A couple noted I looked calm at the end of the show and it was green. One person [male] was curious to try it himself."

As it was a darkened theatre, the pendant's LED matrix stood out and attracted attention, another musician who wore the pendant added:

> "People were curious. If it was worn for a longer period I think it would become 'part of the furniture' and less noticeable."

It was good to hear that he thought the pendant could become 'part of the furniture', meaning acceptable to wear, and blending in with the rest of the wearer's clothing (though this acceptability in public might depend on electronic accessories with LEDs being worn generally).

Another group who took part in interacting with and observing the pendant was a class of undergraduate computer science students when their lecturer wore the pendant to give her lecture. The students did not interact with the pendant during the lecture, but were keen to ask questions at the end. In describing how the pendant was received, the lecturer commented:

> "As it was not a general social interaction it isn't really possible to get feedback on what the students felt as they interacted but there was a definite and evident fascination with it."

To investigate how the pendant would be received at a social event with a group of people, I organised for four attendees at a work's Christmas get-together in a busy pub in Soho, London to try the device. Participants wore the pendant at different stages of the evening, when interacting with various colleagues, ex-colleagues and their partners. One of the women participants described her experience of the attention it brought which was typical of the feedback gathered:

> "People were interested in taking photos and asking questions about it. They also helped to see if they could help me change the colours on the pendant. So I tried reading a news story, I tried concentrating, I tried feeling relaxed and mindful and then just enjoyed wearing the item and letting others tell me if I was feeling relaxed or asking what I was thinking about if it seemed to be that I was concentrating on something."

My observation was that it became a talking point of the evening, but the experience was not taken too seriously, which correlated with feedback from another participant:

> "Well, we were all talking about it anyway, so all my interactions were about the pendant while I was wearing it, apart from one short discussion with the researcher on my own PhD research (cue red lights across the board)."

It was noted that participants and those observing spent time experimenting with the device to affect output, which revealed a self-consciously playful aspect regarding possible usage of the pendant. However, those in the group who said that they would feel too awkward or shy to wear the pendant also said that it did not stop them from interacting with those wearing the device.

FIGURE 7.3: A field trial participant wearing the *EEG Visualising Pendant* and NeuroSky MindWave Mobile, shortly before performing (2014)

Headset

When asked to describe the experience of wearing the *EEG Visualising Pendant*, most taking part in the field tests included the experience of wearing the NeuroSky MindWave Mobile headset. To recap, the headset is adjustable, but has to remain quite tight against the head of the wearer to keep the single electrode in place on the forehead, as it does not use a conductive gel. The headset also has an ear clip for grounding the device and also to help the headset's chip filter out electrical noise from the body and environment (NeuroSky, 2015*b*). How comfortable the participants found the headset ranged from uncomfortable to fairly comfortable. I have compiled examples of feedback on the headset below, beginning with a male musician who was wearing it during a performance. The headset slipped off, due to movement and possibly sweat, and the electrode lost contact with the forehead:

> "It felt slightly precarious. If it was tailor-made there would be no problem. Otherwise I wasn't aware of it."

The comment below is quite typical of the feedback I received:

> "I felt very self-conscious about the headset — I would much prefer the monitoring technology to be subtle and discreet."

Feedback from a male who did not wear jewellery gave a different insight into wearable technology. He was keen to try the experience of wearing the headset and reported that it was:

> "Initially amusing, the headpiece is quite strange and I could feel it, because of the ear connection, for the whole time."

A different perspective came from a woman participant who found that after a short while her experience with the headset got better:

> "[The h]eadgear was a bit uncomfortable to start with, but after a few minutes you don't notice it too much."

Overall in the field tests, the fit of the headset was not ideal as human heads vary in size and shape greatly. It was possible to adjust the headset to fit many, but it was often too tight or too loose. One participant commented, "The EEG unit needs more adjustable straps". When it was too tight it was quite uncomfortable to wear. Some mentioned that

that the ear clip pinched. Conversely, many of the participants mentioned that as time passed during the field trial they began to forget that they were wearing the headset and the pendant. This evidence connects with my finding in Chapter 5 (p. 120) of a gap in the field for research to be applied to the bespoke design and personalisation of these headsets and other head-worn technologies.

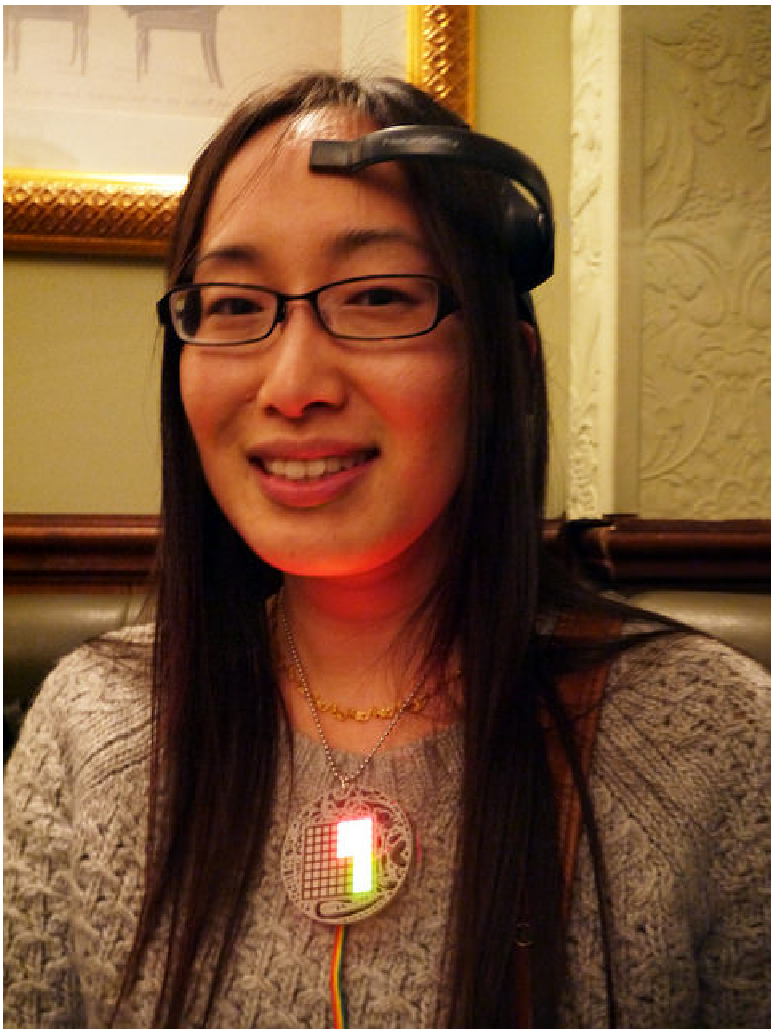


FIGURE 7.4: A participant in the field tests wearing the *EEG Visualising Pendant* (2014)

Theme two: Placement on the body and form factors

The subjects of form preferences and desired locations on the body were often discussed together so have been grouped together as one theme.

Participants in the three women's groups stated that they would prefer a choice of form factors so they could determine the areas on the body where they would wear an emotive wearable. These form factors broadly included various forms of jewellery, accessories and garments. They also brought up that when using the device, they'd like to choose whether to reveal their data or to keep it private; for example, if it was a brooch they could choose to wear it inside their jacket or on the inward facing part of a sleeve. Controlling when and where data was visualised and shared with others was a key outcome of the discussions.

> "I think it'd be cool to wear it like a badge, that way you could pin it anywhere you wanted and you could pin it to a shirt and hide it with a coat and it wouldn't always be showing like a necklace, unless you tuck it in, giving you more choices how you would display and wear it."

The participants of the women's 25–35 age group also wanted the opportunity to see their EEG data displayed on different form factors, such as a brooch, a bracelet, a hair slide, earrings, fascinators, accessories, or garments. They also requested an easily viewable interface, rather than only facing outwards towards the observers they would be interacting with. The request for the data to be visible to the wearer was also mentioned by several others. On considering the practicalities of wearing an emotive wearable every day, some creative ideas came out of the discussion, which could impact on the final form factors or the ways in which they might be able to be made customisable:

> "You were talking about making it into a fascinator and that's the kind of thing I'd wear now and then. But, if I was to wear it often then I'd want it to be really plain, so like something you'd wear everyday like your coat or your hat, so something like a knitted hat or something that would go into your coat rather than making a fascinator or something you'd wear once a week. But, if you could, make small things that people could attach into their own hats or whatever."

Field test participants also mentioned alternative locations on the body and similar forms to the focus groups such as badges, brooches and other jewellery. Participants were varied in their choices, for example, some gave parts or areas of the body where they would be happy to wear devices and others stated that where they would be prepared to wear artefacts would depend on certain conditions and caveats. For example, one of the male participants stated:

> "Depends on the product design. I would consider anywhere if the product was comfortable."

The following quotes highlight the breadth of the opinions on location and form, one size does not fit all!

> "As a data display I think I would like to be able to see the screen, maybe somewhere on the inside of my arm."

> "As I have mentioned, as a pendant I would not wear it, but as a 'badge' type object I could. I would be interested in how fabrics could be made to 'change colour/pattern' with such feedback, and while I would not wear a jacket out of such material, imagine the lining to a jacket that swirled with representations of your emotional state, just glimpsed etc."

This participant requested a longer chain for self-viewing of data alongside other aesthetic and form requirements:

> "Smaller. Shinier. Red :-) Longer chain for self-reflection."

Another participant listed their preference as being based on the functionality of the device:

> "Wrists, arms, ankles, neck (for display), torso for things other people get to see, anywhere else really if it's just for you (collecting data or haptic feedback)."

What became clear in these discussions is that there are many possible form factors that emotive wearables might take, and that these are related to where people might want to wear them. To some degree, these preferences are simply related to aesthetic preferences or possibilities for the devices. In many cases, however, they reflect considerations about how the devices might be used, the data they might display, and the degree of control or privacy people might want.

Theme three: Aesthetics and personalisation

The feedback gave insights that ranged from those who would prefer a less "geeky" looking device, for example, that could be described as subtle in terms of the size and brightness of the LEDs, to those that were more extrovert and said they would be happy with a not so subtle use of LEDs and designs. It also illustrated how people have different preferences about how they'd like to wear emotive wearable technology. In terms of the pendant's LED matrix, for instance, one participant of the women's 18–24 age group described its LEDs as "quite aggressive, they're really in your face", which initially sounded quite negative, but went on to say, "I'd definitely wear it, I think it's very interesting".

In the women's 25–35 age group, there was an enthusiastic response to personalisation and the participant quoted below was clear on how she might customise the design of the electronics enclosure:

> "I really like the idea of being able to customise my own piece, smaller and compact. I'd like to see some of the functionality built into the chain or the housing. If it was a clutch bag or rucksack or jacket, I can see part of it being integrated as a single unit, so you would just wear the hairband with the electrode and that would be enough."

Other comments in the discussion included, "I do like the idea of personalising it (the device), as it's your personal information". Also, the discrete design of activity trackers was seen as a plus point for another participant who said, "I'm more likely to wear wearable tech which has a discrete value about its aesthetic". The LED display was a subject of scrutiny and questions were asked about what the data shapes meant and whether it was possible to change the visualisation, with one participant asking "is it a secret language?" This is a very pertinent question, because the research questions the possibility of creating new forms of nonverbal communication using wearables — this was also a notion brought up by the women's 36+ age group.

For the women's 36+ age group the majority of the discussion time was dominated by talk about the aesthetics and materials, including precious metals and nylon (3D-printed), with each participant having defined thoughts on what they would like to wear and how. In contrast, there was no complimentary feedback on the aesthetics of the NeuroSky MindWave Mobile headset, which connects with the comments of those who wore it in the field tests.

> "I think it's genius and I love that; however, there's one thing I dislike about it and that's the headgear (EEG headset), it's obvious!"

Another complementary comment was from the women's 18–24 age group:

> "I really like the design of it, it looks like something you might buy in Cyberdog or something, you'd wear to a rave."

Size was key to the many of participants, also the usage of LEDs. In general they were prescriptive about how they envisaged the pendant to look and work as a wearable for them. For instance, some wanted the display to be softer in terms of brightness, envisioned using diffused, glowing LEDs, and made suggestions such as:

> "You could have two LEDs: one that stands for attention and one for meditation, and have something that blends through colour ranges, and that would bring it down in size quite a bit."

> "I love it [the pendant]! I would definitely wear it and I'd be very interested in being able to adapt it and customise it depending on what I felt like. It's a hell of a lot nicer looking than things like my horrible tracker that I bought a few days ago and am already disappointed with!"

Participants from the field test made similar comments about design and personalisation:

> "If I was to wear a piece of wearable tech on a regular basis then I would want it to suit my image and to fit with my lifestyle. This pendant has that potential."

Though, as this participant mentioned, bright LEDs were not to everyone's taste:

> "I think that I would be more likely to wear the device if it were smaller, and more subtle. I think having the large lights flashing under someone's face could be a little bit distracting in certain situations."

Another criticism came from one of the male field test participants:

> "Looks a bit too makerish/amateurish? Red/Green LEDs? Also a bit girly for general wear in public."

The Quantified Self Europe focus group discussed the pendant's data visualisations in detail, commenting on their abstractness and how it would work alongside one's body language:

> "The abstractness of the display, while aesthetically really nice, it makes it hard to interpret. So it's almost like if you're talking to somebody, you have to tell them what it is — that thing that you're wearing and how to interpret it."

There were also critical comments regarding the visualised data shapes. The LED shapes (rectangle, circle and diagonal line) reflecting the EEG data jumped between forms, and this was said to be 'disturbing' by one of the participants, who described how they'd prefer to see the LED shapes changing by morphing smoothly into each other.

Theme four: Functionality

Many thoughts on functionality came from the women's 36+ age group, which included proposals for devices that had various modes, for example, to express when the user was bored, angry, sleeping, stressed or feeling approachable. These modes could be expressed via a variety of LED colours, shapes and pulsating speeds. Another suggestion from the group was to incorporate haptic feedback into the device. This would address a difficulty for the user to view the LED visualisation without holding up the pendant. Participants also suggested a random visualisation mode for when they did not feel like sharing their data with the world.

The 36+ women's group also wanted the ability to to send data from their wearables to visualise or be recorded on other technology such as smartphones and household lighting. This was a key piece of feedback, which partially inspired the development of my post-studies research prototype, the *AnemoneStarHeart* (p. 210).

> "Something I'd love to see once it becomes commonplace and a lot of people have it, is to change the lighting in a room. So you can actually pick up the mood and you can visualise the mood in a room according to colour, and you can see a grumpy office!"

At the Quantified Self workshop an enlightening conversation emerged around the suggestion to incorporate various mode settings for the pendant as also mentioned in the previous paragraphs. The mode settings would accommodate wearers' differing relationships with observers and the situations in which they would find themselves. One participant, who was a lecturer, gave some examples of work and social situations that would require and benefit from having mode settings to adjust what selection of data was visualised by the pendant:

> "But when I'm a lecturer in front of 50 students and they know that I'm not really paying attention because the questions the students have asked me, I've heard it 100 times or I'm somewhere else, I might not really feel comfortable with them seeing that I don't pay attention!"

And later in the discussion added...

> "If it had 10 functions or variables or whatever, I would probably turn all 10 on at home with my husband, maybe with my parents — maybe not!"

In a further area of discussion which concerned explaining to the Quantified Self group the *EEG Visualising Pendant's* record and playback modes, that can be used for emotive engineering, one participant mused that if the wearer displayed a pre-recorded LED visualisation of a relaxed state to an observer, it could have the effect of making both the wearer and the observer relaxed: "Things that say you're calm actually make you calm, right?" This may not be the case for all wearers, but it's an intriguing effect to consider, especially for those entering stressful situations, whether personal or professional.

Ideas for modes for devices also came from the field tests. The field tests suggested that modes for different situations and for different groups of people to view could be useful. So there could be a modesty/privacy mode, which would change the visualised pendant data from something readable by observers to being totally private, for example by randomising the patterns on the LED matrix. Another idea from the field tests involved allowing the wearer to design or personalise the visualisation patterns on the LED matrix of the pendant:

> "It could be interesting if the user could set their own visualisation pattern so things could be randomised, and the viewer wouldn't necessarily know what emotions they were feeling at the time."

Theme five: Privacy and data

In this theme issues around privacy and data were discussed, including concerns about areas such as collection and ownership. Women in the 18–24 year-old focus group stated that they were already concerned about keeping in-check the amount of data being gathered about them via the internet, so the prospect of personal fitness or wellbeing data being collected and possibly sold by manufacturers of devices such as fitness trackers was not appealing to them:

> "My main concern would be about, firstly, there's certain people you don't want to show everything to, and, secondly, the data collection. Especially the data collection, I'm really concerned about - who knows what about you."

These participants were particularly worried about manufacturers of fitness and wellbeing devices collecting physiological data.

> "I think something as personal as this (physiological data) is quite worrying. It is building up a demographic you fit into. It's too personal as it's about what's happening to your body rather than what you're doing with the internet. It's a bit more invasive if people have that kind of data."

In the women's 25–35 age group, there was a significant discussion about data. The group's general feeling was that they were knowledgeable regarding the risks and consequences of parting with their data. It was implied that this was due to the influence and shared knowledge of the particular social groups and institutions that the participants moved in, which had a technology bent, such as hackspaces, hackathons and universities, with one participant asserting:

> "We are more data-conscious now than we have ever been and I think that's going to escalate with who owns your data."

Conclusion

In this chapter I have explored aspects of the results I gathered from my user studies reflecting on emotive wearables, with the research prototype *EEG Visualising Pendant* used throughout the studies as an example device for critiquing. This feedback has been key in answering my research questions and has revealed evidence that will form part of my contribution to knowledge. This is reflected in terms of the concerns, preferences and requirements of the potential users of emotive wearables and will be shared with my communities in academia and the wider field of wearables communities and practitioners.

The results and discussion were assembled into five main themes that evolved as the main topics of discussion and critique during studies and which have helped me answer my research questions.

The results of the first theme, *Wearing emotive wearables in public*, have helped evidence the interests and concerns of those who are potential users of emotive wearables. This includes suggestions for possible uses of this technology. However, the results also give examples of criticisms and aspects that could lead to putting off users.

Discussions from the women's focus group revealed concerns about how broadcasting physiological data in public could result in self-consciousness. Examples such as attending a job interview illustrate when such devices may not be helpful. Other occasions when data would be inappropriate to broadcast included in workplaces and at conferences. One specific example of a time when the user wouldn't want to broadcast data was when teaching, which was brought up by an attendee of the Quantified Self Europe conference in reference to not appearing to be bored by presenting repetitive subjects.

Aspects mentioned that could put a participant off wearing such devices included having to explain the purpose/functionality to others which would result in the user limiting the usage to "people I already trusted and knew". However, this was also considered a feature by some, with some participants appreciating how the device's use of patterns, shapes, signals, and cues creates a secret or covert language.

Reflecting on how the perceived usage of the pendant compares to its actual usage, it is telling that two field tests out of a total of twenty-two were abandoned due to participants feeling awkward when arriving at the location to take part. This indicated how location and the presence of strangers can affect confidence to wear an emotive wearable in public. However, when rescheduled the participants were happy and comfortable in taking part in a new location of their choice, with one commenting "Wearing it was fun". This indicated how location and the presence of strangers can affect confidence to wear an emotive wearable in public.

A key insight reflecting on possible reasons for usage of the device came from a discussion with the 18–24 year-old group of women who said that casual sexual harassment was a much discussed problem and concerned them when out socialising. They envisaged that an emotive wearable, which might take the form of a repurposed derivative of the *EEG Visualising Pendant*, could be used in public social encounters, such as clubbing, to signal to a bothersome observer to leave the wearer alone, or subtly alert friends to intervene. Other social uses suggested were for communicating in loud environments, such as clubs and bars, and noting how friends were feeling from a distance, such as across a crowded room.

The studies produced many suggestions regarding the possibilities for using emotive wearables as health and wellness indicators. This was for the individual and friends and family of which there are examples of commercial products emerging in this area such as Empatica's wristbands for tracking indicators for epilepsy (p. 58). Other suggestions included usage at concerts and movies as a form of feedback for research or marketing purposes, which has been explored by companies such as Studio XO's usage with show reel audiences (p. 50).

An experiment of how the device would be used by a group in a social setting was carried out by asking people at a work Christmas get-together, where the mood was informal, to wear the device. The wearing of the *EEG Visualising Pendant* was reported to be complementary to the situation, with wearers and observers experimenting with the device in a way that was exploratory and playful. The wearing of the pendant was not reported to have caused any awkwardness, possibly due to the relaxed atmosphere and participants being in the company of friends.

With regards to the headset, the terms used to describe wearing it included: 'precarious', 'uncomfortable', and 'strange'. Most field test participants needed help to fit the headset and position the electrodes to have contact with the scalp and ear. The headset was often tight and the ear-clip was reported to pinch the earlobe. User movement also caused problems. However, many reported that after a short while and when getting into a conversation or task they started to forget that they were wearing the headset and some uncomfortableness eased off. The headset used is a mass-produced product, and although it can be adjusted to fit, feedback does indicate that bespoke headsets are required for usage of more than a few minutes. Suggestions for design improvements and aesthetics preferences were discussed as an improvement that would make the headset more acceptable. This research represents evidence of a key gap in the field which I intend to investigate in future research.

The next section referenced the second theme, *Placement on the body and form factors*. These two areas were often critiqued and described together so it was appropriate to group them as a theme. The list of form factors that appealed to the participants included: badges, brooches, pendants, necklaces, earrings, rings, bracelets, watches, bags, various attire (shirts, coats, dress', jackets, plus pockets, sleeves, cuffs, and lapels), hair slides, fascinators, and other headwear. Preferred form factors were diverse and reflected personalities and habits. For example some people did not wear jewellery, so for them form factors only included one or two choices, such as a watch or a badge, others included many items, with choices reflecting their personality.

Placement of devices on the body also brought a diverse range of issues, with some reactions influenced by factors such as personal style or comfort, or practicalities such as requesting that the technology be embedded in informal or everyday wear. Placement choices were also dependent on whether the wearer wanted to choose when and where data would be revealed, with some participants wanting to keep visualisations for their own personal viewing at least part of the time. Size was also a key factor, with most users preferring the device to be on the smaller side, though two participants said they would wear large and bold data visualisations. The most popular area mentioned was the wrist, followed by the neck and ears, which was not surprising as they are popular choices for wearing jewellery and accessories.

An unforeseen, but key design criticism, overlapping with feedback on the experience of wearing the *EEG Visualising Pendant* through field tests, was that many wearers found they could not view the data from the pendant, as it faced outwards on the chest .

Thoughts on aesthetics and personalisation were often discussed together, as indicated in the third section. The use of LEDs in the *EEG Visualising Pendant* divided the opinions of participants, with those wanting more subtle usage of LEDs and artefact size tending to want to keep their data to themselves or friends, and those who liked the multiple LED aesthetic being more willing to display data publicly. Other criticisms of the *EEG Visualising Pendant* were that the pendant looked "too makerish/amateurish" and there were some negative comments on the way the data patterns jumped between shapes, with one participant at the Quantified Self group saying they would prefer a smooth transition between shapes. However, there were also complementary comments ranging from "I love it" to the pendant resembling an item bought from Cyberdog[39].

Feedback provided evidence that personalisation and bespoke designs were indeed an aspect that many of the participants would want, along with being able to "adapt and customise" their artefacts. One participant summed up the popularity of personalisation and the bespoke by stating that if they wore a wearable on a regular basis, they would want one "to suit my image and to fit with my lifestyle".

The EEG headset, which has already been discussed in the first section in terms of the experience of wearing it, also received critical feedback on aesthetic grounds, from participants who wanted a more 'subtle and discreet' or aesthetically designed headset

The fourth section and theme, *Functionality*, in which preferences and suggestions for functionality laid mainly around ideas for different modes that could be used with emotive wearables, of which many ideas came from the women's 36+ age group. The modes would reflect various emotive states but also to signal or give cues to when people were feeling approachable or stressed, in social, formal and work situations. Settings that regulated the types of data visualised were also requested for an array of different personal relationships and social and formal situations, plus also for privacy. A Quantified Self attendee suggested using the visualisation of certain modes to affect the moods of others which connects to emotive engineering. Suggestions were also given for alternative and user-personalised methods of visualisation in colours, shapes, patterns, and pulsating speeds to convey and give meaning to data shared with those who could decode it.

New methods were also suggested, such as using haptics as cues to allow wearers to know what feedback was being presented. A random mode was also suggested for when

[39] Cyberdog is a rave and futuristic fashion shop in Camden, London https://www.cyberdog.net

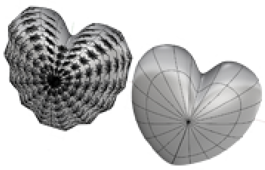
they did not feel like sharing data. Extending beyond the body was also a desired functionality, with the ability for data to be broadcast through personal technology such as smartphones, social media apps and also household lighting.

In the fifth and final section and theme, *Privacy and data*, discussions about privacy and data brought up a different set of concerns from the participants. Women from the focus groups discussed their awareness of data tracking from using the internet, but voiced new concerns about wearables that included the collection of physiological data, worries about who had access and how it might be used to identify personal information about the user. Many of the participants felt they would want to keep their data private and only want to share data, via emotive wearables in select company, and terms such as 'trust' were often used in this context.

In *Chapter 8: Practice post-user studies*, two new research prototypes are discussed which have benefited from study feedback and critiques. This chapter also reports feedback on one of these prototypes from surveys completed by attendees of the ISWC 2016 Design Exhibition.

Chapter 8

Practice post-user studies



Development of two new research prototypes

This chapter describes the creation of two new research prototypes that are extensions of my practice and iterations of the *EEG Visualising Pendant*. These research prototypes have benefited from the feedback I received from the results of the user studies discussed in Chapter 7, but as design outcomes they reflect many more influences than just the feedback.

AnemoneStarHeart EEG visualising device

AnemoneStarHeart can be used as a handheld, standalone device or oversized pendant. It has been developed for broadcasting, amplifying and visualising EEG data. The device is a bespoke iteration of the functionality of the *EEG Visualising Pendant*. I use data sent via Bluetooth from a NeuroSky MindWave Mobile EEG headset to illuminate a laser sintered heart enclosure.

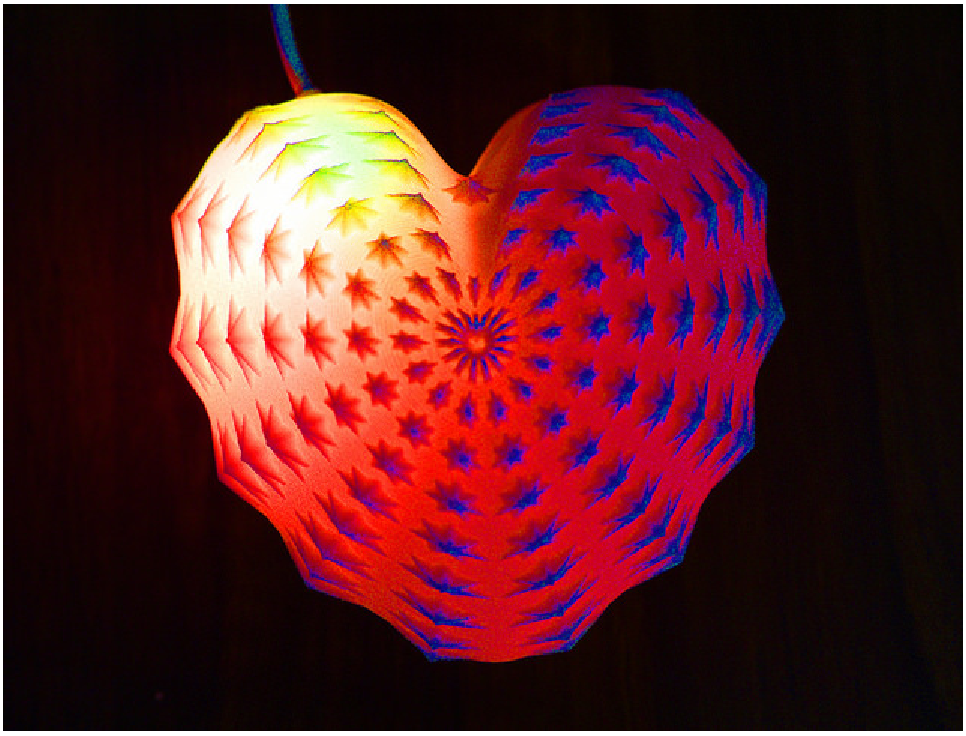


FIGURE 8.1: *AnemoneStarHeart* EEG broadcasting and amplifying device (2015)

The pendant can be used in various situations, which I will discuss in the next paragraphs. The prototypes expand on my own practice, but they have also benefited from the feedback from the participants of the focus groups and field tests about the original device's design and functionality. The participants were interested in finding out about their physiological data but often did not wish to share it with strangers, crowds or when in public places. The reasons they did not want to share their data included feeling self-conscious or awkward, or simply because they wanted to keep their personal data private. Instead, the prototype has evolved as a wearable for use with close friends, loved ones or by themselves. The new device has been designed more for personal use than for the public broadcasting of data, so it can now be used to produce 'mood lighting' in the room in which the wearer is situated, or it can be used by the wearer for practising mediation or to check their levels of productivity (p. 201). In discussions around intimacy, functionality such as being selective about when to use the device, being able to tone down the brightness of the LEDs and having bespoke functionality for choosing how and what data is revealed for different relationships and situations also featured. Further examples of feedback on privacy/private usage are documented in *Chapter 7: Results and discussion* (p. 184).

The device can also be used as an aid for meditation or relaxation. The user is able to sit with the device in their hands, on a chain or close by while they are meditating. While they are doing so, they may if they wish open their eyes at intervals to view their meditation data being amplified as green light. They can also see if their meditative state is wavering as it fluctuates between green and red (for attention) illuminations. *AnemoneStarHeart* also has record and playback modes, so users can record their data while they are meditating and view it later. The live, record and playback functionality also means that the prototype can be used for emotive engineering, as discussed in Chapter 2 (p. 38). The device has a micro USB port so it is possible to record the data straight on to another device or store it if required.

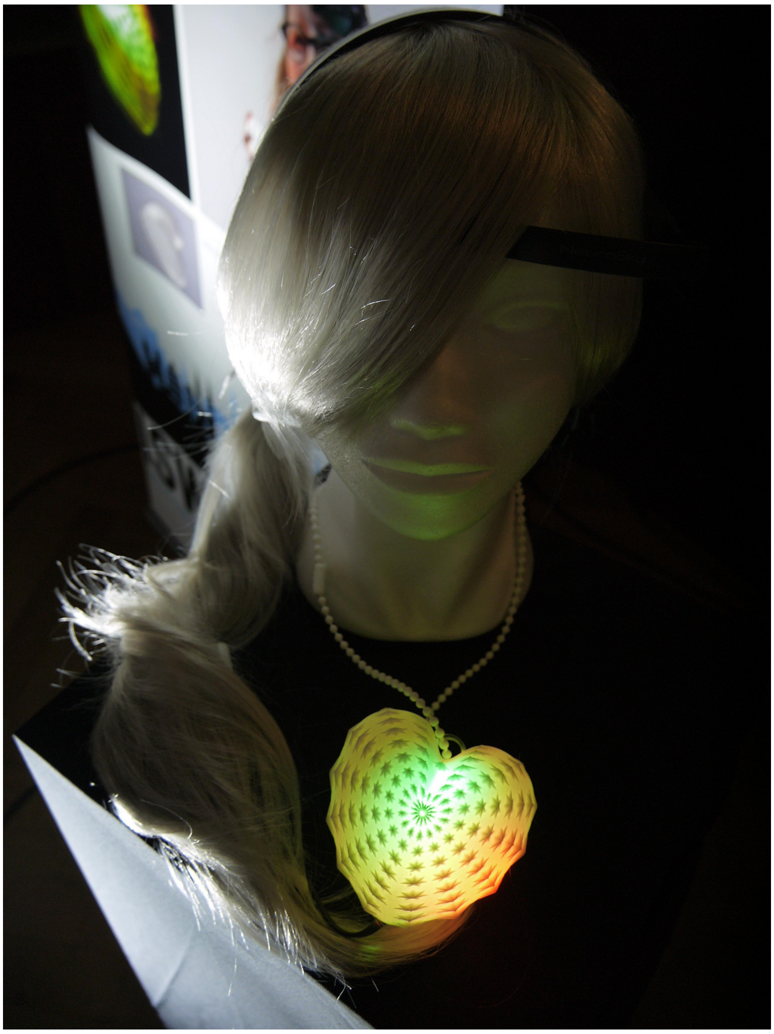


FIGURE 8.2: *AnemoneStarHeart* at ISWC 2016 Design Exhibition where attendees were invited to give feedback on the device (2016)

Design

The aesthetic design of the device is a response to examples of user study feedback that emphasised a preference for the bespoke and personal (p. 186). With this in mind, I have created a heart-shaped device that fits into the palm of the hand, on a chain around the neck or can be kept in a pocket, that can be revealed periodically when the user wants to view it (Figure 8.2, p. 212). The heart shape is reminiscent of traditional Western sentimental jewellery and keepsakes such as a locket or pocket watch, a theme also investigated by Jayne Wallace and discussed in Chapter 2 (p. 44).

I explored a heart-shaped enclosure, akin to a locket, faceted with tiny stars, reminiscent of a sea anemone, which I created in *Rhino 3D*, a CAD software application. This required overcoming a learning curve in order to use the software. The 3D model was laser sintered in white nylon, which gave the heart-shaped prototype a detailed finish. The prototype was printed at 0.8 mm shell thickness to allow LED light to diffuse easily when very bright or turned down to a more subtle glow. This left the enclosure still strong enough to encapsulate and bear the weight of the electronics safely.

Electronics

I designed the smallest electronics circuit possible on stripboard with an *Adafruit Trinket Pro 5V* microcontroller and a *BlueSMiRF* Bluetooth dongle. Because the NeuroSky MindWave Mobile uses Classic Bluetooth, I was not able to use a BLE (Bluetooth Low-Energy) device, because it is not backwards compatible. This was somewhat frustrating because BLE would have enabled me to build a slightly smaller circuit for this device. The device is illuminated by an Adafruit 16 Neopixel RGB LED ring, which is very bright and can illuminate an area of a room.

Code

The code is written in the C programming language and uses a modified version of the code that drives the *EEG Visualising Pendant*, with certain changes as regards to the algorithm that controls the LEDs to allow for smooth mapping and glow/fade of data. The number of LEDs lit at any one time reflects levels of data received from the headset and is processed to reveal it in real time.

Feedback from ISWC 2016 Design Exhibition attendees

At the ISWC 2016 Design Exhibition held in Heidelberg, Germany, I invited attendees from my main academic community to give feedback on the *AnemoneStarHeart* research prototype. Comments from the ISWC community on the concept of the pendant included questioning how the device could affect self-awareness and could effect a change in mental state, and another attendee was interested in seeing the results of evaluations, particularly the social effects of the pendant. These two questions, especially the latter, were answered by the feedback from the participants of my study, the results of which can be found in Chapter 7, which includes insights from those who have worn the *EEG Visualising Pendant*. The feedback highlights various perceived and experienced social effects of wearing the pendant (p. 189). Other feedback from the ISWC Design Exhibition concerned the aesthetics and form of the artefact, comments included describing it as "very bold" and "fascinating to look at", to "I love the aesthetics of translating physiological data into an abstract pleasing representation". However, criticism was aimed at some aspects of the styling of the artefact and another attendee commented that a less obvious wearable would better suit them.

In terms of suggested and future uses for emotive wearables such as the *AnemoneStarHeart* prototype, people thought "it would be useful for individuals who cannot easily communicate emotion/thought" and for linking people to help them understand each other, while other people thought it could be trialled on couples "to verify if meaningful data can be gathered". In terms of privacy, in common with some of the participants' views in previous studies, two of the ISWC attendees said that they would not wear the pendant in public, one commenting further that emotions were a private matter, but went on to say that they thought there were people who would share them. The full list of feedback from ISWC 2016 Design Exhibition attendees can be found in Appendices (p. 283).

ThinkerBelle EEG Amplifying Dress

In common with *AnemoneStarHeart*, the dress benefited from feedback and opinions I garnered from my user studies. As opposed to the aforementioned pendant, the *ThinkerBelle EEG Amplifying Dress* is intended for wearing in public. Its creation was influenced by study participants' feedback, which explored ideas for emotive wearables that would visualise their physiological data in social situations such as clubs where there was loud music, low lighting and dancing (p. 205). Depending on the relationship with the wearer, the onlooker might take cues from the data visualised on the dress and then decide how to interact with the wearer. As with other emotive wearables it would be up to the wearer to decide what they reveal, if anything, about the meaning of the visualisations. For those who are not informed of the meaning behind the visualisations, the garment can be observed as an aesthetic light display. In keeping with the *EEG Visualising Pendant* and *AnemoneStarHeart*, the dress visualises two streams of data as red and green light: attention as red and meditation as green via fibre optic filament. The dress also has the functionality for the wearer to record and play back their EEG data. This could be useful if the wearer wishes to portray themselves in a certain way, for example if they want to appear to be in an intense conversation, they might play back data to illuminate the dress as more red in colour. The significance of this to onlookers could be that because they're in an intense conversation they do not want to be disturbed. Alternatively, illuminating the dress as more green in colour could signify that the wearer is more relaxed and thus approachable (Figure 8.3, p. 215).

FIGURE 8.3: The *ThinkerBelle EEG Amplifying Dress*, illustrating how the fibre optic filaments can be arranged to create bespoke forms (2015)

Dress and fibre optics

The dress is constructed from a medium-weight satin fabric. It was chosen to be comfortable but also able to hold the weight of the electronics. Fibre optic filament woven into a fine organza was chosen as an alternative to multiple LEDs and to a certain degree it is bendable and can move with the wearer, for example when dancing. This fabric was challenging to use as it could only be cut in one direction and had constraints on how it could be manipulated and folded. For example, if the fibre was bent too far it could snap or have an unwanted kink that would prevent light from travelling down it. I wanted to build an an element of personalisation into the dress, as well as movement, and for it to be a sculptural piece. The fibre optic fabric was cut strategically into vertical strips in order to drape and shape it, which also made the fabric much more malleable. I experimented with hooks, poppers, clips and Velcro to find the best way to allow for shaping the fibre optic strips. The ability to shape the fibre optic strips was also an important feature when deciding how the two data streams from the NeuroSky MindWave Mobile headset could be displayed alongside each other. In terms of sustainability, all electronics including the filament can be removed for cleaning the dress and it is powered by a slim rechargeable battery, which makes the garment lighter and more comfortable to wear.

Electronics

The fibre optic filament is illuminated by two super-bright LEDs, though it is relatively low-voltage compared to using multiple LEDs or LED strip. This required researching how to integrate fibre optics with code and other hardware for mapping EEG data. The electronics circuit to drive the fibre optics is small and similar to that of the *AnemoneStarHeart*. It too uses a Trinket Pro 5V microcontroller, but uses extra I/O input and output pins to connect the fibre optics. The dress is sent data from the headset via Bluetooth to a *BlueSMiRF* dongle on the circuit alongside the Trinket.

Code

The code is written in the C programming language, similar to previously mentioned EEG devices, the *EEG Visualising Pendant* and *AnemoneStarHeart*. What was different about the code for the dress was that I experimented with thresholds of packet data. This was to determine how the live data should work with the fibre optic filament and how changes in the data would affect the brightness and fading of light. This allowed me to find a more aesthetically pleasing 'tipping point' for when to begin a change in the fade in or out (Figure 8.4, p. 217), rather than an instant or stark change between increments of a change in levels, but still reflect the packet data, which approached study feedback regarding the patterns/shapes on the *EEG Visualising Pendant* changing too abruptly (p. 201).

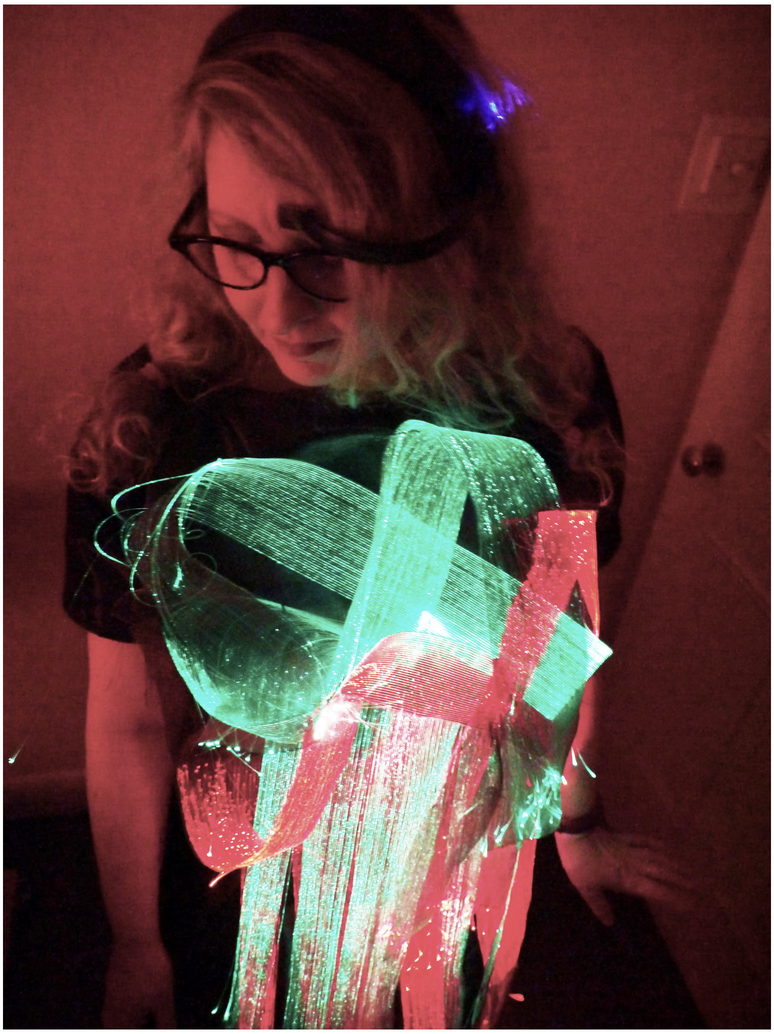


FIGURE 8.4: The *ThinkerBelle EEG Amplifying Dress* displaying sculptured fibre optic filament, to which data is mapped (2015)

Conclusion

My practice has been explored further through the development of two new iterations of the *EEG Visualising Pendant* research prototypes: *AnemoneStarHeart* and the *ThinkerBelle EEG Amplifying Dress*, which respond to themes developed earlier in my practice around nonverbal communication, personalisation and the bespoke. Specific feedback from studies has pinpointed concerns and opinions that have benefited these two prototypes, which have built on the original *EEG Visualising Pendant* prototype. However, as design outcomes they reflect many more influences than this feedback as they have developed from a starting point of my own practice.

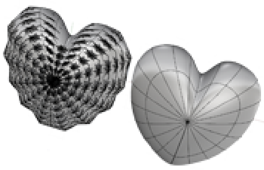
In constructing the two new prototypes, I had to learn how to use CAD software to produce 3D models that could then be used to create enclosures for the prototypes using laser sintering, I also had to explore how fibre optic filament could be used as a new means of displaying and mapping physiological data. These investigations were aided by using the cyclical method I developed for creating and testing multidisciplinary prototypes, which is outlined in Chapter 6 (p. 160).

Feedback on the *AnemoneStarHeart* from attendees of the ISWC 2016 Design Exhibition reflected the community's interest in the social effects of emotive wearables through interest in evaluations and questions about self-awareness. Aesthetics and form factor were generally well received, though there was some criticism about certain details of the artefact and wearing the heart-shaped device was not appealing to all. Attendees gave positive feedback about the potential for the device and emotive wearables in general to be used by people with medical conditions or when the wearer is in specific social situations as a means of communication. Privacy was an issue for some and these participants stated they would not emotive wearables in public. This feedback will be useful for developing future iterations of the *EEG Visualising Pendant* and other emotive wearables, especially in terms of providing examples of the areas to investigate when developing prototypes for individuals with medical conditions that make it difficult for them to communicate.

In the next chapter, *Chapter 9: Conclusions*, I combine the results of my research and practice, and discuss my contributions to knowledge.

Chapter 9

Conclusions



An investigation into wearables and nonverbal communication

This thesis has investigated the possibility that through the exploration and development of wearable technology research prototypes it is possible to create new forms of nonverbal communication using physiological data. I have conducted this research by way of exploring the development of practice prototypes which gather and process physiological data, then visualise and broadcast it. This has been achieved by using various forms of visual display which have been designed to be worn on the body as aesthetically considered pendants and garments.

Through user tests, I have established that there is a potential audience for wearables that convey forms of nonverbal communication by broadcasting representations of physiological data in the form of visual display. This has been achieved through a dedicated approach to participant research that I have designed and structured, based on my experiences conducting user tests around interactive media, to recruit and understand the feedback and concerns of possible wearers of such devices.

There are a number of contributions to knowledge I have established from this research and have listed in Chapter 1 (p. 12), below I have chosen four to demonstrate distinctive and original themes:

Responsive and emotive wearables

I have introduced two distinct terms to describe the field in which my practice is situated within the larger domain of wearable technology/computing. The first was 'responsive wearables' and, as the name suggests, represents devices that 'respond' to the wearer's environment, interactivity, or physiological data from *sensors* placed around the body. The data collected is processed and amplified as sensory output to the wearer and observer, such as through visual, aural, or tactile means. After further investigations, and in order to distinguish my field of research further, I introduced a subset of responsive wearables called 'emotive wearables', that focus on visualising physiological data which can be associated with nonverbal communication, or 'cues', or assigned to communicate or imply the mental states, emotions, or moods of the wearer. These terms have been used by academics and practitioners reporting on this field.

Emotive engineering

Through the development and investigation of artefacts, I have discovered how users of emotive wearables could record and play back their visualised physiological data in a differing synchronicity that would allow the user to change how they are perceived by others and, if required, to manipulate social and formal situations. In order to investigate this area further, and for users to be able to experiment with using their recorded EEG data in different circumstances, I added record and playback functionality to three subsequent research prototypes that I developed. These artefacts were EEG-driven emotive wearables. Emotive engineering is evocative of Goffman's theories around presentation of the self, such as 'fronts' and 'dramatic realization' (p. 146): when a person puts emphasis on certain actions to embolden them to others (Goffman, 1959, p. 40). Emotive engineering takes self-presentation a step further and fills a gap in the technological age by allowing wearables to become a vehicle for adapting and enhancing how we present ourselves to others. This practice has personal, societal, cultural, and ethical dimensions to consider regarding the manipulation of data, for example whether it is considered to be used to deceive or for therapeutic use.

Research prototypes

Through the development of my practice I have generated four distinct research prototypes. These are: the *EEG Visualising Pendant*, the *Baroesque Barometric Skirt*, the *AnemoneStarHeart*, and the *ThinkerBelle EEG Amplifying Dress*. The first two prototypes informed the development of the latter two, which benefited from the feedback and design critiques elicited by my user studies. They have been exhibited, and information on their development has been shared with my research communities through published papers, posters, and exhibitions. These artefacts have demonstrated how data can be broadcast from physiological and environmental information as a form of nonverbal communication or 'cues'. These cues signal or convey information to the user and those around them using mapped light that can be decoded if the user wishes to divulge what the shapes and colours indicate. User studies' participants compared this to a 'secret' or covert visual language, for which potential users suggested various potential scenarios in both private and public situations.

A method for driving multidisciplinary projects

I have found a number of useful methodological approaches to facilitate my research, however I discovered that I required something more exact to solve the problem of managing the progress of complex multidisciplinary projects that combine programming, electronics, and materials in order to create my research prototypes. I created a method which has been useful to facilitate the advancement of my practice artefacts, which uses a cyclic approach of 'Identifying, Concluding, and Updating' via a series of prompts to help me identify problems and make useful decisions in between testing and updating projects in order to push them forward to completion.

Key lessons learned

Through my user studies, and through exploration of projects in the field, I have been able to make observations with regard to how emotive wearables may affect relationships in personal, social, and cultural terms. This was demonstrated by participants who gave examples of how they expected they could use the visualisation of physiological data as a new form of nonverbal communication between friends and family. Despite this, other participants were not comfortable visualising data in public situations for reasons of privacy or because they felt self-conscious drawing attention to themselves by wearing technology so prominently on the body.

A discovery that was pertinent to my research was that potential users are very interested in design and aesthetics. Wearables have had a history of being cumbersome, and lacking in aesthetics, and with wearables gaining in popularity there has been a backlash over the lack of these design and aesthetic considerations. Through my user studies, I have discovered that potential users are very keen to put their stamp on wearables by personalising them so that they become part of their personal style. Having complained about fitness devices lacking in design, they were really keen to express their personalities through technology.

What I have found that has been of interest to my research peers at ISWC and the Quantified Self when I have demonstrated this technology is that emotive engineering represents a new way of presenting the self, and in discussions with peers there are many more instances of when a situation could occur than I had originally envisaged. For example, an individual could relay their relaxed data as as a confidence boost in stressful situations.

Applying this to professional use, for example by doctors, police, or teachers, it could be used to inspire confidence, or to quell an intense situation by appearing calm or attentive while giving instructions.

One of the more compelling discoveries to come out of my research was that user studies' participants compared visualisations to a 'secret' or covert visual language, for which potential users suggested various uses. This was especially evident for groups of friends who would like to keep in contact with each other when they aren't close enough to easily do so verbally, such as when they are out clubbing or socialising. The benefits of this were seen as being able to keep a check on friends in case they were being hit on, harassed, or were being left out of the group.

Reflecting on how the perceived use of the pendant compares to its actual use, it is telling that two field tests out of a total of twenty-two were abandoned due to participants feeling awkward about taking part having arrived at their own initial choice of venue. This indicated that the location and the presence of strangers can affect a user's confidence in wearing an emotive wearable in public. Having considered their own reactions, each of these participants were happy and comfortable taking part in a new location of their choice when rescheduled, with one commenting "wearing it was fun."

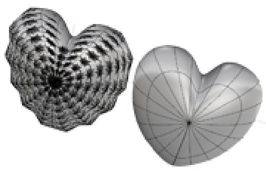
What became clear in these discussions is that there are many possible form factors that emotive wearables might take, and that these are related to where people might want to wear them. To some degree, these preferences are simply related to aesthetic preferences or possibilities for the devices. In many cases, however, they reflect considerations about how the devices might be used, the data they might display, and the degree of control or privacy people might want.

Future practice

Post doctoral studies, I have plans for important work to be done in the area of emotive wearables. As we have seen, the user studies uncovered that there is much more to be done in the investigation of emotive wearables. For some time, I have been discussing new projects and collaborations that will lend emotive wearables to new form factors and sensory engagement which takes emotive wearables beyond visuals. I also wish to further explore bespoke and personalised wearables, and the customisation of modes and visuals for pushing forward opportunities to connect and create cues, signals and "secret languages".

Responsive wearables and emotive wearables are still evolving areas, and have the potential to be explored by both the academic and the creative industries. I am looking forward to getting the chance to return to ISWC to discuss the possibilities with my peers. Technological opportunities for further research include the development of sensors, and methods for interpreting the data, but also research into materials and improving bespoke electronic components which raise the possibility of collaborations with scientists and engineers.

Appendices



Appendix A

Glossary

3D Printing — a term to describe various processes employed to create a three-dimensional object. In 3D printing, consecutive layers of material are laid down following a computer's control, this is also known as additive manufacturing.

Actuator — is a device that converts electric current into motion, such as a motor.

Adafruit Trinket Pro 5V — a small microcontroller without headers, but uses the Atmel 328p microcontroller chip, so is comparable to the *Arduino Uno*, but much smaller.

Affective Computing — the study and development of "computing that relates to, arises from, or deliberately influences emotions" (Picard, 2000, p. 3). It is an interdisciplinary field that includes psychology, cognitive science and computer science.

Affordances — a way of focussing on the strengths and weaknesses of technologies in respect of the possibilities they offer to users (Gaver, 1991, pp. 79–84)

Amplify/Amplifying — I use these terms to describe the process of taking data and 'amplifying the signal' for example making it apparent to others, for example, by visual, tactile and audible means.

Alumide — nylon mixed with powdered aluminium, used for SLS (Selective Laser Sintered) 3D printing models.

Arduino Uno — a microcontroller board used for prototyping. It has multiple digital and analogue I/Os (inputs and outputs) for connecting to electronic components. `https://www.arduino.cc/en/Main/arduinoBoardUno`

AR (Augmented Reality) — technology that enhances a real world view of an environment by superimposing computer-generated input, such as graphics, video, sound, or other data.

Barometric — relates to atmospheric pressure. A barometer is a scientific instrument used in meteorology to measure and indicate barometric pressure.

BBC (British Broadcasting Corporation) — the public-service broadcaster of the UK. `http://www.bbc.co.uk/`

Behaviour change — to change an aspect of one's behaviour. A behaviour change method or intervention could be described "as coordinated sets of activities designed to change specified behaviour patterns." (Michie et al., 2011, p. 1)

Bluetooth — a wireless technology standard for sending and receiving data over short distances from mobile and static devices, plus personal area networks. There currently exists Classic Bluetooth and more recently Bluetooth Low Energy (BLE).

BPM (Beats Per Minute) — used for counting/pace, for example heart rate or in music.

Breadboard — a reusable electronics terminal array board, used for prototyping electronics. The board comprises lines of connected points in a perforated block of plastic that are used to plug in electrical components to build and test circuits.

C Programming Language — a general purpose programming language developed by Dennis Ritchie between 1969 and 1973 at AT&T Bell Labs. Many subsequent programming languages have drawn from C directly or indirectly.

CAD (Computer–Aided Design) — specialist software and computer system that is used for the creation and optimisation of a design. It is used to improve the quality of 2D and 3D designs and files, used, for example, for graphics, product design and 3D modelling, as well as for industrial use, such as mechanical design.

CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering) — consumer group. `http://www.nocards.org/`

Chimera — a single creature with genetically different cells, which can result in mutations and variations in its form. The name 'chimera' comes from Greek mythology of a fire-breathing animal with parts of more than one species of creature.

Cloud computing — is the practice of storing regularly used computer data on multiple servers that can be accessed through the Internet (Merriam-Webster, 2018*a*)

Computer Mediated Communication (CMC) — is the act of human communication via two or more electronic devices.

Conductive Thread/Yarn — thread containing a metallic element to conduct power and/or a signal between electronic components.

Cyborg — "a person whose physical tolerances or capabilities are extended beyond normal human limitations by a machine or other external agency that modifies the body's functioning; an integrated man–machine system" (*Oxford English Dictionary Online*, 1999).

Darlington Pair — a pair of transistors in an IC (Integrated Circuit) that acts as a single transistor, but has a much higher current gain. This means a smaller amount of current can be amplified to drive a larger load.

Dynamic wearability — the interaction between the human body in motion and wearable artefact.

ECG (Electrocardiogram) — a test to check for electrical activity problems with the heart. The test shows the electrical activity as line tracings that peak and dip.

EEG (Electroencephalography) — recording of electrical activity of the brain, via electrodes on the scalp that pick up small electrical impulses.

EEG Visualising Pendant — a pendant constructed of an 8 x 8 light-emitting diode matrix and 3D printed frame, which visualises via a series of enlarging and shrinking shapes, the attention (shown as red LEDs) and meditation (shown as green LEDs) data from an EEG headset.

EEPROM (Electrically Erasable Programmable Read–Only Memory) — a type of non-volatile memory (can be retrieved after turning off and on) that is used in computers and electrical devices to store small amounts of data.

EMG (Electromyography) — an electro-diagnostic technique for recording electrical activity from the skeletal muscles. A device called an electromyograph is used to create a recording called an electromyography.

e-textiles — also known as 'smart textiles' are fabricated by integrating electrical circuits into traditional textiles to modify their functionalities. They are considered to be 'smart' as they have functionality that enable them to respond to environmental stimuli, such as mechanical, thermal, chemical, electrical and magnetic (Dias, 2015, p. 22).

Fashtech — abbreviation of fashion technology, which describes the fusion of fashion and technology.

Fimo — malleable clay that comes in various colours, and which is most often used for craft purposes. It sets hard when oven baked.

Fibre optic filament — made from glass or plastic, fibre optic filament is mainly used as a way of transmitting light from one end of the glass or plastic to the other.

Finite State Machine — a mathematical model that can be applied to logic circuits or programming and has a finite number of states that it can be in at any given time. It can only be in one state at a time. An example of a finite state machine is a light switch — it can only be in one state at a time, on or off.

Fitbit — a small electronic pedometer that measures the wearer's steps, stairs and sleep. The device can be worn as clipped on to clothing or as a wristband. Data from the device is uploaded to the manufacturer's website and transformed into graphics, such as charts. www.fitbit.com

Framework — structure underlying a system, concept, or text (Oxford Dictionaries, 2017).

Google Glass/Project Glass/Glass — an OHMD (Optical Head Mounted Display), wearable technology device. It allows the wearer to browse information from the internet, plus take photographs and video using voice commands. It was first made available to developers in the US in April 2013 for $1,500, and then to the pubic in May 2014. In January 2015, it was announced by Google that it would stop producing the *Google Glass* prototype, but would move on to the next phase of the project. The device was beleaguered by controversy, regarding privacy, ethics and security issues, which led to it being banned in various facilities and public places. `https://www.google.co.uk/intl/en/glass/start/`

GPS (Global Positioning System) — a navigation system using four space satellites with an unobstructive line of sight to pinpoint a location on or close to the earth.

GSR (Galvanic Skin Response) — a method of measuring electrical conductance across the skin, which fluctuates according to the moisture being produced by the body's sweat glands. This fluctuation in moisture is of interest because sweat glands are controlled by the sympathetic nervous system and is indicative of psychological and physiological arousal in the body, such as excitement or fear. *Also known as EDA (Electrodermal Activity) and EDR (Electrodermal Response).*

Hack/Hacking — to take a piece of software and/or hardware and change or extend its capabilities.

Hackathon — an intensive event, often held over a weekend, where hardware and/or software developers get together with designers and others to share ideas and build projects. Usually with a theme or common goal. *Also known as a hack days or hack fest.*

Haptics — technology that recreates tactile/sense of touch feedback to the user by the application of vibrations, forces or stimulation via mechanical means.

HCI (Human Computer Interaction) — research into the design and use of computer technology, particularly the interfaces between people/users and machines.

HMD (Head Mounted Display) — a HMD is a small optical display mounted in front of one or both eyes. They are used in areas such as medicine, aviation, science and gaming.

Horripilation — 'goose bumps' or the bristling feeling of hair standing on end due to disease, terror or chilliness (Merriam-Webster, 2017*b*).

IC (Integrated Circuit) — a set of electronic circuits placed on one small plate, usually silicon, and is useful because it is small and can replace a circuit made from multiple electronic components. *Also known as a chip or microchip.*

Infrared — invisible radiant energy, which is electromagnetic radiation that has longer wavelengths than the red end of the visible light spectrum, but less than microwaves.

Informatics — Also known as information science: the processing of data for storage and retrieval.

IoT (Internet of Things) — humans, animals or objects embedded with electronics that are uniquely identifiable and are able to exchange data over network to other devices.

Laser sintering — see *Selective laser sintering*.

LED (Light Emitting Diode) — a diode that emits light when a measured voltage is applied to it.

Lifelogging/LifeGlogging — is the practice of recording one's life constantly, using technology such as wearable cameras with an automatic timer shutter, or video cameras.

LilyPad Arduino — a sewable microcontroller (small computer board) developed by Leah Buechley and SparkFun Electronics in 2007 for e-textile and wearable technology use. It has multiple sewable digital and analogue I/O input and output pins for connecting to sensors and actuators with conductive thread. `https://www.arduino.cc/en/Main/arduinoBoardLilyPad`

Lizzy — an experimental wearable computer system developed in 1993 by Doug Platt and Thad Starner at MIT Media Lab that was intended as a general-purpose wearable computing system. The name 'Lizzy' came from the nickname of the popular vintage American Model T Ford motor car: 'Tin Lizzy', because the machine could be adapted to do whatever task was required (MIT Borglab, 2017).

MAC (Media Access Control) — a numerical network address, which uniquely identifies a device.

Machine Learning — the capacity of a computer to learn from experience and to modify its processing on the basis of newly acquired information (OED, 2018).

Microcontroller — a small computer on an IC (Integrated Circuit), it features a microprocessor core, memory and programmable input/output for peripherals.

Microprocessor — a processor on an IC (Integrated Circuit) that incorporates the functionality of a computer's CPU (Central Processing Unit). The device accepts digital data input for processing and storage in its memory. It will output data results as per instruction.

Mindfulness — "the practice of heightened or complete awareness of one's thoughts, emotions, or experiences on a moment-to-moment basis" (Merriam-Webster, 2018*b*)

MIT (Massachusetts Institute of Technology) — a research university in Cambridge, Massachusetts, USA, founded in 1861.

MIT (Massachusetts Institute of Technology) Media Laboratory/MIT Media Lab — an interdisciplinary research laboratory in Cambridge, USA, dedicated to projects at the intersection of science, technology, art and design. `http://www.media.mit.edu/`

Muse — an EEG (Electroencephalography) headset produced by InteraXon. It has has seven sensors, five on the front band and one on the band that goes behind each ear, which according to their developer site detect: Alpha, Beta, Delta, Theta, and Gamma waves, blink and jaw clench detection. InteraXon have released an SDK (Software Development Kit) for the headset. `http://www.choosemuse.com/`

Narrative Clip — formerly known as Memoto, which was launched on the crowdfunding website, Kickstarter.com, is a wearable camera used for continuously recording images during daily life. The device has a timer setting for recording images (*Narrative Clip 2* also records video) at set intervals. This practice is also known as 'lifelogging' or 'lifeglogging'. `http://getnarrative.com/`

NFC (Near-field communication) — a wireless technology for digitally transmitting information over short distances (usually between a smartphone and another device) using radio waves (Merriam-Webster, 2018*c*)

NeuroSky MindWave Mobile — a single electrode, consumer EEG (Electroencephalography) headset.

Nike FuelBand — an activity tracker worn on the wrist as a bracelet that featured coloured LEDs to show activity progress. The device allowed the wearer to count movement such as steps. It was launched in 2012 by fitness clothing company, Nike.

Nonverbal Communication — communication between humans using cues without speaking, such as body language (kinesics), time-based cues (chronemics) eye contact (oculesics), distance (proxemics) and touch (haptics).

Observers (in field tests) — those who were engaged in social or work exchanges with the wearers of the pendant.

OHMD (Optical Head Mounted Display) — an OHMD is an optical display that can both reflect projected images and also allow the wearer to see through it. A HMD is a small optical display mounted in front of one or both eyes.

Onlookers (in field tests) — those who happened to be in the vicinity, for example a bar tender or waitress in a restaurant who was intrigued by what was occurring.

Open Source — originally from the context of computer software, 'open source' refers to a set of values that make an item or project freely available to reuse or modify by individuals or groups.

PCB (Printed Circuit Board) — a thin, board usually comprised of laminated copper sheet, which allows for the connection of multiple electronic components using conductive tracks. PCBs can be found in all electronic products, except for very simple circuits.

Performativity — derived from the verb 'to perform', it is a term used for the act of embodied presentation to act out or consummate an action. For example to act in a play or to dance.

Proxemics — one of a number of subcategories used to describe nonverbal communication. It was coined by Edward T. Hall in 1963 and described in his book *The Hidden Dimension* as "The interrelated observations and theories of man's use of space as a specialized elaboration of culture". (Hall, 1966, p. 1)

RFID (Radio-frequency Identification) — the use of wireless, radio-frequency electromagnetic fields for transferring data. This technology is used for identification, tracking and transference of data.

RGB LED — Red, Green and Blue LED. Usually refers to a single package containing one of each LED that can still be lit individually.

Rhino 3D — a CAD (Computer-Aided Design) software application, used for 3D modelling and computer graphics. `http://www.rhino3d.com/`

Selective laser sintering (SLS) — a technique that uses a laser to meld particles of plastics and other powdered materials such as glass and ceramics into a three-dimensional shape. It's often used for small runs or creating prototypes from CAD (Computer-Aided Design) files.

SenseCam — a wearable camera that takes photographs automatically by timer or by heat sensor, audio or accelerometer triggers. It is used for 'lifelogging' (also known as 'LifeGlogging') purposes. The device is produced by Microsoft Research. `http://research.microsoft.com/en-us/um/cambridge/projects/sensecam/`

Sensor — a device that converts a physical energy signal into an electrical signal.

Shrimp kit — a low-cost microcontroller kit that comes as a bag of components. It uses an Atmel 328 microcontroller and is comparable to the *Arduino Uno*. `http://shrimping.it/blog/shrimp/`

Smart Clothing — refers to clothing embedded with electronics, such as microcontrollers, which perform a useful function for the wearer. *Also known as smart clothes. See also,* Wearable Technology.

SMS (Short Message Service) — the text messaging service used by a phone, mobile communications system or the web.

Star Trek — a current American science fiction franchise, which began with a television series in 1966. It follows the altruistic peace-keeping missions and predicaments of a group of humans and aliens travelling the universe. Many of their dilemmas echo modern-day social themes. Since the original series there have been a number of spin-off TV series, films, comics and novels.

Stripboard — a generic name for prototyping board that is comprised of a grid of holes that connect in tracks to allow for connectivity between components. It is made from a hard epoxy substrate with a copper backing that can be cut depending on where components are positioned. Once components are positioned, they are soldered into place.

Twitter — a social networking platform that allows users to send messages of up to 140 characters, called 'Tweets', and also read messages by others. `http://twitter.com/`

Ubiquitous Computing — the concept of computing post-desktop era, with everyday objects and devices unobtrusively networked, integrated and communicating so that they are always available.

Unconference — a themed event where attendees present all talks and sessions. Usually, the attendees create the schedule on the day of the event by adding their name and presentation topic to an open grid schedule. The unconference format is said to have originally been created by the technical book publishers O'Reilly, who in 2003 ran an invitation-only event called FOOCamp (Friends Of O'Reilly Camp). The unconference idea was taken up by others and developed into various types of facilitation events, such as 'BarCamps', where the emphasis was on anyone being able to attend or participate (Bacon, 2012, p. 426).

USB (Universal Serial Bus) — is an industry standard for defining communications protocols, cables and connectors that are used to connect computers and electronic devices to transfer data and power.

Wire Library — allows *Arduino* microcontrollers to communicate via I2C (pronounced I-squared-C), also known as TWI (Two Wire Interface) devices. It is used for attaching ICs (Integrated Circuits) to microcontrollers.

ZigBee — used for creating wireless personal area networks (PAN) to, for example, send and collect data, ZigBee is a low cost, low power, low bandwidth suite of high-level communication protocols. It is used by small devices such as devices in the home, medical wearables and various wearables prototypes, as well as hobbiest projects.

Appendix B

Focus group and field test materials and transcripts

In this appendix I have included images of recruitment materials, survey and consent forms that were used for focus groups and field tests in November and December 2014.

DEPARTMENT OF COMPUTING
Goldsmiths, University of London,
London, SE14 6NW.
Email: r.ashford@gold.ac.uk
Rain Ashford, PhD candidate

Goldsmiths
UNIVERSITY OF LONDON

Focus group testing participants required: EEG Visualising Pendant

Are you, female, aged over 18, a user of, or have opinions on wearable technology? Would you like to participate in a focus group about attitudes to wearable technology and help evaluate a device for visualising EEG brainwaves in social situations?

What is the purpose of doing this study?
The purpose of this study is to investigate how women feel about using wearable technology and in particular a device that records, amplifies and broadcasts their physiological data to those around them. It is also to help improve the design and function of the next prototype of this device.

What will happen in the focus group?
I will be running 3 focus groups with women aged 18-24 and 36+(25-35 group now filled thanks!). Participants will be invited to attend a small gathering of 6-8 participants at **Goldsmiths Campus in New Cross or C4CC in Kings Cross**, on the **2-6th June 2014**, please contact me for exact times and dates.

Participants will be demonstrated the EEG Visualising Pendant, including how it works and what it is intended for. Afterwards participants will be asked for their opinions in a discussion on the device and wearable technology, and also to complete a questionnaire on thoughts about wearable technology. Participants will not be asked to wear the device I offer a £20 thank you (+ £5 towards travel if needed) for 2 hours participation. I will record the sessions, though all data will be anonymised.

Where can I find out more about the study?
If you are interested in participating or for further information on this study, please contact Rain Ashford at **r.ashford@gold.ac.uk**

r.ashford@gold.ac.uk
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FIGURE B.1: Recruitment flyer for focus groups in November, 2014

<u>Field Trials: EEG Visualising Pendant</u>

Thank you for taking part in the EEG Visualising Pendant field trials, I'd be very grateful if you would consider the following questions about your experiences to help me improve the prototype pendant and also to feed into my research and presentations. All questions are optional and you may stop the field trial at any time. Data will be anonymised and stored securely. If you have any questions or feedback please contact me at r.ashford@gold.ac.uk

Please describe your experience of wearing the EEG Visualising Pendant, for example, how did wearing it make you feel?
How did the pendant affect your interaction with others, for example, did they question or engage with the device?
What feedback / reaction did you get from those you interacted with?

FIGURE B.2: Survey, page 1, used to obtain feedback on emotive wearables (2014)

What was your opinion on the look and feel of the device: it's design/form factor, position on the body, did it attract others to engage with it?
Is this kind of physiological feedback useful / attractive to you – if so how and in what circumstances would you be prepared to wear it?
Do you have any other comments or feedback on the pendant?

What nationality are you?

What is your age group?
18-24 [ ]
25-35 [ ]
36-49 [ ]
50-64 [ ]
65+ [ ]

Gender: Male / Female

Leave as blank any questions that you would prefer not to answer.
Thank you very much for your help.

FIGURE B.3: Survey, page 2, used to obtain feedback on emotive wearables (2014)

Goldsmiths
UNIVERSITY OF LONDON

RESEARCH ETHICS CONSENT FORM

Title of Project: EEG Visualising Pendant

Researcher details:
Rain Ashford
Department of Computing
Goldsmiths, University of London,
New Cross,
London SE14 6NW.
Email: r.ashford@gold.ac.uk

Please Initial Box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason. ☐

3. I agree to take part in the above study. ☐

4. I agree to the focus group / session being audio/video recorded ☐

6. I agree to the use of anonymised quotes in publications / presentations ☐

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

FIGURE B.4: Consent form used by all participants of focus groups, field tests and ISWC participants (2014)

Audio transcript 1, focus groups, women 18–24 age group

The focus group was comprised of four participants, who happened to be students and was recorded on 4th June, 2014, at Goldsmiths, New Cross, London.

Participants:

- MA student of Digital Anthropology.
- MA student of Political Communications.
- BA student of Communications.
- BA student of Communications.

This discussion follows a presentation that I gave for the first half an hour on emotive wearables. I have listed participants' initials instead of names, when I am speaking I have used initials [RA]. I have discarded chat at the beginning/during that included informal/personal information not related to the research.

[RA] What would happen if groups or all people started wearing this (the pendant), how would it change things culturally?

[BL] What do the coloured lights mean, the green and the red?

[RA] The 'attention' data is red and the meditation data is 'green'. So allegedly when you're concentrating, like reading a book or thinking about something, such as 'mm crisps' or interested in something, then the attention lights up as red. The shapes also grow and contract. It cycles through diagonals, rectangles and circles. They (shapes) do not mean anything in themselves; I've just done that as an aesthetic idea to give the user experience more oomph. If you didn't want to tell people what it was you could just wear it as an aesthetic object, but if you did want to tell them about it you could.

[AK] Is it heavy?

[RA] No one of the things I want to do is reduce the size of the battery, as right now I want to carry this around (shows battery). I want to get rid of that and get a smaller version, maybe a lipo (lithium polymer)

[ES] wouldn't always be showing like a necklace, unless you tuck it in, gives you more choices how you would display it and wear.

[XZ] It would it also depends what purpose you're using it for, I'm really interested in the idea that you can use it to figure out when you're most productive, wearing it would be fine but if you want to monitor or find out your daily behaviour without people knowing, that would be a good solution, it depends on the purpose though.

[AK] Yeah, if it was a situation where everyone started wearing them then everyone would be yeah let's have it as a necklace then everyone could see it really easily. Yeah, it might create a situation where you as you want to discover you having to say to anyone to see what you're feeling, but that would be a situation where a lot of people would wear it and it's like become a thing.

[BL] I don't know if people would wear it because they won't feel like revealing their feelings, I don't think the majority of people would like that. If you feel good about yourself then that's really great. But what purpose is it for?

[RA] I envisage it will be used for new forms of communication and I'm investigating that in my research.

[AK] I was just thinking that what strikes me about it is, it's a really honest thing and maybe because it shows your feelings, obviously just because your heart rate is speeded up it means a certain thing, it could be for a number of reasons, but I think so much of what we put across on social media is just a representation of how we want to show ourselves, like I follow so many bloggers and people on Instagram and stuff and it always seems like their life is perfect, but when you think about it, it's what they put forward but then with technology like this it's not fake, well you can probably manipulate it eventually, but you can't fake what it's showing, but it's like a new level of honesty. If you're in a job interview, the thing is they tell you 'don't be nervous', ' don't act like you're nervous, keep your hands in your lap and not fiddling with your hair ever, and I've been to so many job interviews where at the end they say 'oh you seem really confident' like I am confident but I wrack with self-doubt at every point of my life but I can hide it quite well and I put on this front of being confident, so if I had this thing on that actually showed that I was freaking out it would ruin my front that I'd taken so long to perfect.

[RA] Have you read the work of Erving Goffman?

[AK] No.

[BL] I have a little bit

[RA] You'd probably appreciate his work as he talks about social fronts (continues to describe Goffman's work).

[XZ] I'd probably wear it if I was going to a party or a rave to see what emotion I would have during the night, but at the same time being self conscious would be a drag, to always know what I'm feeling or knowing there's something around my neck telling people what I'm feeling is probably scary. I think it's probably good for 14 year olds who don't know what they want in life and they can wear it and look at things they might react positively to certain things then say I want to do this when I grow up.

[RA] I thought it might be nice to wear in a rave or noisy pub as you can't always hear what people are saying. . .

[ES] Re. record and play: if you were to wear it at a job interview and it made you look alert, if your body language slipped wouldn't it give it away that you'd recorded?

[RA] Well that's a very good question, how true is our body language compared to our thoughts – can we be that alert that we can control it. It's really difficult to control minute facial movements and that's where there's a huge amount of discussion, say if someone's lying or if they really like something.

[BL] What I find interesting is how do the programming of transferring the EEG qualify that as emotion or a certain amount of attention, does it differ from person to person?

[RA] Oh definitely. The signals are there for interpretation; I was looking at this device in terms of giving social cues.

[ES] Might be interesting to wear it at speed dating if everyone in the room was wearing it.

[AK] I go on a lot of dates and it's really hard to tell what's going on, you'll be sitting there half way through thinking 'this is going well' but this is going awfully and they're just putting on a front, so yeah I think it'd be really interesting, but also probably really scary to try and end up analysing what you see on people's necks. to try and work it out. For dating as it signifies the start of a relationship, where as though not all social situations would be appropriate for that. If you were meeting new people or meeting a group of friends in a bar and there were other people you didn't really know you wouldn't want to show them everything or your feelings straight away.

[XZ] It might be a bit of a discouraging if you approached a group of new people and wanted an 'in' but they all had meditative responses I wouldn't even try.

[AK] It would be like the new social exclusion if I could see they were all bored and uninterested in me.

[BL] What if you used it a court setting or a something during a prosecution, I could see that being a requirement of the participants of the court case to be wearing.

[RA] GSR, similar to use of (lie detectors in TV shows like) Jeremy Kyle?

[ES] I'd like to use it to make sure the jury are paying attention.

[RA] But what if you started having to use these devices at work to see if you're all paying attention?

[AK] Oh god, we'd all get fired 'cause no one pays attention at work most of the time!

[BL] Maybe it'd be a good thing, as it would show that an eight-hour day is necessarily the most productive way of doing your work. Maybe it would help increase people having proper breaks and lunch hours as your productivity does decrease, a lot of people spend a large amount of time on something and not get a lot done, but if you're focussed for say three hours you can get a bit done and maybe it would change the workplace

[RA] Do you all know what activity trackers are? They're fancy pedometers. In return for data services they sell your data – what do you think of that side of it?

[XZ] What, selling your data?

[BL] It puts you in such a vulnerable position, because do you really have a choice to use the *Fitbit* if you were put in a workplace situation where you had to or do you just have to pay a higher premium for your insurance if you refuse?

[RA] Um I'm not sure, I read some companies base their staff insurance premiums on how much you and your family exercise.

[BL] Maybe there's a way to manipulate the tracker, maybe there's a machine that could shake it so you get the steps or something?

[RA] Yes, I like the idea of manipulating the data in that way.

[AK] I think there's already enough outlets via which we don't even know our data is being sold and used, even simple stuff like cookies and tracking online, it is quite scary how little we all know about how much we are on a system and we're on the radar and would be wary of that. There are certain types of data, it doesn't matter if someone has it, or if they've got enough data from different outlets that they can build a picture of you and you don't even know who you're putting out there. So I'd find that worrying.

[XZ] Yeah I think something as personal as this (the pendant?) is quite worrying. It is building up a demographic you fit into, it's too personal as about what's happening to your body rather than what you're physically doing with the internet. It's a bit more invasive if you're people have that kind of data.

[AK] What if we were all wearing these kind of technologies and you took drugs, it would mess with the readings wouldn't it? And then if someone had that data and they knew the patterns or readings of those if they took drugs. It sounds like a good idea, but there's always negatives of how people chose to use things, like social media is a great idea, but really, is it? Because you're putting yourself out there and you can stalk someone by just knowing their first name and where they're from.

[BL] So does any data that goes through some process of anonymisation that exact process can be engineered backwards-engineered and non-anonymised I guess.

[RA] What do you think about having the choice between paying an extra premium for the software to process your data, so you get to keep your data for yourself vs. letting a company have your data?

[AK] I'd rather not, because why should I have to pay someone to secure my data because that means if you don't have money, you don't have the right to your data.

[ES] If I had to have it I'd rather pay the money though, like if it was compulsory.

[RA] What do you think about this pendant? Thinking about would you wear it, what do you think of the aesthetics?

[ES] I think it would be good if it was in an iPhone case, the phone could charge it and it would be pretty.

[XZ] I'd probably wear it to a party and meeting people, but only if other people had it or I'd feel self-conscious and I'd not enjoy the rave.

[AK] I really like the design of it, it looks like something you might buy in Cyberdog or something, you'd wear to a rave. I'd be interested to wear it but I wouldn't wear it all the time, I would wear it in certain social situations as a badge or a pin I could cover up.

[RA] So something you don't wear all the time or could switch on and off?

[AK] Switch on and off would be good.

[ES] I think I'd wear it as a pendant, if it didn't have such a big battery and headset.

[XZ] I think the lights are quite aggressive, they're really in your face, but I'd definitely wear it, I think it's very interesting,

[BL] I think I'd be a bit self-conscious to wear it, especially at first you'd have to explain it every time and it does put you in such a vulnerable position, and it's definitely something you'd have to get used to. I'd wear it around people I already trusted and already knew. I think a badge or a brooch is a good idea as well, because of the gender aspect because males would be interested in wearing it – maybe, maybe not, I dunno.

[RA] What other comments do you have?

[BL] Pets would be really interesting!

[RA] Yes it would be really interesting to find out about pets! Last slide... What do you think about emotive wearables in general? Consider how do define wearable tech, where it's going, do you think emotive wearables sounds like a possibility and what would you broadcast?

[AK] I don't know how you would measure it, but whether you were comfortable or uncomfortable in a situation. If there was some way of determining that, I think it would be quite interesting because I'm quite active as a feminist and there's quite a lot of discussion about casual sexual harassment and a lot of guys don't realise it's classed as sexual harassment, like when they come up to you in a club and start hitting on you. If they could see that you're uncomfortable with that they would maybe realise more that you don't want to talk to them as they're assuming you want to talk to them. I don't know how you'd do that, maybe heart rate or something, but I would mind broadcasting that I was uncomfortable in a situation.

[XZ] I don't understand why you just can't tell them you're uncomfortable! Like if you're in a club and they can see that you're uncomfortable, to see it, like a fashion accessory like a skirt, vs. you don't know is more effective.

[ES] I people respond differently to visual things and verbal things so it depends on the person if they respond to verbal, so if they saw you were visibly uncomfortable the wouldn't put you in that kind of position.

[RA] Describes about *Yr In Mah Face* t-shirt – comfortable/uncomfortable in social situations.

[AK] What do you mean by augmenting emotive wearable tech. . . .

[RA] Additions to the body that would create new ways of visualising nonverbal communication.

[ES] Well if it caught on enough then you wouldn't have to be looking at someone's body language, you'd know by what lights were flashing.

[RA] So what would that do societally and culturally for us staring at interfaces?

[AK] Turn us into robots? (Everyone laughs).

[BL] I don't know how easy it is for people to start looking at them because, it's sort of instinctual to look people in the eyes or to look at people's facial features or their body language it's sort of wired in their brains. So to think it'd have to be a whole set of new social cues and such that would have to start up around at wearables instead. There's also like you know when you're on Skype and stuff and you start using this for the first time and you really saw yourself communicating and you're talking to something and you see yourself in the corner and then you'd be something very similar. You'd be so used to seeing a person's face and all of a sudden you're paying attention to something in the corner

[ES] (on wearables) Yeah you always check over it yourself (like when you're checking yourself on Google Hangout or Skype) — it might be that you'd be checking your own wearable or something. You might engage more with what you're doing — at least you're not looking at your phone. Rather than looking your phone or looking at someone else's data and applying that — it might make the conversation more interesting?

[RA] Thinking of people on trains, etc, you see looking at devices, but alternatively with wearables would we look at those instead and be a bit more curious of the people around us?

[AK] That would be nice, actually, if it gave you an opportunity to like engage with strangers, especially in London, which you don't really do. Even if you were up in their armpit on the tube you wouldn't stoop to say hello to them or anything. So yeah that would be a really positive and interesting thing and that would be a fun side effect of wearing it, then that would encourage me to wear it.

[BL] The same kind of wearable could be almost sinister in that if someone was just looking at your data and they didn't even have one themselves but they were paying really close attention to yours. What if they weren't talking to you but staring at your chest looking at your pendant and you just think y'know, that could be really uncomfortable too, especially if they weren't showing off their own pendant. It might be one sided in that sense you might start feeling, I'd start feeling a bit vulnerable.

[RA] So where on the body would you feel less vulnerable?

[BL] I don't know actually, because I wouldn't feel so vulnerable if as a pendant if there were other people around, but if you were the only one it might start feeling a bit uncomfortable, but I think its a natural place (pendant on chest) to wear it because it's close to your face. It like you see it being there, I think it takes a bit of getting used to.

[ES] It's almost like I can never talk on the phone in public areas when it's quiet everywhere because will people know more about my life and I find that scary in the same way.

[BL] There's always that obnoxious person on the phone too, really loud on the bus or something.

[RA] Where would you wear something? You said you'd wear it here (points to chest) but were would you wear it if you had a choice?

[XZ] I would only wear it 24/7 if everyone was wearing it, so you didn't have that fear of vulnerability. In particular situations and if you were in an argument with someone and you wanted to enhance your emotions.

[BL] I can see it being a cocktail ring size, because that's easier to slip on and off if you want, or show it off or if you feel they haven't been paying enough attention or something. Or to hide it too.

[XZ] A watch might be interesting to have it on your wrist, or a bracelet, 'cause it's less out there. A badge I guess you'd just pin it there (on chest).

[ES] I think an implant would be amazing!

[RA] In the 70s mood rings were all the rage...

[AK] Yeah, they were all the rage when I was little in the 90s, I had so many, it's that feeling of it's telling me I'm calm so I must be calm and keep checking your mood ring,

[BL] The afternoon after I got it I spent putting it (mood ring) in hot water, then cold water to see it change.

[XZ] You almost then almost trick yourself into thinking you're okay, what if it was programmed to make you seem really relaxed and then you'd think 'I'm really relaxed' that could potentially make you more relaxed.

[RA] I hadn't thought about that — as something to bolster someone's confidence or if they were down, to make them feel better about themselves. I wonder in the future we could use these devices to recognise, say if you were bi-polar, if an episode was coming on by looking for a certain set of indicative traits?

[BL] Maybe for epileptics?

[RA] Someone asked me yesterday if this tech would be able to detect migraines.

[AK] I get migraines too but I get aura and blind spots in my vision, I know about 20 minutes before, but that's still not enough time even if I take my medicine, I still have to go to bed and my day is a write off after then. But like if you could tell hours before you to could take medicine and lie in a dark room and stave it off? That would be cool as if you have them frequently it's completely debilitating and if I have one the next day I feel hungover and spaced. It'd be interesting to see what happens in your brain before a migraine.

[ES] Yes, that would be an interesting and useful aspect.

[RA] Yes it would definitely be useful to know a migraine is coming so one can get somewhere safe.

[RA] Are there any other devices that would be useful?

[XZ] Can't think of any apart from what we've already mentioned.

[RA] In terms of aesthetics and design, would you be interested in design enclosures and stuff?

[All] Yes!

[ES] Yeah, if you were going to wear it you'd want it to be personal. If you could personalise it, it'd be really cool.

[RA] Would you pay a bit extra to be able to do that?

[All] Yeah!

[RA] We seem to have come to a natural end — is there anything that you'd like to say to close/sum up?

[BL] Well I think going on what we've just talked about, I think there's a real medical benefit side to this that I hadn't really realised how beneficial it could be for certain individuals. If they could recognise patterns for themselves and triggers and be able to tell them when something was going to happen, I think that could really be helpful and more helpful than in social situations. Because initially social situations at least at the beginning it could be very awkward as until people are fully used to seeing these wearables around and are used to seeing these wearables in everyday environments I think can be a lot more explaining and a lot more uncomfortable interactions before it becomes comfortable and then seamless. Plus the conflict you have to deal with every new technology.

[AK] Yeah, I think it's a really cool idea and there are like loads interesting ways it could be used. My main concern would be about a. not wanting, there's certain people you don't want to show everything to and secondly the data collection. Especially the data collection I'm really concerned about, who knows what about you. It's a really interesting prospect; it's not one that I've come across before.

[ES] I think I would wear it but not for any specific purpose. I'm not that curious about myself and my feelings, so it wouldn't really add anything. It'd be cool if you could show it to other people.

[XZ] I think it'd be interesting if it was adopted for what kind of staying power I'd have. I know it'd be a lot simpler but my brother had a shirt where he could track some music he was listening to. A t-shirt that changed to your temperature would be so cool because it would have more uses it could have a lot more staying power than other wearable technology, just because it is more versatile. Because it has medical as well as fun social functions.

The discussion was followed by time spent filling in the survey.

Audio transcript 2, focus groups, women 25–35 age group

The focus group was comprised of four participants, who happened to be students and was recorded on 2nd June 2014, at C4CC, Kings Cross, London.

Participants:

- PhD student in electronic textile design.
- Freelance photographer.
- MA student in Visual Society.
- MA Fashion student.

This discussion follows a presentation that I gave for the first half an hour on emotive wearables. I have listed participants' initials instead of names, when I am speaking I have used initials [RA]. I have discarded chat at the beginning or during that included informal/personal information not related to the research.

[VP] Going back to the visualiser, I think you asked what we think in terms of how it is how we would feel perhaps. I'd be really conscious to be wearing something that's telling other people how I'm feeling and that's probably because I'm quite a private person that way and particularly because if I'm feeling nervous I probably wouldn't want people to know. Particularly in social situations so for me that's a big thing, but it's something I would want to know personally. I find that information really interesting to know if when I was the most confident, when I was the most nervous. I see the value in the information, just not in public sharing.

[VP] In terms of visual display, I would find it difficult to see for myself what it's saying. I think it's a nice aesthetic; I don't have problems with it, I something moving, something digital and some secret code that people don't know how to read. But I'd like to have the pendant attached to my jacket as something I can actually see.

[KW] Maybe as a bracelet?

[VP] Yeah as a bracelet so it's visible to me in some ways as well. I don't wear that much jewellery, well not presenting or working, for me as an accessory it would be better as a portable accessory than a wearable accessory. It's just personal preference and also I can be in control of when it's visible and when it's not, which is quite important. That's my main response to the function of it. I guess my other comment is on the design itself and being in the design field I think for me, it's quite big and often people like big jewellery or they don't and I like discrete things and I'm very picky about the shape and aesthetics. I really like the idea of being able to customise my own piece and smaller and compact. The chain I wouldn't wear, I'd like to see some of the functionality built into the chain or the housing. If it was a clutch bag or rucksack or jacket, I can see part of it being integrated as a single unit, so you would just wear the hairband with the electrode and that would be enough.

[KW] I also don't wear a lot of jewellery and am also picky, but the furthest I would go would be hair wise, I don't even wear a watch and if I do they tend to be quite slim, and if I was wearing this I would be worried about breaking it. I wouldn't want to wear it out in case I broke it and be worried I wouldn't be able to fix it.

[CK] I don't wear necklaces but I do wear brooches and I'd probably wear it as a brooch. Or earrings, but you can't really look at them. I do like the idea of personalising it, as it's your personal information. Having your data out for people to see — I'd be private as well. Say it was to become a thing and everyone was wearing this. I can see if you were seeing someone's heartbeat it would be it would make me a lot more aware of what the other person was thinking or feeling, not that I'm cold. Say you're having an argument or a serious conversation; a heartbeat would make me a lot more aware.

[KW] Would be possible to change the visualisation? Because having the heartbeat or having someone who's more nervous, in terms of showing. I wasn't sure of how you were feeling based on what you were showing?

[CZ] I couldn't read it, is it a secret language?

[KW] Some of them are linear formats and some are grouped — I wasn't sure what the lines and grouped, some connected — what do they mean? Is it considered or significant?

[CZ] I don't know what's behind the shapes.

[RA] I've taken data and it's cycling through circles, rectangles and diagonals.

[VP] In terms of there being more red light and less red light — the proportion of colour is more significant to your emotions?

[RA] The proportion of colour is consequential how meditative or attentive you are.

[VP] That's what I thought but I wasn't sure if the actual shape of the icons meant something?

[CZ] I was finding that you have more greens than reds, does that mean you don't think too much during this talk? You're more relaxed?

[RA] Yes, so that could mean that I was more relaxed or becoming more relaxed.

[CZ] It seems to me it's more green than red.

[CZ] People are more interested to see it than on themselves. I don't like to share data, but I'm intrigued and curious about all this wearable technology. I think it's fun but then wearable technology is at this moment is still see what is best to wear, but it is fun. Do you think this EEG signal expression will develop into a more functional or just for self or fashionable piece?

[RA] I personally think because of the first wave of wearable tech was commercially successful is based around fitness; I actually think that people will want more personal data. Like a lot of people wear their *Fitbit* for a bit and then get bored and so the data starts to lack meaning for them and they start to feel it's a bit dull and wearing everyday to work they start to know their steps and things. I think in the future people will want more personal data and I think emotive wearables will be more sought after as people will want something that gives them more personal reflection, whether that's their emotions or moods, or feeling thoughtful or angry — that will be more meaningful to them.

[CZ] I am curious for myself, but I don't feel like sharing with others.

[CK] I was at a workshop where people were talking about how wearables might be useful for people who suffer from chronic pain to communicate to people that like now is not a good time to bother them or you could show that someone is really not approachable. But cringingly, but I don't know how you could communicate that.

[RA] You might use GSR (Galvanic Skin Response) to track stress.

[CK] My mother suffers from migraine a lot and I just wondered if you could let them know, as it's hard to predict when it might come on? Maybe some kind of device to let you know when things are changing. But it's not something you'd want to communicate with other people. That would be a personal device.

[RA] It would be useful to predict. But there's a tradeoff with the amount of kit you'd be prepared to wear!

[KW] How much kit do you think your mum would be prepared to wear?

[VP] Something like a fascinator or a hat. There's an aesthetic on that, the LED could be mounted on that and the electronics if they're small enough so thing is compact in one unit. I think part of the design has to be 3 parts. It's dependent on three areas, so if it's all on one site or one unit then it's less to worry about for the consumer or wearer, and it's easier to manage in some ways as well. Like a mobile phone is perfect design — it's compact and in one unit, and you don't have to worry about other devices except for the charger for charging it up. I guess that's part of the appeal; as well you haven't got all these plug-ins and add-ons.

[KW] You would probably have the choice to add-on if you want and you could always pull out data from it.

[VP] You have your module that delivers the data, but you have the option of pulling it out, having it wireless, for personal environment. You could have it on public view or detach it for personal view and I think that would be quite a nice option to have, instead of a permanent display that has to be connected by a battery pack that has to be carried in a pocket. I think it's quite confined in some of the parameters and there may be some more flexibility that can be lent into that.

[RA] So would you be happy for it to be sending your data to your smartphone?

[VP] Yeah, I'd be happy to wear a display on a single headband and a single unit or fascinator. I'd be more inclined to wear that than have a pendant and an independent battery pack, if it was all in one unit. At the same time, if the data could be sent to my phone, I'd probably appreciate that a bit more. Just because I'd be in control.

[KW] And you could easily see your data and I can turn it off or play something else while I'm getting over this.

[VP] And having the choice of taking it off altogether or attaching it, the choice should be there because some people might like the aesthetic of it, I guess the initiation of the design would be to have it as a public view piece and I guess people like myself who would be more private their situations and would want it controlled and if I was presenting like you I would not want to have it there to see how exactly how stressed I am, or on the screen as part of my PowerPoint presentation or my phone to show me. There could be some nice compatibility in some respects as well.

[RA] How would you feel about meeting someone who was wearing it?

[KW] I would be quite interested — like 'what have you got there and why is it doing that?' I guess I have lots of friends that are very nervous when meeting other people and going out of their comfort zone. I had one friend who spent years before he came to the hackspace and spent three years before he came to the hackspace and was really nervous about meeting new people. I was like okay, I don't really see why, but okay that's fair enough, whatever you want, but fine — chill. But it's always I find it really interesting for other people to interact with their surroundings whether it is still based in technology and how you can visualise that with colours or images or whether it's just people interacting one-to-one in this specific environment and so I think it would be just really interesting. Most people would go 'ooh look at the flashing lights that that girl is wearing in her hair — I must go talk to her'. It definitely would be like a selling point for me.

[CZ] I'm just thinking, so if it's meditation and concentration — so what are the implications of that? So it's basically in conversation like audience and conversation with people?

[RA] So I'm interested social situations, so conferences, talking to people in bars, dates, work situations, etc, is where I'm coming from.

[CZ] I'm just thinking if it's more fun if more people have it at same time so data comes at the same time for example it is a movie and the audience can express themselves — like I think it's fun. Or dating or meeting each other — I think it helps communication.

[KW] I think sometimes we forget that we are all human and that we have to seem a certain way — at work you must be poised, you must be confident, in whatever you're going to do, but with friends you're more carefree and I think having something that everyone wears, I really agree with that.

[CZ] I think it's more fun, crowd reaction is about more personal — but sometimes you deal with for example the speaker and when it's the audience.

[RA] I think it's interesting that you bought up the colours on my pendant — you can be relaxed with people.

[CZ] I was thinking normally, when people are speaking especially addressing people it's more concentration and presume the red will be dominating — it is interesting to see and maybe it is just have to think about what you have to say, so maybe meditating on things?

[RA] I guess when you're concentrating more attention would be showing, the thing about this technology is, it's one electrode and as I said before it's got this proprietary chip in it which I'm not sure how it's working out the algorithm, I'm not sure where it's finding my threshold where it's going from more meditation to attention.

[VP] I think what was mentioned about having a group setting then doesn't — it's still about the individual but the data is more valuable as a group who are sharing this data together, so it could be more a response to a film or concert, then it becomes about generating data — as part of the aesthetics of where you are at a concert or it could just be a visualiser in groups. I can see it's potential and it's not so relevant to the individual and it becomes a generic and consensual visualisation of how someone or groups are feeling. I think on a personal level, having that choice of if you're amongst you're friends you'd want them to see your new gadget, but if you were at a conference presenting then I probably don't want people to see it or be aware of it. Particularly as you mention how would you feel if you see someone else wearing it — I think that would depend on if I knew what it meant — what it was saying, in which case I'd be able to read it, as we were today. If I didn't know what it was and how to read it I'd think it was a quite nice aesthetic brooch or necklace or just a display — I think there's a little bit of difference of having that knowledge or not having that knowledge of how to read the data. I think it would just depend on if you have that information or not.

[KW] The next conference you're going to go to you'll get everyone to wear them!

[CZ] It's like American Idol — it's like when you're showing the audience like in lights, but this is automatic and the audience don't have to move their fingers. I think maybe the entertainment programmes they can probably use it now even to show the audience are so excited about this guy. A visualising tool for emotional response.

[RA] Does anyone have anything more to say about the pendant?

[CK] It's a thing I could see in a group setting like in a pub or something and it's particularly loud and you could see if people were getting left out if they weren't paying attention if they weren't in the conversation — actually I'd say that'd be pretty useful. In a conference or an interview I'd want a lot more control over who could see it, so I probably wouldn't wear something like that in that situation.

[RA] Another slide which I put together to have in the background — I wanted to wrap up the session by discussing what would you broadcast and what would you wear

— things like social appropriateness and stuff — we've already touched on some of these. I just put some thoughts on slides, such as data — at the moment the activity trackers that we're using they're all kind of cloud connected and the only way that we get to process all that data is by uploading it and they sell it on and make money from it. If you look in the terms and conditions they sell it on and you agree by uploading your data that they will process it and for doing that service for you they will sell it on.

[KW] But I think that goes with a lot of the tracking things.

[RA] At first what seems quite innocuous. I got bored with my activity tracker and stopped wearing it as I stopped having any kind of engagement with it, but the other side of that is where does that lead us in terms of thinking 'it's only our steps' now, but if we were uploading our stress or heartbeat or EEG data which becomes more personal — if we're giving that to people to process then the outcomes could be more sinister.

[KW] So people could steal your data and say 'in this situation she would appear like this'.

[CK] Like triggering your stress!

[CZ] There's a book called 'Hacking Happening' — they're saying that basically it's a trap to have data tracked in one place and your data it's traceable. I think more people are aware of this and try to do something about the misuse of their personal data.

[VP] I'm going to go back to one of your questions, I'm more likely to wear wearable tech which has a discrete value about its aesthetic — I do like something like the Jawbone up because it is discrete and particularly the ones that can blend in and look like part of your watch or just as a wristband, but I don't know much about the functions and I didn't know about the data ownership thing and I particularly like types of wearable tech which has data that might mean a bit more to me, so things measure body and physiological data could be interesting. Accuracy — I've known that home medical devices whether it's blood pressure monitors or heart beat readers, they're not accurate and to have something on a micro or miniature scale, in tiny little device that is smaller than my watch, then I do question how accurate that is and what value does that really have? I think the technical side of me where I'm a bit more concerned about am I actually getting for my money and what am I paying for, and what is it that's being delivered to me and what is its worth? So I think those questions have a big part to play — how valid is that data in terms of its accuracy and what is it measured against and how is it tested? But those types of things as a consumer are what I'd ask before purchasing. And then in terms of its design, I am quite conscious of it not being so overt; I'd want it to be quite discrete and discretional in terms of how I use it.

[CZ] I'm quite interested in where wearable tech is going to be in 5 years time. That's my questions — now there's so many interests academically and students and small start-ups. I think probably pretty soon that everyone will be connected and data will be shared, you can't stop it, it's unstoppable. I'm not comfortable that you have to play the game that's created by somebody else and you just have to play it and you are just exploited by it and you feel uncomfortable. But I think everyone and objects will be connected for sure. Data and wearable technology, I'm not sure, now it's like medical functions or more functional.

[RA] I think there's more money being put into medical, military and extreme environmental wearable tech research than fashion. I don't think fashion gives a hoot about the data or accuracy it's portraying, so I don't think they'd be concerned with that at all. So although they've got loads of money, I don't think it's the same kind of intensity or the same kind of money that the military or medical backers are willing to put into wearable tech.

[VP] I think I have to agree with that just because my research has touched on a lot of that side of things as well, definitely military events and healthcare are the biggest investors, still are and have been in the past and their findings have trickled down into the commercial sectors and fashion is probably the most smallest sectors because it's high turnover. And in terms of usage as well, you're not likely to wear the same garment every day so in terms of an investment, are you going to get the same usage out of it as you would an accessory or a hard technology? And I think the value in terms of healthcare and ID is a lot more they'll get out of that and the margins they have to play with is significant compared to what the fashion industry — very high turnover and low margins as well it's not that investable. Also what the function is, so with fashion it's very much about the aesthetics, whereas the MOD, defense and healthcare is about function — it's very different areas. I'd say in five years or even longer, I look forward to the day when it's actually truly integrated — so that' my question I'd like to have/try to answer. When you see the technology integrated into the textile or wearable. So it's truly wearable and not just portable, there's a difference between it being attached onto rather than into, but that's my big question.

[KW] Would you consider wearable tech, as like, I know Kevin Warwick had a chip in his neck that's portable and wearable.

[VP] Is it though? I think it's implantable. I think wearables are something you have a choice that you can put on or take off — I think a permanency has to be an implantable, which is a technology that's embedded into yourself and you are still a key unit of it's function, but I don't see it as a wearable per se.

[VP] Implantables is another big one, it's grown quite big and I was quite surprised to see how popular it is and how serious people take it as well, and biohacks and things like this, it's quite interesting.

[CK] I was just thinking there, it's kind of off topic, but you were talking about making it into a fascinator and that's the kind of thing I'd wear now and then. But if I was to wear it often then it'd want it to be really plain, so like something you'd wear everyday like your coat or your hat, so something like a knitted hat or would go into your coat rather than making a fascinator or something you'd wear once a week. But if you could make small things that people could attach into their own hats or whatever.

[KW] I think it will be interesting to see where wearable tech is going, but as we seem to be progressing, we are more aware of the data we give out like if we go online and suddenly Google or whoever is advertising to us and 'ooh look you're looking at childcare, you must be having a baby!' It's like er, no, no thank you! We are more data conscious now than we have ever been and I think that's going to escalate and if with who owns your data I know that some people won't use Dropbox and it's a bit like function over form, is this like also going to end up being a lot sitting on the fence because of all the data going in and coming out the other? Is it going to be truly customisable for yourself? Or is it going to be made by smaller companies? Although I enjoy seeing your work in wearable tech and a few other people who I really enjoy watching come up with new things, but I think it'll get fucked up by healthcare and military and it'll be a shame to see people not being creative because they are so worried about their data.

[VP] I think we're quite aware of data and what it means, but if you look at the layperson I don't think they're as aware. And things like Amazon tracking and I was buying a present for my niece and every time it tells me I want to buy Lego every time I go. I'm not completely aware of how data works.

[KW] I think because it is of my environment, people talk about data and security of data a lot. I don't know what my mum thinks of sharing data, she just thinks data is in the internet and that is as far as it goes, but I'm thinking like with the internet we can get any information at the touch of a button if someone were to go 'oh BTW for all you lovely runners out there who aren't in the tech world, check this out, they're selling all your data', are they going to lose a lot of customers because 'oh I didn't realise this — is data personal information?' I think it's a tipping scale, I think if someone were to come along and go 'Hey you we're selling all your data and we're going to announce it', then either some people will be like 'okay now you've announced it' kind of like the horsemeat thing people were outraged because they were being told it, not because it actually was horsemeat!

[RA] Do you have any closing comments?

[VP] I guess my last words are: I really like your work, Rain; I think you're doing really interesting approach to it. I do see value in wearable tech and I do see how using whether it's emotions or data there is some value in that whether we can definitely distil it, whether it's for aesthetics or energy harvesting — there's definitely something there that we can actually use. I think the form and function is a bigger job than we can envisage and I've found this in my work as well. It takes a lot more consideration and a lot more expertise bringing together to make this final, ultimate design of wearable tech. I'd like to think it's going to happen in 5 years, but I don't know if it'll be the case.

[CK] I could see people sharing this this information the way people Snapchat (social media app) and things like this because people want to share their personal information on online networks more than people in front of them in real life. Would they want to show this necklace to people in from of them in real life or is this the kind of information they could just show online?

[KW] I would definitely be interested to see where wearable tech is going and I would like to see about the data sitting on the fence or people would be morally outraged about it!

[CZ] I'm getting to know wearable technologies and data but I feel I have benefited a lot from the two discussions (of Rain's) I have been to.

The discussion was followed by time spent filling in the survey.

Audio transcript 3, focus groups, women 36–plus age group

The focus group was comprised of four participants, who happened to be students and was recorded on 6th June 2014, at C4CC, Kings Cross, London.

Participants:

- eLearning Producer.
- PhD student in Human-Computer Interaction Design.
- Software engineer.
- Fashion expert.

This discussion with the participants follows a presentation that I gave for the first half an hour on emotive wearables. I have listed the participants' initials instead of names, when I am speaking I have used initials [RA]. I have discarded chat at the beginning or during which included informal/personal information not related to the research.

[RA] Do you have any feedback on the *EEG Visualising Pendant*?

[GR] I think its genius and I love that, however, there's one thing I dislike about it and that's the headgear, it's obvious.

[TB] It's actually quite small compared to what I thought it would be.

[OV] I went to a reunion and there was a guy wearing *Google Glass*. And it was literally like (people were saying) 'so he doesn't have an eye problem?' So they thought it (*Glass*) was like an aid, not like because he was a bit out there.

[RA] (On the subject of headsets) What I want to do for the next iteration is break the headset apart and redesign the form factor.

[GR] There's also the Melon (EEG) headband coming out from Kickstarter, which does similar things (as an EEG headset), but it's literally just a headband. Why they called it 'Melon', it's stupid! It is due for delivery soon — I can't wait! It hooks up to an app and it's meant to train you to relax or to concentrate. The prototype literally looks like a very thin plastic headband, it's just a lot less intrusive than a bulky, sticky-outy-thing!

[RA] So what are the alternative uses of the *EEG Visualising Pendant*? You can use the record and playback modes to find out when you're most productive or what distracts you.

[OV] Especially things like pitches and presentations you get nervous and you need something to say slow down, calm or looking at afterwards is okay. Be great to know how people get into 'ticks' when presenting things like that. Or you say a word like 100 times — so calm down, you're speaking too quickly, or tensing up, or stuff like that. You'd be able to see it (the device) or looking at the data after. Having something that you know what it (the pendant) was saying but no one else does. Those symbols (shapes visualised on LED matrix from data), I (as an onlooker) don't know what it says about you, but you do. Certain groups have always communicated by what they wear, it's like a secret code, like a handkerchief in the left pocket or an earring in the left ear or whatever it was, but you needed to know that to understand it.

[GR] I noticed that when I track everything I eat and I keep an eye on the calories, I can stick to a diet, whereas if I willy-nilly decide to diet and not track anything I eat, I don't succeed. I can't do it. So just having that feedback (from a device) and seeing it in numbers helps me keep on track with certain things. If you have that feedback on getting nervous and you see it, it'll have the opposite effect — I don't know!

[TB] There was an item called Breath, It was described as a 'wearable therapist', it was by a Dutch researcher and was like something out of a David Kronenberg film. It was like a thing that latched onto your arm and it worked with your heartbeat, and if it sensed you were getting stressed it would change shape. So its tail would come up and its little head would come up, and then as you calm down, it would. It had other modes so it would train you as well: to calm down it would pulse, so it could get you to follow the pulse, so you could regulate your breathing. And the thing about it was it was very subtle, so you could wear it under a sleeve and no one would know it was there, unless you chose to expose it. But that was for monitoring what was happening with yourself in real time, and then slowly being able to learn how to adapt your behaviour, or physiological state. But I don't know, unless you know what that is (the pendant), is showing some sort of real time data from a person, it does look purely aesthetic. And the more you hide the sensor, that's giving it that data, the more likely that reinforces that. But then it becomes a puzzle as well. It opens up lots and lots of questions. But I really like it and I would like to move it around (the body), so I'd love it (the pendant) as a brooch or on a hat.

[RA] You could wear it as a brooch; I've pulled the pendant to pieces so you can see what it's made of (has pendant components laid out on table)!

[VC] I wouldn't fancy wearing one at work – to see if I'm concentrating or not!

[RA] One of the intentions of the pendant is that the data is only shared if you want people to know. But if people did wear these sorts of devices in the future, people would recognise them and know what they are. Companies are already using employee data (to monitor them).

[OV] That was my big worry when we went to WT (Wearable Tech) Conference in Munich. There was one company that did a big sales thing, almost like 'we can now sell all this data to your insurance company!' I was like; right now I'm not going to get health insurance. But you could put it (device) on the dog and get it to run around!

[GR] People can't focus all the time and the brain naturally needs breaks and of course that comes out of it as we track data.

[GR] Thinking about the size of it (EEG pendant) and the energy that it needs and the battery pack. Have you considered not using so many LEDs or use NeoPixels (RGB LEDs) and make it colour change that way? Just to bring the size down and the energy consumption down for batteries.

[RA] I hope to do so, but haven't looked into it yet. At the moment I'm just opening it up to suggestions. I just want to ensure that I get the granularity of the detail so I can show the attention/meditation data enlarging and constricting.

[GR] You could have two LEDs, one that stands for attention and one for meditation, and have something that blends through colour ranges and that would bring it down in size quite a bit.

[TB] I'd like to be able to choose the colours (of the LEDs on the pendant). If you wanted somebody to interpret it they'd have to know what the colours you've chosen are. But in terms of aesthetic, it would be quite nice if it, say matches your hair.

[OV] I'd probably want the lights to be, as I'm not the biggest fan of LEDs, a bit softer or diffused through something or to glow.

[VC] What was with the different shapes — was it an aesthetic?

[RA] Yes, it's taking the data and cycling through rectangle, circle and diagonal shapes (to display it aesthetically).

[TB] I quite like the rectangles (as shapes to display data).

[TB] I want to be able to choose (how data is displayed) — 'I'm in a rectangle kind of mood!'

[OV] You could choose the shape, but then it's more the colour and the speed that it flashes or something. There's loads of personalisation i.e. you could choose your shape or speed.

[TB] I'd like the changes in colour!

[GR] If you're really stressed and you've chosen the speed gives other people a sign — 'don't stress me out!'

[OV] At work sometimes, you do want to put something up in an open plan office, e.g. 'piss off I'm busy!' Like when you've just put the phone down and people come up to you, and you're like 'no I'm in the middle of something!' It would know that automatically or you would have a manual override.

[VC] Or you could just take it off?

[TB] Depending on where you put it (the device), it's something that other people see more than you see yourself. Have you thought about having any haptic feedback? So being able to if certain ratios are achieved, or reach a particular threshold, to get some little 'buzzzt'! Maybe not an electric shock, but some sort of haptic (feedback).

[RA] Yeah, because you can't see it (the pendant) because it's here (points to chest) and if you're in a conversation you wouldn't be staring at your own chest! The reason I got into making this kind of wearable tech was because of going to geek conferences and not feeling comfortable and wanting to let people know.

[RA] What do you think of customising and making bespoke wearables — do you think there would be a market for that?

[OV] If it's truly bespoke you can get the margin on the high side, if the quality matches the bespokeness. I think people would want that if you're doing small runs and so you've got to give them something. I think the thing with iPhones are they're still expensive and stuff, but I don't know if people think electronics in general are cheap and throwaway as they're mass produced. I know there are some high-end luxury audio electronics like Bang & Olufsen or something like that. They do come to your home and fit them and it's all installed. A girl I worked with, her partner did that, he went to the rich people's houses and put in their really expensive electronics, so it was bespoke. If your printer doesn't work you throw it out! I think electronics can have that kind of effect, which you don't have with i.e. bespoke made textiles or hand-woven silk. And even though there is (electronics) stuff that costs a lot, we don't see that because we don't see the human hand in there.

[GR] The other way is to market and sell them is as kits, with different things, so they can actually put them together themselves. And customise it themselves; the way they want it.

[GR] Yeah, I'd love it (the pendant)! I think it's a fantastic conversation starter. I don't have to tell people exactly what it does, do I? If I was uncomfortable about it, I could just say it flashes randomly — provided you can disguise the big headgear thing! I think you could shrink that (the pendant) down too. I was at a party recently and there were tiny little fairy lights all over my hair, but I only managed that because the battery pack was one of the tiny little ones, the coin ones, and I was able to disguise it, with my hair. I was able to put it up and hide the battery pack underneath and everyone was coming up to me and saying 'how do you do that?' If it was possible to make it so small to disguise it maybe in hair or in a hat or a fascinator, so it's not so obvious that it's pulling your brain data, then I'd love it, absolutely!

[TB] I would like it! I wouldn't want everybody knowing all the time what I was feeling, so having the ability to override and have the playback would be great. It'd be fun to tell some people, but not everybody!

[VC] Could you have it set up so that my partner would know when I'm really pissed off because he can never tell! Can we have an anger monitor on it?

[RA] I met a guy at a conference, who had made a device that gave him haptic tingles when his wife's attention was drifting away during conversation, if he was boring her.

[VC] I want one that tells me when my partner is asleep as he denies it.

[RA] Yes, you could do that — you could build a device that detected, for example, Theta brain waves to show when he was asleep!

[VC] And make something that automatically prompts him (when asleep) or passes the remote control to me.

[OV] That (a prompt when falling asleep) would be very good function for drivers, a nice medallion maybe. Then it's a safety device that can tell if you're about to fall asleep.

[GR] A device that slows the car down when the driver is getting dozy?

[RA] So is there anything else you want to say about the pendant?

[OV] I'm not a massive jewellery person anyway, I probably wouldn't wear something like that, but if it could be small enough to be a ring — because then you could see it yourself.

[GR] Or a wristband, a pretty one, rather than a functional one.

[OV] If you used that cut out like you've done (a 3D printed wristband) I could see that. I sometimes wear a pendant; though I'm not sure I'd wear something that obvious (EEG pendant)!

[VC] If I having something in jewellery, I'd want it in precious metal, rather than in costume jewellery.

[OV] I mainly wear costume jewellery because I lose stuff. I do prefer costume jewellery, but I'm more into textile jewellery. But I'm not into flashy/bright jewellery, so things like LEDs don't aesthetically appeal to me. I like that (the frame), but LEDs are just not me.

[TB] The size of the electronics doesn't worry me at all, as in the LED matrix. I would wear something this big; I would also wear something smaller. I would wear it in 3D printed stuff and I would wear it in metal. I would quite like to be able to swap it out into different things (frames) depending on what I was doing. I wear some really trashy jewellery sometimes, but other times I don't want to wear trashy jewellery. So, something a bit more sleek, such as precious metals. To be able to take that (the matrix) and swap it out into different things, that suited what I wanted at the time and wear it on the wrist would be good.

[OV] You could have different price ranges, if you had the same module, something more expensive in gold or silver or something different.

[RA] You can do that at Shapeways, they've got a whole list of materials and you can go from the cheapest coloured nylon up to precious metals — you just send them a CAD file and they will do it for you.

[TB] As a variant, I can imagine a concentration earring and a meditation earring.

[RA] Something I need to solve is the size.

[RA] Here's another slide on emotive wearables, what sort of things would you broadcast?

[GR] Everything! Though if I'm in a bad mood everyone knows about it!

[VC] I like the idea of having it on someone else so I can see when not to disturb them. I need to buy them for people as gifts and say 'wear this'.

[OV] I guess at the moment; I think they're (wearable tech) a bit blunt Feelings are so subtle and there's people who are good at that, and I'm not the best at it, but it's an art. But it's like any technology that's taking away the human subtlety and expertise of reading each other. We've been doing it so long and now it's red light or green light! Whereas I can be quite expressive or try to keep it all in and I'm not sure how that can all be done (with technology) at the moment. I don't know the times it could be useful for anyone else, as it'll tell them stuff I don't want to know, or it's just confirming what I'm sure I can see. It'd be bad saying about me, emotionally, and would make it worse.

[TB] It's still open to interpretation though, in the same way that other nonverbal communication is. And you frowning because you're pissed off with me, or you've got something on your mind in the same way that whatever I'm seeing via that pendant, could be due to anything. It's reporting a state — it's not actually telling me what led to that state necessarily.

[OV] It would be good if you could calibrate it for each person, i.e. 'they're acting really grumpy, but their thing (device) says...' But again, if you know that's because their thing is calibrated right and they're not really being rude, that's just how they are because everyone's different.

[VC] When you got one would you need to calibrate it for yourself?

[RA] It's got a chip and proprietary algorithm called 'eSense', which processes the data. I wanted to find out what it's doing so I did the bar-graph test because I wanted to find out where the data thresholds were. But you wouldn't have to calibrate it.

[OV] So I guess they're set to an average (person) brain response, so would they not work on anyone outside the normal range for whatever reason medically or whatever? Would it help people that had more physiological reasons? Something that would be good for people that do have brain injury to express stuff that they just can't. Like maybe people with Bells Palsy, can't express emotions very well and this would help them.

[RA] Possibly, if it was focusing on different areas of the brain, so maybe the electrode wouldn't be here (on the forehead) but somewhere else. I'm really interested in how I can get to raw data from different parts of the brain and look at areas that are associated with anger and other states. So that's fuelling me to break the headset apart, and that it's really uncomfortable. I'd also like to use the blinking sensing aspect (of the headset), though it's hard to control as blinking is mostly unconscious.

[OV] Blinking misconceptions: 'I don't fancy you — I've just got something in my eye!'

[GR] Something that would be really interesting: where is it going to be in 5 years. Something I'd love to see once it becomes commonplace and a lot of people have it, is to change the lighting in a room. So you can actually pick up the mood, and you can visualise the mood, in a room according to colour. And you can see a grumpy office!

[OV] It would be good in situations like this (focus groups); that you have to do professionally. Where you've got a group of people and the energy goes, and you start thinking about what you've got to do when you get home. Then you've got to ask 'what do you think of this' that might work!

[TB] Thinking of research, it would be really good!

[GR] Actually, I don't know if you can connect this (pendant) via some sort of contraption, like those Philips light bulbs, via online services that would take your data then communicate that to a light bulb. Maybe you can already do that — I don't know?

[OV] Maybe you could get something, for conference organisers, that everyone has to wear and shows how good their speakers are.

[OV] It'd be quite funny: you'd do a talk about it and got people to wear (the pendant) to show if they were concentrating on listening to your talk. And then you could present your research in an interactive way to show that the whole room were aware.

[GR] I work in eLearning and part of that is learning spaces. I'd love to have lecture theatres responding to people's moods, or change the oxygen levels in a room. You can do that with sensors; the technology is there but we're not doing it! We're talking about improving learning environments and that to me is obvious. I mean, wearables and sensors that we have on us are a logical source of data and how we can improve on what's there.

[VC] I wonder if I could use it to get my kids to do their homework. At the end of it, if they've been concentrating for 15 minutes, it turns into snake mode and they get to play a little game!

[OV] This makes me think, in a conference are they concentrating on you (the speaker) or messages on their phone? I think group activities could be a way to get people interested in the idea, like you say, if only one person had a phone who do they call?

You've got to know the language and feel of it. And get people to understand what it does and play with it, in an emotive but semi-functional way.

[OV] This makes me think, in a conference are they concentrating on you (the speaker) or messages on their phone! I think group activities could be a way to get people interested in the idea, like you say, if only one person had a phone who do they call? You've got to know the language of it and feel of it, and get people to understand what it does and play with it, in an emotive but semi-functional way. Whereas they want to know what other people as much are saying, but in a kind of, well everyone's in the same boat in as far as they could judge you.

[TB] I've been working on a research project for about a year and a half now, which is working with people who have had strokes. They have communication difficulties and we did a lot of user evaluations of things. But with this, if it was playful and didn't look threatening, then people might be quite likely to wear it.

[RA] There's definitely a need for de-stigmatising medical devices and personalisation.

[RA] Wrap up time! Can we go round and just say a sentence to sum up how you feel or a comment about the EEG pendant, or emotive wearables?

[GR] I love the idea and love that (the pendant) I think the size is at the moment is a temporary thing and it will shrink down. Once it does shrink down, I'd love to try it.

[VC] I can see applications for it, I don't think it would be for me, regardless of the aesthetic of it.

[RA] Is there anyone who thinks it'd be good for someone they know?

[VC] Yeah, but not sure they'd be willing!

[TB] I love it. I would definitely wear it and I'd be very interested in being able to adapt it and customise it depending on what I felt like. It's a hell of a lot nicer looking than things like my horrible tracker, that I bought a few days ago, and am already disappointed with.

[OV] I'm not sure I'd wear the LED thing everyday and I'd probably just want it for me to see it, rather than broadcast it to people. A constant thing that helps me in some way acknowledge my own emotions, but in an aesthetic way, so it's something that I can design appeals to me anyway. That would be good to 3D print.

Audio transcript 4, focus groups, Quantified Self Europe 2014

The focus group was comprised of attendees of the Quantified Self Europe Conference, held in Amsterdam, on 11th May, 2014.

This discussion with the participants, of mixed age, gender and nationalities, followed a presentation that I gave for the first half an hour on emotive wearables and the *EEG Visualising Pendant* (Figure B.5, p. 272). I have not listed the participants' names as I could not identify everyone when listening to the audio recording, instead I have simply listed whether the person speaking was male or female by the use of W = woman and M = man. When I am speaking, I have used my initials [RA]. I have discarded chat at the beginning or during which included informal/personal information not related to the research.

FIGURE B.5: Wearing the *EEG Visualising Pendant* during emotive wearables focus group at Quantified Self Europe Conference (2014)

[M] Does this (the pendant) have moving images can you elaborate a bit more on the type of changes?

[RA] I like the mystery of communicating data, so I've tried to make the piece have an aesthetic design. So one could wear it out and about as a piece in its own right, say as an arty pendant, or for those who you want to know you can tell them. I'm wearing this device and look (at the pendant) I'm quite relaxed or I'm not really paying attention to you...

[M] How do you use the meditation data?

[M] I don't use any of the raw values off the NeuroSky because I haven't been able to ascertain how they're calculated as it's proprietary. I just prefer to work with raw signals, that way I can set thresholds around various different bands that state activity and accommodate the brain's individual variability. I think with the NeuroSky I don't know how it's calculating those values, like I know that the mediation is probably based on some Alpha, but given the amount of facial movement and eyes and stuff I'm not exactly sure what it's getting or even what it is.

[M] Does it like measure focus or concentration with this device? Because it would be very interesting, as I have a short focus span and for me it would be helpful if I could see what I was distracted by.

[RA] Absolutely — another use for this would be to see how productive I am at different times of the day using the record and playback modes.

[M] When you show the state of someone and the thing shows a false state of being calm, because the other person expects, things that say you're calm actually make you calm, right? And shows the effect it could have!

[RA] Indeed, you could use it to give you confidence.

[M] You bring up and interesting point, I've always felt that I'm not that terribly good at reading people's body language, but what's interesting is there's been so much research in the last decade of basically interpreting people's emotions by their visual expression. Dogs are really good at this with human beings. I always thought it would be more interesting if you have a *Google Glass* basically running a continuous algorithm telling you the person you're looking at is sad, bored or angry right now.

There'd be this disconnect between what the machine was saying about your face versus what you're emotions are on your pendant.

[RA] That's an interesting idea, at the moment *Google Glass* have put a ban on any facial tracking software because they've decided it's unethical to do so for reasons of privacy

[W] I can't focus on all at the same time, either I see you and your face and then I see the colours, but I can't distinguish the forms and shapes. I see it's more green or more red, but if I really focus on your face I don't know if it's a line or a circle and if I really concentrate on the pendant, I see your hands but I lose completely your face — because I really concentrate on the different forms. Do you think I will get used to looking at all that or I really have to focus on the one thing? The question I wondered is, is the transmission direct, I mean is it the same millisecond you feel, you see it on the colour or is there a little delay between what is here (brain) and what is there (pendant)? Yes? Is there a little delay, I find that really strange because somehow you get the feedback a second later — it's like when you watch football and your neighbour has a faster transmission and you know a goal is going to happen and in the transmission you can't see it yet because if it's one or two seconds later.

[RA] Yeah, there is a bit of latency and where do you look are valid points.

[W] What I think is distracting is jumping from one thing to another very quickly. I don't know, it's so fine tuned and nuanced that it can detect these minute changes in your mood and emotion or is your mood and emotion pretty constant throughout your interaction? It's not going to jump around like that, it's going to stay pretty constant as a display, and then as the person is interacting with you it wouldn't be so distracting. I'm not sure if that display, in a real time interaction, is going to be ever changing or if it's going to be fairly constant unless there's a big shift in your mood or emotion. And I guess the other related point, I think is the abstractness of the display, while aesthetically really nice, it makes it hard to interpret. So it's almost like if you're talking to somebody, you have to tell them how, what it is — that thing that you're wearing and how to interpret it.

[RA] Absolutely, so at the moment I can see tons of problems with it, so I'm trying to look at those. And I'm trying to get the balance between something that's has an aesthetic and something that actually does something. So those are all really valid points, thank you.

[M] I'm curious, lets assume that she gets and solves all the problems and it's perfect. Would you actually find the information useful? Would you like to see this on someone else?

[W] Yeah, I guess the question is who are you wearing it to — is it useful to you, or are you wearing it because you want to help somebody interact with you or both?

[W] Not just because I'm interested in wearables, but my mind just totally changed as of yesterday. I thought wearables should be discreet, passive, hidden. I thought even bands were too large and I thought it should be something you never see, like people shouldn't know that you're monitoring yourself. And then I wore this (heart monitor on chest with one flashing LED) it's monitoring my heart and it's very obvious, it's right there, and then I was like well maybe it should be obvious that I'm monitoring myself, why should I hide it? But it was annoying to me that I had to look on my phone to see it working. So that's why I'm here because I think it's really cool, like if I could see my heartbeat and look down and see it — that's like real information that I was tracking myself, seeing myself, maybe in a more clear version than that, but I feel I could communicate with people with my heart. I went to a club wearing this (the heart rate monitor) and I was getting a lot of attention and it would have been really cool if I could see how I was feeling as I was talking to people: if I was freaking out, or really enjoying the music or something. To bad I didn't have the power to, but it would have been really cool to try I guess.

[M] Can I just add a point in here, it gets very interesting because we very much understand how our own heartbeat has changed as we're going through the day. We'll be getting there before we say something, and if we see that on somebody else we can put it into context. What I find interesting about this, with EEG, given the full broad spectrum of signals that you can actually detect off the scalp is they're very pinpointed signals from very particular things. Like if I visually disengage it'll generate a very particular signal back here (points to head) for various activities, but we're not used to seeing those or understanding those in the same way as a heartbeat. Like what I find interesting about this technology is that we have presumptions about the types of things we're going to be able to see and pick up on while we're talking to a person. Questions to do with lag and latency, and given the variety of things to detect and display, we don't really have a sense for wearing it. Like I think before, I think it, would be difficult or we would have very different points if we were to wear it for a while and interact with each other for fluidly and notice 'ah, when I say that in a conversation he's definitely phasing out or shouldn't talk about this topic'. We don't know what we don't know! That's just my point and I've sort of done something around this area before, where I've used the NeuroSky and put it over posterior site and I've linked it to my wife's telephone with a particular signal called Alpha and it's amplitude. But the phone would buzz in a synchronised fashion with these actual signals. What was interesting about this, is that I get this very high Alpha when I faze out or I'm thinking — it seems to be something with me visually disengaging. So her phone was buzzing and she was able to tell in conversations over the space of a few days that I would stop listening. That I'm not actually paying attention, I'm watching the TV, but I'm not actually watching the TV, but there were subtle details to pick up on. But it wasn't until that interaction started that she started telling me things that I hadn't noticed.

[M] Was it embarrassing?

[M] No, I didn't care, it was my wife — I didn't mind! But I think it'd be interesting to do with everybody else. It's the same point that you raised there about the heart rate. Before I spoke then, my heart rate went up, I wonder how many people that happens with? Maybe we're not all that different and stuff like this is going to make it an awful lot easier for us to communicate?

[W] I was trying to imagine your different scenarios! When you put the question to the room, for some here, there's some confidence and other people try to share different things, but we are all more or less the same. I might feel comfortable with it, but when I'm a lecturer in front of 50 students and they know that I'm not really paying attention because the questions the students have asked me: I've heard it 100 times or I'm somewhere else, I might not really feel comfortable with them seeing that I don't pay attention! It might be the situation with your vibe might be comfortable to share something in a club, it might be fun because you have some other topic and verbal communication is somehow difficult. But there might be some settings, like with your boss or your students or whatever, where you try to hide different feelings that you have. So that you can decide what will be shown on it, I mean, you might show some things to your students, interest, etc, and maybe you're allowed to take off the negative things like non-attention and so on.

[RA] Absolutely, to have preferences so you could choose what you revealed.

[W] Exactly! Normally while you know how to hide things, with your body language and so on, so you get more to control your stress, your heartbeat and speak up. Although you know you'll be stressed, you manage to think and somehow to have this model (pendant mode), to say now I'm in a situation so I can't put all this out. But now I'm in front of my boss and I should tell him that it's really interesting that and I would like to work on it. I don't want to, but I need this in situations where you maybe you don't want to put it off because you don't want to show. Some kind of preferences and models, for example from 10 models (modes) I would take the first 5 and keep the last 5 — I would keep them secret.

[M] But then the question is why are you doing this exactly?

[W] Well it seems it would lead to increased self monitoring, in that situation you'd be very careful to kind of maybe control yourself in some ways so the negative emotions don't come out. And then if I were interacting with you, I would be constantly paying attention to the pendant and thinking 'oh she's getting bored!' The answer is: I'm constantly monitoring myself for interactivity. It's really interesting. I think emotions are so nuanced and I don't know enough about this technology to know if they're capable of capturing that nuance. If I'm talking to you and you're showing that you're having a negative reaction to me somehow, what I don't know is if you're tired, or you dislike me, or it's disgust — I mean there's such a whole a spectrum of emotions and they're all incredibly nuanced, so if I'm all I'm able to say is that something negative is going on but I don't know what it is, then, how do you react to that and how do you deal with it?

[RA] Indeed!

[M] Maybe, she looks bored or this thing (pendant) says she's bored, or not paying attention to what you're saying. So maybe I'm boring her, but maybe she has just learned two hours ago that her mother is seriously ill. So thoughts wander and you might be telling very interesting stuff, so cannot be sure it's you causing the emotion or its some other (distraction). Maybe you just see a very nice looking guy and really pay attention, but you continue having boring stuff!

[W] Obviously you're not reduced to just the pendant, there's still the person to ask questions about what you're feeling.

[M] I think you're right, but it really draws attention to it (pendant).

[W] I agree that I would, like you said, if it had 10 functions or variables or whatever, I would probably turn all 10 on at home with my husband, maybe with my parents — maybe not!

[M] If that shows some emotion and you're wearing it, I think everyone understands the reality, even like know it's not only that, 'oh you're turning red', that's going to be the leading emotion I think from your side.

[W] Just the first phase in the far future, when it would be normal for everyone to wear it and then it would kind of normalise, maybe. So that it would just incorporate with all the other interactions and body language that you have.

[M] I think that fundamentally that's one very important thing as well, we're discussing what the device is displaying and how well we can trust what that exactly is displaying. What's notoriously difficult about EEG data is gaining context around it to be able to interpret it. Like if I know I was showing you images on a screen and look for responses, but when you're recording stuff in this environment it's very hard to capture and integrate that to be able to break apart those types of signal. But, I think what's interesting is that if you still remain whatever the integration unit is that's understanding, but you have to take in the context. Like you could easily discern something from the way someone was twitching their eyelid or something when they were looking at you as well. The responsibility still rests on the person interpreting what they're seeing and you need to have a better feel for what it's actually showing — like we're saying things like 'detecting emotion' and the concept is getting very abstract. But what you can actually pick up from EEG, there is a selection of things that you can pick up very well, but there's other things, definitely if you have some direct link with them, whether that's visually or through a phone will begin to get a sense. You can get this in a lab looking at people when you're running an experiment when you're looking at their EEG data, things and timing and context, and you'd see certain signals, but it's something that a computer is not going to be able to do well. And it's something that a human is going to be able to do well and it's not something that you or a computer is going to be able to pick up very well, measured in a quantified way — this is your exact attention level, this is really your attention. I could visually disengage because one of you asked me to remember a telephone number and I just visually think about it like that. I'm imagining the moving the thing on my hand, you'd have to get to know somebody and their neurosignals. Having the one thing, like it's meant to be a common language when you meet people, I don't think that works, there's too many idiosyncrasies to a person. You'd have to know them and you'd have to know the interactions, and then you could have all these customised profiles. You might realise after a while that 'profile 9' is giving away when I'm in this situation, I think it's going to be more about knowing yourself and the signals and ways to display them. Then you can become very creative, in the ways and stuff they're shown afterwards. But I think that's one important thing that's easy to overlook, is what you can do and in terms of that loop with sensing and the technology, seeing it or actively using it like that. I'd say if lots of people were wearing them, the strong validation from NeuroSky posteria Alpha and phased increased signals, have you thought about using more electrodes?

[RA] Yes I have, so I've thought about getting an Emotiv second hand and I've also thought about getting OpenBCI, which is a modular EEG system where you can add more channels. So yes, I have.

[W] One little thing that possibly disturbs me is the images jump from one shape to the other, there's no continuity. I think for me it would be less disturbing if somehow the bubble (circle) goes into a line, but not jumping from one, but this is like one second or two second there's a signal is a new shape, a new colour and so on. Somehow if it was a bubble going up and down and getting broader, I think for me, because then it would be some kind of illusion and then there would be least interruptions.

[RA] I hope to improve that and everything you tell me about the aesthetics is really useful.

[W] At the beginning of the discussion I was really agreeing with the concept of visualising certain emotions, but now I'm leaning more towards an abstract visualisation because it would be more of another factor in your body language. Just like when I lift this eyebrow it doesn't tell you anything about whether I'm extremely negative — it's interpretation. So maybe that's an argument for keeping it abstract ,so it's something you have to get to know, that it's part of the whole person instead of trying to make it as intuitive and as understandable as possible. It's just another extreme in the spectrum of how you can visualise.

[W] I can see the point: it's like in the morning you have different jewellery and you chose something to wear. Like today I didn't feel like wearing something red, because a I felt a little more like this (points to clothes). And this would be a more interactive thing reflecting what you feel and how you feel, without having letters, anger, happy, etc. But it's somehow how you feel, and that is nothing interrupted because this morning I decided this morning not to put this huge ring on because I didn't want to show off or whatever! It will read your clothes, like that as a thing in the morning, or as you want to be perceived by the others, so there would be more than this line so it wouldn't be so far from normal habits you already have.

[M] The thing you're kind of proposing is just purely for aesthetics?

[W] No it's not purely for aesthetics! I mean it just doesn't sound right now, for me the other person is this red line (on the pendant matrix), does this mean anger, attention, whatever. But if afterwards it was the same thing, but it's not about 'this LED means this emotion' it's simply about me expressing this thing of how I feel. It's like I feel I'm cold, so I'm putting a scarf on and I might feel cold because I don't feel comfortable here or because I'm new, or whatever. You don't know why I put the scarf on, but putting the scarf on already gives a message to you. Over a long period of time if I were I to interact with Rain for days on end or weeks, getting to know her, then eventually I would learn when I would see a line in my confrontation with her or would see a circle or more red or green. And I don't necessarily need to know beforehand what red or green means, it's just in getting to know her in different circumstances and different people and situations. I would learn what kind of patterns go with that so it's not some kind of 'Eureaka! Hallelujah! Now I can look inside your black box-brain' type of visualisation, just another way of externalising yourself, in a more abstract way. Not for strangers, but once you get to know each other, that's all humans do, recognise in patterns, and integrating them into their internal blueprint of things. Constantly you readjust things so right at this moment, this (pendant) doesn't tell me anything but as time progresses I would see patterns.

[M] It's a bit like body language — I know exactly when my girlfriend is nervous.

[W] So it's just an addition to the body language that is already there?

[W] For the wearer, you know what happens and why? And then it doesn't have to explain for the other people for they will learn it's another language.

[M] I think there are very generalised strategies that could be used, so if you learned the signals off one person, like it could be something, lets just say linked to one particular signal that has a long set of cognitive characteristics and how you're interacting and doing things. That could be generic across people and nuances and stuff like that, but I'd imagine nuances to exist as well in other things, so it's probably going to be a whole assortment of strategies. Obviously you can't wear a giant display or it seems like there's a lot of variety to explore.

[M] There's a woman in San Francisco who is doing that exactly!

[M] Yeah, but actually display that information and getting correlation and thinking about it.

[M] The guy in the UK, he had this thing here (points for forehead).

[RA] Oh Neil Harbisson? There's a chap called Neil Harbisson, he was born colourblind so he developed this thing, that he calls an antennae. It's actually an implant which reads colour and then plays a specific sound to tell him the different colours that he's observing and basically it looks like an antennae.

[W] They do it with blind people too with sound? A sort of a sensor that builds a visual from sound, so when you're standing really close to an object there's a haptic/sound. So it's transferring one kind of sensory input to another type.

[M] I like the remark about the simple and explicit. There was a designer who made this house, a wooden house and there's a light in it. And basically the light goes on when her parents wake up — they're a bit older, and she just wants to know when they go to bed and everything is okay, so a light goes on and she knows there's activity in the house, when it stays off for a day it's a sign that something is not right, but it's a very simple sign. If you came into my house you wouldn't recognise it, so I really like this low-fidelity design to things, so it shouldn't all be explicit and detrimental, but its really low fidelity design, I think it's a really nice thing, that's why I like it that remark (from previous person) it shouldn't be so explicit. Something that you get to know, like a personality almost.

[W] Have you tried wearing it for a day or long period of time, or do you just wear it in meetings like this for demonstrating?

[RA] At the moment I just wear it for demonstration purposes because it's not very practical and it's really sore (the headset). The longest I've worn it is for about 3 hours and it drove me mad in the end and made my head sore. I've not walked around the streets with it on. I've walked around conferences and places and with friends.

[W] I suppose it would need some context to be able to gauge the right connection maybe? If you were walking down the street I'd just think it's a futuristic aesthetic, except when you were wearing the headpiece as well — then I would probably make the connection.

[RA] I'm really aware that the closing session is in a few minutes, so shall we wrap this up so I don't make you late? But if you do have time and you don't mind I'd really love it if you'd complete my survey and I can feed some of your observations and ideas into my research and thesis.

[W] Really, before I was super interested in skin tattoos and I thought you should hide it, you shouldn't let people know you are tracking yourself, but I was like 'no, I don't think so' because yesterday I was like — this is cool — because if I see someone tracking themselves it's a way to connect. I was at a club and it was really interesting, I realised I couldn't hear anyone, but this would be a great way to communicate. I wore this (medical grade device that records respiration/heart rate/temperature) and it ran out of battery, it's USB and at dinner I just plugged myself in for a while and recharged it! They took a photo of me because I was powered up! You know like the transhumanists, I felt like a cyborg, I was like 'what am I doing?' it was cool! I actually liked it, I'm going to wear this tomorrow — I think it's awesome and I would like to make this into a consumer product.

[W] Couldn't it be integrated into your bra or something maybe?

[W] They already have one (bra version) — the thing is I don't want it to be discreet, I want to tell you how I feel!

[W] I just totally changed my mind, I don't think Quantified Self needs to be discreet. Why should it have to be? I'm a quantifier myself and I would like to see other people who are and communicate with them. Yesterday I was thinking it would be so cool if it was beating to my heart but a colour also, if it was a really low heart rate it would be a certain colour and if it was really high it would be a certain colour, and if we see someone else and we're both having the same colour it would be really cool! Maybe I could like link them and grab their contact, like a quick way to exchange/add each other and then later I can find them!

The discussion was followed by time spent filling in the survey, though not everyone in attendance filled in a survey as they had to leave the conference or go to the conference closing session.

AnemoneStarHeart feedback, ISWC 2016 Design Exhibition, Heidelberg, Germany

At ISWC 2016's Design Exhibition I invited attendees of the event to give informal feedback to my research prototype. To give this feedback context I have put them into themes.

1. **Concept**
   - Very cool - it opens up a concept I had never thought of.
   - It would certainly be an interesting and interactive way to express and suppress emotion in public areas and conversation.
   - Use cases are very well thought out, would be interested in seeing the results of evaluations, particularly the social effects of the pendant.
   - I'd be curious on how it could affect self-awareness and mental state change - active coping strategies for?
   - I like the concept for tracking in addition to normal health tracking like exercise EEG can be in a smaller wearable.
2. **Aesthetics and Form factor**
   - It's very bold.

- Very interesting form factor.
- A wearable that is less obvious for others would suit for me.
- I love the aesthetics of translating physiological data into an abstract pleasing representation.
- Love the heart part. The band (chain) could be nicer or at least match with the heart somehow.
- It is fascinating to look at.

3. **Uses**

- May suit a niche personality or a performer.
- It would be useful for individuals who cannot easily communicate emotion/thought - ALS (amyotrophic lateral sclerosis), locked in syndrome, autism patients.
- Nice application of wearable technology to link people and help them in understanding each other.
- Great to start 'in vivo' trials with couple, preferably long term to verify whether meaningful information can be gathered.

4. **Privacy**

- For me, feelings and emotions are a private thing, so I want want to show them in an obvious way, but I think there are people that will.
- I would not wear it in public or long periods.

Images of user studies participants

FIGURE B.6: Portraits of field test participants wearing the *EEG Visualising Pendant* and *NeuroSky MindWave Mobile* headset (2014)

FIGURE B.7: Emotive wearables focus group with women participants during discussion (2014)

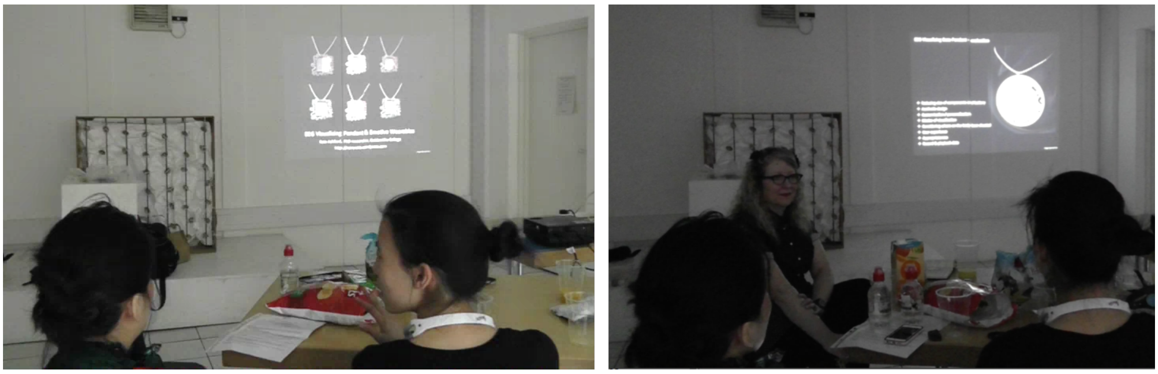


FIGURE B.8: Emotive wearables focus group with women participants during presentation (2014)

Sketches of prototypes and circuit diagram from sketch books

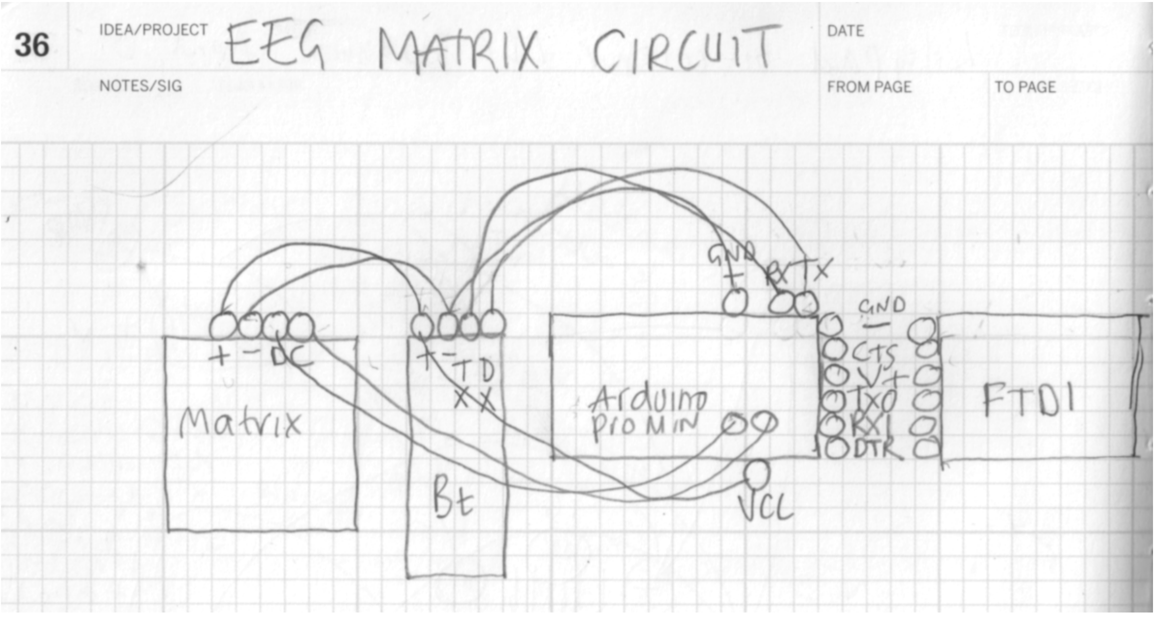


FIGURE B.9: Sketch of *EEG Visualising Pendant* from PhD sketchbook (2014)

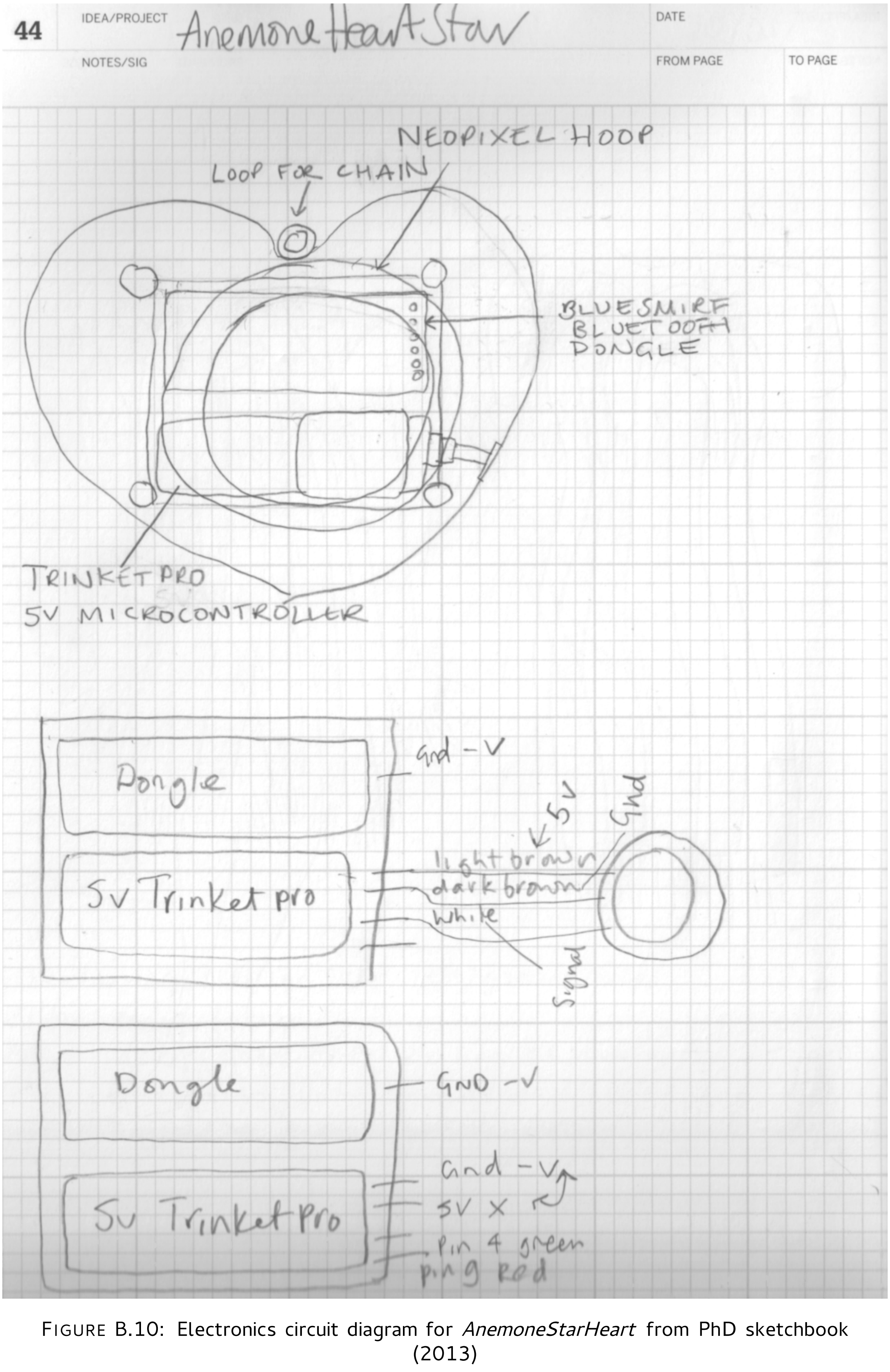


FIGURE B.10: Electronics circuit diagram for *AnemoneStarHeart* from PhD sketchbook (2013)

FIGURE B.11: Sketch of *ThinkerBelle EEG Amplifying Dress* ideas from sketchbook (2015)

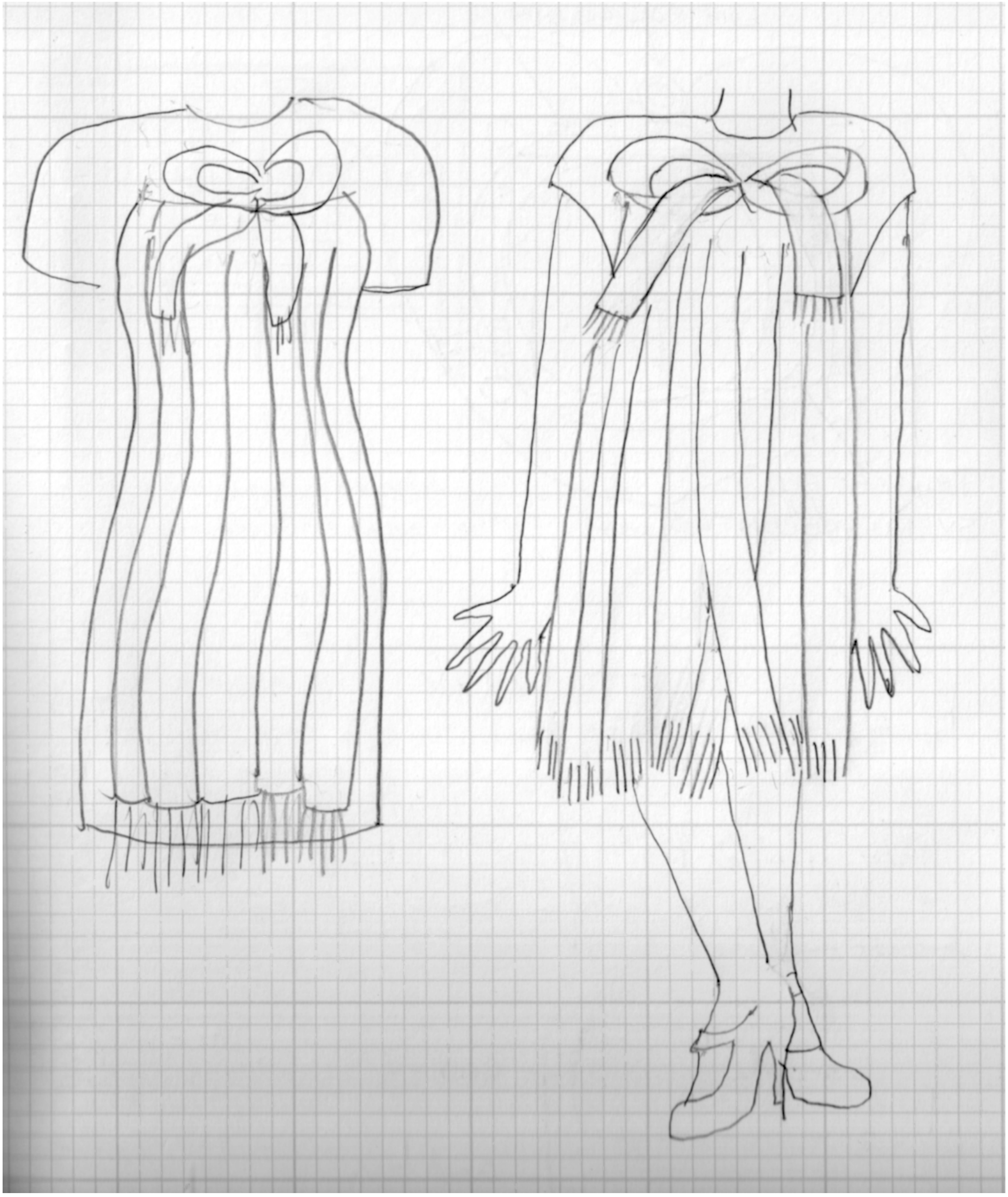


FIGURE B.12: Sketch of *ThinkerBelle EEG Amplifying Dress* ideas from sketchbook (2015)

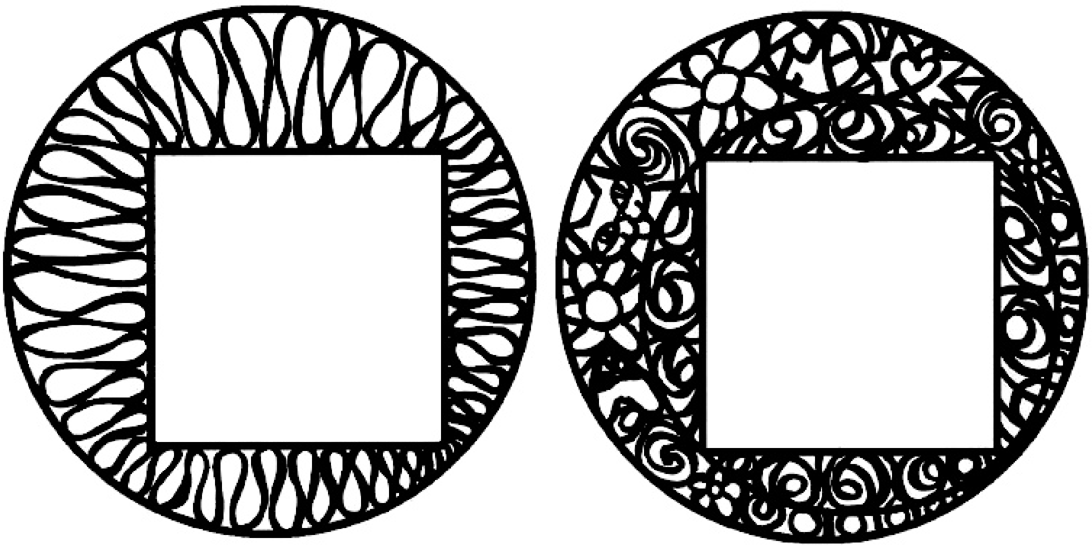


FIGURE B.13: Ribbons and swirls sketches for *EEG Visualising Pendant* bespoke laser sintered frame (2013)

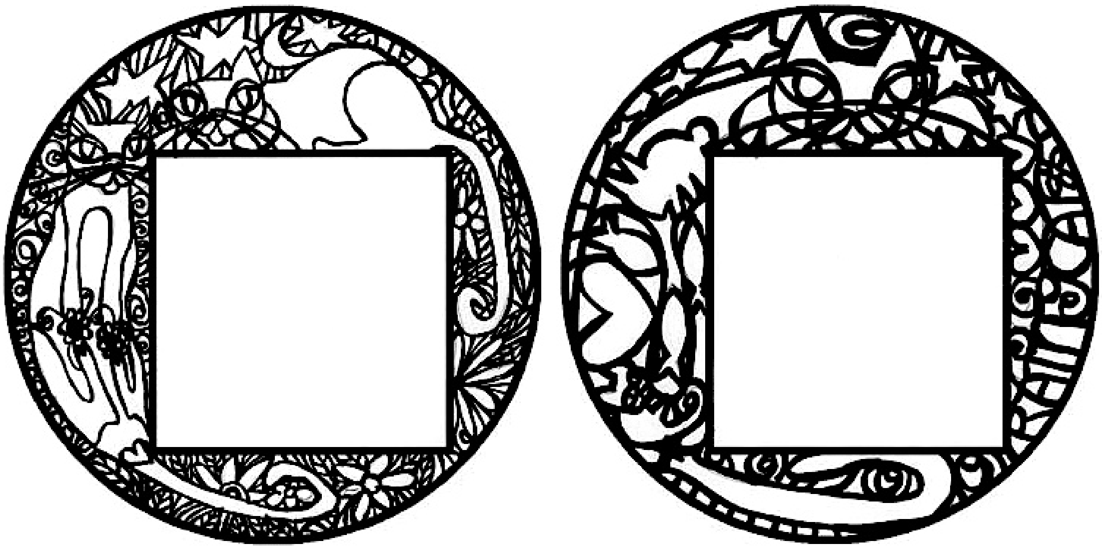


FIGURE B.14: Cats sketches for *EEG Visualising Pendant* bespoke laser sintered frame (2013)

Appendix C

Device source code

EEG Visualising Pendant

```
// Talks to Bluetooth dongle, gets it to listen out for
// specified headset and do useful stuff with the data.

// Includes Adafruit (Adafruit 2013b) and Wire libraries
// (Arduino 2013)

// Bluetooth dongle code was based on sample code from
// NeuroSky Developer
// website (NeuroSky 2012)

#define MINDWAVE_MAC "9CB70D72CCAD"
#define MINDWAVE_PIN "0000"

#include <Wire.h>
#include "Adafruit_LEDBackpack.h"
#include "Adafruit_GFX.h"

Adafruit_8x8matrix matrix = Adafruit_8x8matrix();



// packet processing state
static enum mindwave_state {
  NO_SYNC,
  HAVE_SYNC,
  PACKET_LENGTH,
  PACKET,
  PACKET_CHECKSUM
}
state = NO_SYNC;
```

```
// packet processing
static int packet_length = 0;
static int packet_index = 0;
static byte packet_checksum;
static byte packet[170];

// track current values of these
static int attention = 0;
static int meditation = 0;

// debug
static int flashcount = 0;

static int byte_in();
static void parse_packet();

void setup() {
  matrix.begin(0x70);  // pass in the address
  matrix.clear();
  matrix.writeDisplay();
  // debug
  pinMode(13, OUTPUT);
  digitalWrite(13, LOW);
  Serial.begin(115200);
  // attention bluesmirf!
  Serial.print("$$$");
  delay(200);
  // master mode, please
  Serial.println("SM,1");
  delay(200);
  // bluetooth pin
  Serial.println("SP," MINDWAVE_PIN);
  delay(200);
  // mac address of mindwave
  Serial.println("C," MINDWAVE_MAC);
  delay(200);
  // ok, done
  Serial.println("---");
  delay(200);
  // um...
  //Serial.write(194);
}

void loop() {
  int b = byte_in();
  if (b == -1) {
```

```
    delay(10);
  }
  else {
    switch (state) {
    case NO_SYNC:
      if (b == 170)
        state = HAVE_SYNC;
      break;
    case HAVE_SYNC:
      if (b == 170)
        state = PACKET_LENGTH;
      else
        state = NO_SYNC;
      break;
    case PACKET_LENGTH:
      if (b == 170) {
        break;
      }
      if (b > 170) {
        state = NO_SYNC;
        break;
      }
      packet_length = b;
      packet_index = 0;
      packet_checksum = 0;
      state = PACKET;
      break;
    case PACKET:
      packet[packet_index++] = b;
      packet_checksum += b;
      if (packet_index >= packet_length)
        state = PACKET_CHECKSUM;
      break;

    case PACKET_CHECKSUM:
      if (b == (255 - packet_checksum)) {
        parse_packet();
      }
      state = NO_SYNC;
      break;
    default:
      break;
    }
  }
}
```

```
static void parse_packet() {
  // start by assuming quality is poor
  byte quality_byte = 200;
  byte attention_byte = 0;
  byte meditation_byte = 0;
  byte blink_byte = 0;
  boolean get_length = false;

  for (int i = 0; i < packet_length; i++) {
    // extended command - ignore
    if (packet[i] == 0x55) {
      continue;
    }

    // has size byte - not using any of these, skip for now
    if (packet[i] \& 0x80) {
      i++;
      if (i < packet_length)
        i += packet[i];
      continue;
    }

    // otherwise, possibly useful data
    switch (packet[i]) {
    case 2:
      i++;
      if (i < packet_length)
        quality_byte = packet[i];
      break;
    case 4:
      i++;
      if (i < packet_length)
        attention_byte = packet[i];
      break;
    case 5:
      i++;
      if (i < packet_length)
        meditation_byte = packet[i];
      break;
    case 22:
      i++;
      if (i < packet_length)
        blink_byte = packet[i];
      break;
    default:
      break;
    }
```

```
  }

  // update attention \& meditation values if quality good
  // enough
  if (quality_byte < 200) {
    digitalWrite(13, (flashcount =
                      (flashcount + 1) \% 2) ? HIGH : LOW);
    if (attention_byte != 0)
      //attention = attention_byte / 10;
      attention = (attention_byte * 8) / 100;
    if (meditation_byte != 0)
      meditation = (meditation_byte * 8) / 100;
  }

  // update bar graph
  matrix.clear();
  matrix.drawRect(0,0, 4,attention, LED_ON);
  matrix.drawRect(4,0, 4,meditation, LED_ON);
  matrix.writeDisplay();

}

// read byte if available, else return -1
static int byte_in() {
  if (!Serial.available()) {
    return -1;
  }
  return Serial.read();
}
```

Baroesque Barometric Skirt

```
// Includes Wire (Arduino 2013) and Adafruit libraries
// (Adafruit 2013a)

#include <Wire.h>
#include <Adafruit_BMP085.h>
Adafruit_BMP085 bmp;

const int strip1_R = 3;
const int strip1_G = 5;
const int strip1_B = 6;
const int strip2_R = 11;
const int strip2_G = 10;
const int strip2_B = 9;
```

```
const int strip3_R = 13;
const int strip3_G = 12;
const int strip3_B = 2;
const int strip4_R = 4;
const int strip4_G = 8;
const int strip4_B = 7;

typedef struct {
  int R, G, B;
}
colour;

colour digital_colour[7] = {
  {
    LOW,  LOW,  HIGH                 }
  ,  /* blue */
  {
    LOW,  HIGH, HIGH                 }
  ,  /* cyan */
  {
    HIGH, HIGH, HIGH                 }
  ,  /* white */
  {
    LOW,  HIGH, LOW                  }
  ,  /* green */
  {
    HIGH, HIGH, LOW                  }
  ,  /* yellow */
  {
    HIGH, LOW,  HIGH                 }
  ,  /* magenta */
  {
    HIGH, LOW,  LOW                  }
  ,  /* red */
};

const float min_temp = 0.0;
const float max_temp = 32.0;

const float min_mytemp = 200.0;
const float max_mytemp = 250.0;

const float min_altitude = 0.0;
const float max_altitude = 75.0;

const float min_pressure = 100000.0;
const float max_pressure = 102000.0;
```

```
int i = 0;

void setup() {
  pinMode(strip1_R, OUTPUT);
  pinMode(strip1_G, OUTPUT);
  pinMode(strip1_B, OUTPUT);
  pinMode(strip2_R, OUTPUT);
  pinMode(strip2_G, OUTPUT);
  pinMode(strip2_B, OUTPUT);
  pinMode(strip3_R, OUTPUT);
  pinMode(strip3_G, OUTPUT);
  pinMode(strip3_B, OUTPUT);
  pinMode(strip4_R, OUTPUT);
  pinMode(strip4_G, OUTPUT);
  pinMode(strip4_B, OUTPUT);
  pinMode(A3, INPUT);
  if (debug) {
    Serial.begin(9600);
  }
  bmp.begin();
}

void loop() {
  float temp = bmp.readTemperature();
  set_colour_analogue(temp, min_temp, max_temp,
                      strip1_R, strip1_G, strip1_B);

  float mytemp = analogRead(A3);
  set_colour_analogue(mytemp, min_mytemp, max_mytemp,
                      strip2_R, strip2_G, strip2_B);

  float altitude = bmp.readAltitude(102900);
  set_colour_digital(altitude, min_altitude, max_altitude,
                     strip3_R, strip3_G, strip3_B);

  float pressure = bmp.readPressure();
  set_colour_digital(pressure, min_pressure, max_pressure,
                     strip4_R, strip4_G, strip4_B);

}

  delay(500);
}

float proportion(float number, float minimum, float maximum) {
  float range = maximum - minimum;
```

```
  if (number < minimum) {
    number = minimum;
  }
  if (number > maximum) {
    number = maximum;
  }
  number = (number - minimum) / range;
  return number;
}

void set_colour_analogue(float temp, float mintemp, float maxtemp,
                         int pinR, int pinG, int pinB) {
  temp = proportion(temp, mintemp, maxtemp);
  int tempR = 0;
  int tempG = 0;
  int tempB = 0;
  if (temp <0.5) {
    tempG = 255 * temp * 2;
    tempB = 255 * (0.5 - temp) * 2;
  }
  else {
    tempR = 255 * (temp - 0.5) * 2;
    tempG = 255 * (1 - temp) * 2;
  }
  analogWrite(pinR, tempR);
  analogWrite(pinG, tempG);
  analogWrite(pinB, tempB);
}

void set_colour_digital(float value, float minimum, float maximum,
                        int pinR, int pinG, int pinB) {
value = proportion(value, minimum, maximum);
value = value * 6;
int index = (int)(value + 0.5);
digitalWrite(pinR, digital_colour[index].R);
digitalWrite(pinG, digital_colour[index].G);
digitalWrite(pinB, digital_colour[index].B);
}
```

Appendix D

Research history

Practice

EEG Visualising Pendant A *NeuroSky* EEG (Electroencephalography) headset is used to send data to an LED (Light Emitting Diode) matrix pendant to visualise the changes in the wearer's EEG attention and meditation data to during social situations. Its distinctive approach to visualising one's physiological state may be helpful in awkward social situations or be a useful exercise for those who would like insight into how they interact with others. The pendant also has record and playback modes, so one can playback and examine data at a later time, for example, to monitor productivity. This data can also be played back to change the way one appears to others in a situation, for example to appear more attentive or relaxed, which I have termed 'emotive engineering. I have created two versions of this device. The first I demonstrated as an example of 'emotive wearables' that I sought feedback and opinions on at focus groups with 27 participants and events. I also tested the pendant in everyday work and social situations with participants in 22 field tests. The pendant was also tested with a group of onlookers. I have presented and exhibited this device at multiple conferences and events in Europe and the USA.

AnemoneStarHeart The design and functionality was informed and inspired by feedback from focus groups and field tests held in 2014. The device can be used as an aid for meditation, relaxation and concentration, as well as for personal viewing or sharing physiological data in social situations with others. The device also has record and playback modes. Data is sent to the *AnemoneStarHeart* via Bluetooth and it is a battery operated, standalone device. It can either be viewed in the palm of the hand or placed in a convenient area of a room — illuminating the space with coloured light. Whilst sensors are transmitting data to the device, it constantly visualises it, changing colour and brightness based on the data it receives. The smaller, wearable version hangs from a chain as a necklace or in the style of a pocket watch so it can be brought out, looked at, then put away again.

ThinkerBelle The *ThinkerBelle EEG Amplifying Dress* is an emotive wearable. It responds to EEG signals from a *NeuroSky MindWave Mobile* EEG headset to amplify data on fibre optic filament. The dress illuminates when it receives data from the headset - attention data = red light and meditation data = green light. The dress also has record and playback modes for data. The dress is designed for wear in evening social occasions. The aesthetic design and functionality of the dress was informed by feedback from focus groups and field tests held in 2014. I exhibited the dress in Osaka, Japan at the Design Exhibition of the International Symposium on Wearable Computers, 2015, held at Grant Front Osaka's Knowledge Theatre.

Baroesque Skirt The skirt visualises data from four sensors on a barometric sensor board. Three of the sensors are environmental: temperature, pressure and altitude, the forth is a temperature sensor that sits on the inside of the skirt and pulls in body temperature of the wearer. I'm interested in how one can display physical data alongside that of the 'bigger picture' of elements that one is surrounded by. I have exhibited this piece at exhibitions and conferences in Europe and the USA. The skirt was featured in New Scientist magazine in September 2014.

GSR Research I have been experimenting with GSR (Galvanic Skin Response) for assessing this technology for various future wearable projects. For example, a dress that responds to detected stress levels, another a discrete Bluetooth module for a bracelet or strap for watch which conveys stress levels of user.

Online documentation

Blog `http://rainycatz.wordpress.com/`

Videos `https://www.youtube.com/user/TheIntrepidLadyFox`

Publications

AnemoneStarHeart EEG Pendant in the adjunct proceedings of the International Symposium on Wearable Computers, 2016 (Ashford, 2016, pp. 446-451)

ThinkerBelle EEG Amplifying Dress in the adjunct proceedings of the International Symposium on Wearable Computers, 2015 (Ashford, 2015, pp. 607–612)

Responsive and Emotive Wearables: Devices Bodies, Data and Communication in the adjunct proceedings of the International Symposium on Wearable Computers 2014 (Ashford, 2014*b*, pp. 99–104)

Baroesque Barometric Skirt in the adjunct proceedings of the International Symposium on Wearable Computers 2014 (Ashford, 2014*a*, pp. 9–14)

EEG Data Visualising Pendant in the adjunct proceedings of the International Symposium on Wearable Computers 2013 (Ashford, 2013)

Twinkle Tartiflette an *Arduino* driven interactive word and music artwork. In the adjunct proceedings of the International Symposium on Wearable Computers 2012

Temperature Sensing T–shirt (AKA: 'Yr In Mah Face!') in the adjunct proceedings of the International Symposium on Wearable Computers 2012

Don't Break My Heart wearable distance warning system for cyclists. In the adjunct proceedings of the International Symposium on Wearable Computers 2012

Focus groups, field tests, and survey

Focus Groups In 2014 I ran four focus groups to evaluate my *EEG Visualising Pendant*, three with women participants of different age ranges in London and one mixed gender / age group at Quantified Self Europe Conference, Amsterdam, in May 2014. In total there were 27 participants.

Field Tests In 2014 ran 22 field tests with participants wearing the *EEG Visualising Pendant* in 'real life' social and work situations, in Brighton and London.

Survey In 2014, I asked participants of the focus groups and field tests group to give their feedback and opinions on emotive wearables and experiencing the *EEG Visualising Pendant*. The survey used open text boxes for feedback on questions asking for thoughts on emotive wearables and their own wearables usage. I received 43 completed surveys. In 2016 I invited attendees of the ISWC Design Exhibition to participate by giving feedback on my ISWC exhibit, *AnemoneStarHeart*. Eleven attendees consented to take part and give feedback.

Courses

June 2016 The Centre for Integrative Neuroscience and Neurodynamics: Cognitive Neuroscience Methods 4-day course (Certificate of Attendance), University of Reading, UK.

January 2015 Francis Bitonti Academie: New Skins 2 week computational design workshop, Digits2Widgits, London.

July 2014 Francis Bitonti Academie, New Skins 2 week computational design workshop, Ravensbourne, London.

Spring/Summer 2013 PhD Academic Practice course run by Les Back, gaining Higher Education Authority (HEA, UK) Associate Practitioner status.

Employment

Goldsmiths College, October 2013–May 2015 Teaching Assistant in the Department of Computing, assisting in all stages of undergraduate Computer Science projects: from initial ideas development to debugging code, designing and creating prototypes and final presentations.

Science Museum, June 2014 e-textiles workshop at Make. Hack. Do.

Goldsmiths College, October 2013–July 2014 Women in Computing Peer Assisted Learning mentor for the Computing Department.

The Point People, November 2013 Consultancy and workshop with parents of toddlers to establish possibilities for wearable technology for children

Goldsmiths College, September 2013 I organised and taught a workshop on e-textiles to Computing Department students, covering the basics of the *LilyPad Arduino* microcontroller, rudimentary electronics and coding.

Bridge Rectifier, April 2013 I have developed from scratch and led a workshop on electronics and programming via e-textiles for beginners at Hebden Bridge Town Hall, Calderdale.

Young Rewired State, Mentor/Developer, November 2012 Working with teenagers from Saudi Arabia who have ambitions to pursue careers in technology, my job was to mentor and help develop their ideas to make software/hardware prototypes at a two-day technical hackday in London.

The Open University, Consultant/Project Manager, March–August 2012 I worked as a freelance consultant for The Open University, with their academics and suppliers to develop a privacy game for Facebook users. It is a learning activity based around personal choices made in terms of everyday surveillance and privacy: `https://apps.facebook.com/ou-privacy-game/`

Technocamps – Learning Consultant/Workshop Leader, December 2011–July 2012 I developed and led workshops for Technocamps, an initiative led by Swansea University in partnership with the Universities of Bangor, Aberystwyth and Glamorgan to inspire young people aged 11–19 via workshops on a range of exciting computing-based topics. I developed a series of wearable technology workshops where students were taught and allowed to experiment with basic skills in C programming and electronics in the form of wearable technology. I taught approximately 300 students over the course of my visits.

Presentations, exhibitions and workshops given

1. AnemoneStarHeart EEG Pendant/Device at Digital Fancies: Bioresponsive E-Textiles and 3D Printing in Fashion, Digits2Widgets, London, June 2018
2. Emotive Wearables: Research, Open University, Milton Keynes, UK. June 2017
3. Emotive Wearables: e-stitches, Victoria and Albert Museum, London, UK. May 2017

4. Emotive Wearable Technology, opentech, ULU, London, UK. May 2017
5. AnemoneStarHeart EEG Pendant/Device, at the Design Exhibition of the 20th International Symposium on Wearable Computers, Heidelberg, Germany, September 2016
6. Emotive Wearables: methods and materials, Design Roast, University of Greenwich, London. February 2016
7. Emotive Wearables, Art and Computational Technology seminar, Goldsmiths, University of London. February 2016
8. Emotive Wearables, at the finals of EPSRC UK ICT Pioneers, QEII Centre, Westminster, London, October 2015
9. Emotive Wearables, at Bartle Bogle Hegarty Expo, Soho, London, October 2015
10. ThinkerBelle EEG Amplifying Dress, at the Design Exhibition of the 19th International Symposium on Wearable Computers, Grant Front Osaka Knowledge Theatre, Osaka, Japan, September 2015
11. Poster: Responsive and Emotive Wearables at the Broadening Participation Workshop at Ubicomp/ISWC, Osaka, Japan, September 2015
12. Organiser: Critical Wearables Research Lab, London College of Fashion, London, UK, June 2015
13. EEG Visualising Pendant and AnemoneStarHeart EEG broadcasting device, Transmission Symposium: Brainwave Interpretation In The Arts, Bournemouth University, April 2015
14. Axion (EEG controlled science storytelling iOS app) CineGlobe Science Film Festival, CERN, Geneva, March 2015
15. Visualising Data Via Wearable Technology, Electronics Stage, World Maker Faire, New York Hall of Science, New York, USA, September 2014
16. Baroesque Barometric Skirt, at Microsoft Research Gallery Exhibition, Redmond, USA, September-October 2014

17. Responsive and Emotive Wearables: Devices Bodies, Data and Communication, poster and demo of EEG Visualising Pendant at 18th International Symposium on Wearable Computers (ISWC), Seattle, USA, September 2014
18. EEG Visualising Pendant demo, Seattle Quantified Self + ISWC/Ubicomp, Seattle, USA
19. Responsive and Emotive Wearables: Devices Bodies, Data and Communication, at the Doctoral School Colloquium of the 18th International Symposium on Wearable Computers (ISWC), Seattle, USA, September 2014
20. Baroesque Barometric Skirt, at the 18th International Symposium on Wearable Computers (ISWC) Design Exhibition, Experience Music Project Museum (EMP), Seattle, USA, September 2014
21. Sensing Wearable Technology at Young Rewired State Festival of Code, Plymouth University, Plymouth, August 2014
22. e-textiles workshop at 'Make. Hack. Do.' at the Science Museum, London, May 2014
23. Teaching with the LilyPad Arduino, OSHUG, British Computer Society (BCS) London, 2014
24. Baroesque Barometric Skirt, Textile Innovation Workshop 1 - From Invention to Consumption: electronic textiles, C4CC, London, May 2014
25. EEG Visualising Pendant, Quantified Self Europe Conference, Amsterdam, May 2014
26. Axion (EEG/biofeedback controlled science storytelling iOS app) Tribeca Interactive Festival, New York, April 2014
27. Axion (EEG/biofeedback controlled science storytelling iOS app) CineGlobe Science Film Festival, CERN, Geneva, March 2014
28. Making Wearable Technology, Wearable Futures Conference, Ravensbourne, December 2013
29. Women In Computing — Dept. of Computing, Goldsmiths College, September 2013
30. EEG Data Visualising Pendant, ISWC (International Symposium for Wearable Computing, Zurich, September 2013

31. Baroesque Skirt, Smart Textiles Salon, MILA Museum, Ghent, Belgium, June 2013
32. EEG Visualising Pendant, exhibited at Maker Faire UK, Newcastle
33. Introducing Wearable Technology, Bridge Rectifier, Hebden Bridge
34. Visualising Physiological Data, Quantified Self Europe Conference, Amsterdam, May 2013
35. Women in Computer Science, Goldsmiths College Open Day, March 2013
36. Visualising EEG Data For Wearable Technology, poster shown at Challenges & Opportunities for Wireless Sensing Systems in Healthcare & Assisted Living Conference, National Physical Laboratory, Teddington, March 2013
37. Sensing Wearables at International Women's Day Technology Showcase, Shoreditch, London, February 2013
38. Here Comes Wearable Technology, QCon 2013 Software Development Conference, Queen Elizabeth II Conference Centre, London, February 2013
39. Art, Creativity, Technology & Wellness, Goldsmiths Thursday Club, C4CC, London November 2012
40. Wearable Technology (+ a bit of Open Sourcery), Open Source Hardware Camp, Hebden Bridge, September 2012
41. Introduction to Wearable Technology, London Threads, C4CC, London July 2012
42. Introduction to Wearable Technology for Creatives, Open GDNM 2012, Rag Factory, London, June 2012
43. Wearable Technology, Processing for Artists workshop, Goldsmiths, University of London, June 2012
44. International Symposium for Wearable Computing 2012 (exhibited three pieces of work), Newcastle, UK
45. Wearable Technology and Open Source, Flossie 2012, Queen Mary, University of London, May 2012
46. Introduction to Wearable Technology, Aberystwyth, April 2012

47. Sensors for e-textiles creative, at Nano4Design, Nanoforce, Queen Mary University of London, March 2012
48. Exploring Wearable Technology, at CultureCode, Live Theatre, Newcastle, February 2012
49. Sensing Wearables, opening plenary at Quantified Self Europe Conference, Amsterdam, November 2011
50. Teapotty at Chi-TEK at the Victoria & Albert Museum, London, September 2011
51. Twinkle Tartiflette and Yr In Mah Face, Transfer Summit, Keble College, Oxford, September 2011
52. Teapotty Chi-TEK at Watermans Gallery, London, April 2011

Events organised

Critical Wearables Lab - June 2015, London College of Fashion. I am a co-organiser of this one-day event, which asks critical questions about the future of wearable technology, featuring a 'material making' session and firestarter talks from practitioners, academics and others working in the field.

TV, press, interviews, and Features

BBC World Service Click Radio, July 2018 practice mentioned in feature about group exhibition, Digital Fancies: Bioresponsive E-Textiles and 3D Printing in Fashion, at Digits2Widgets, London — `https://www.bbc.co.uk/programmes/w3cswhdj`

Top 100 Women in Wearable and Consumer Tech, January 2018 Rain Ashford, wearable tech creator, inventor and mentor `https://medium.com/women-of-wearables/top-100-women-in-wearable-and-consumer-tech-2ffae35a2901`

WoW Woman in Wearable Tech, July 2017 Rain Ashford, wearable tech creator, inventor and mentor `http://www.womenofwearables.com/new-blog/wow-woman-in-wearable-health-tech-rain-ashford-wearable-tech-creator-inventor-and-mentor`

Adafruit, December 2015 My Top Five Almost Famous Wearables for 2015
`https://blog.adafruit.com/2015/12/30/my-top-five-almost-famous-wearables-for-2015-wearablewednesday/`

Adafruit Wearable Weds, June 2015 ThinkerBelle EEG Amplifying Dress
`https://blog.adafruit.com/2015/06/17/thinkerbelle-a-fiber-optic-dress-with-thoughts-wearablewednesday/`

Adafruit Wearable Weds, Jan 2015 Francis Bitonti New Skins blog post
`https://blog.adafruit.com/2015/01/28/a-peek-at-bitontis-new-skins-workshop-wearablewednesday/`

Atmel: Bits & Pieces, June 2015 ThinkerBelle EEG Amplifying Dress
`http://blog.atmel.com/2015/06/17/this-fiber-optic-dress-is-amplified-by-a-wearers-thoughts/`

Adafruit Wearable Weds, Sept 2014 EEG Visualising Pendant
`https://blog.adafruit.com/2014/09/24/led-pendant-visualizex-eeg-wearablewednesday/`

New Scientist, Sept 2014 Baroesque Barometric Skirt in print and online
`http://www.newscientist.com/article/mg22329884.200-one-per-cent.html`

Quantified Self, July 2014 video from 2013
`http://quantifiedself.com/2014/07/rain-ashford-wearing-physiological-data/`

Quantified Self, July 2014 Emotive Wearables
`http://quantifiedself.com/2014/07/qseu14-breakout-emotive-wearables/`

BBC Click Technology News, April 2014 (TV programme) work featured in coverage of StoryMatter Hackathon and CineGlobe Science Festival at CERN, Geneva — `http://www.bbc.co.uk/news/technology-26938150`

BBC World Service Click Radio, March 2014 interview about work at Tribeca Hacks StoryMatter Hackathon at CERN, Geneva — `http://www.bbc.co.uk/programmes/p01tmmzv`

Le Temps, Switzerland, March 2014 coverage of Tribeca Hacks StoryMatter Hackathon at CERN, Geneva

BBC Technology News, September 2013 interview at International Symposium on Wearable Computers, Zurich
http://www.bbc.co.uk/news/technology-24182705

Swiss National Television, September 2013 coverage of International Symposium on Wearable Computers, Zurich

Shane Richmond, September 2013 'Computerised You: How Wearable Technology Will Turn Us Into Computers' — interviewed and feature in eBook

AVS Belgian Television, June 2013 featured in coverage of Smart Textiles Salon, Ghent
http://www.avs.be/donderdag.html

Ghent University, June 2013 brochure for Smart Textiles Salon, Ghent

FreeIO.org, June 2013 Free hardware/Open Hardware Magazine; featured in coverage of Smart Textiles Salon, Ghent
http://freeio.org/2013/06/page/2/

Quantified Self Europe, April 2013 conference preview interview
http://quantifiedself.com/2013/02/qs-europe-2013-conference-preview-rain-ashford/

Linux User Magazine, January 2013 interview from coverage of OSHCamp (Open Source Hardware Camp) (conducted 2012)

Newcastle Journal, March 2012 coverage of Culture Code Conference
http://www.thejournal.co.uk/business/business-news/looking-forward-newcastles-culturecode-hack-4412324

Lectures attended

1. Sarah Angliss lecture, Goldsmiths, June 2015
2. Simon Penny lecture, Goldsmiths, May 2014

3. Various Thursday Club presentations, Goldsmiths
4. Various lectures from the PhD Academic Practice Course, Goldsmiths
5. Computational Creativity Theory project — Alison Pease, Whitehead Lectures, Goldsmiths, February 2013
6. Neural Correlates of Dynamic Musical Imagery, Professor Andrea Halpern, Whitehead Lectures, Goldsmiths February 2013
7. Sketches of Another Future: Cybernetics in Britain 1940–2000, Andrew Pickering, Goldsmiths, February 2013
8. Cosmopolitical Critters: Companion Species, SF, and Staying with the Trouble, Donna Haraway, Senate House, October 2012x

Conferences and events attended

1. Opentech, ULU, London, May 2017
2. International Symposium on Wearable Computers/Ubicomp at Kongresshaus Stadthalle, Heidelberg, Germany, September 2016
3. Finals and exhibition for the Engineering and Physical Sciences Research Council's (EPSRC) UK ICT Pioneers Competition, Queen Elizabeth II Centre, London, October 2015
4. International Symposium on Wearable Computers/Ubicomp at Grand Front Osaka, Japan, September 2015
5. Transmission Symposium: Brainwave Interpretation In The Arts, Bournemouth University, April 2015
6. TSB/Innovate UK Wearable Technologies Contest Final, Digital Catapult Centre, London April 2015
7. Fashion and the Senses, London College of Fashion, March 2015
8. NESTA FutureFest, London, March 2015
9. Threads and Codes, Goldsmiths, London, March 2015

10. International Symposium on Wearable Computers, Seattle, USA, September 2014
11. World Maker Faire, New York, USA, September 2014
12. Textile Innovation Workshop 1 - From Invention to Consumption: electronic textiles, C4CC, London, May 2014
13. Quantified Self Europe 2014, Amsterdam May 2014
14. CineGlobe Festival, CERN, Geneva, March 2014
15. Tribeca Hacks StoryMatter Hackathon, CERN, Geneva March 2014
16. Wearable Futures, Ravensbourne, London, December 2013
17. OCADU/Goldsmiths — Lightning Talks Virtual Graduate Symposium, October 2013
18. International Symposium on Wearable Computers, Zurich, September 2013
19. dConstruct, Brighton, September 2013
20. Elephant and Castle Mini Maker Faire, London, June 2013
21. Maker Faire UK, Newcastle, April 2013
22. Smart Textiles Salon, Ghent, May 2013
23. Quantified Self Europe, Amsterdam, May 2013
24. Energy Harvesting 2013, Hamilton House, London, March 2013
25. Challenges & Opportunities for Wireless Sensing Systems in Healthcare & Assisted Living, National Physical Laboratory, Teddington, March 2013
26. QCon London 2013 Software Developer Conference, Queen Elizabeth II Conference Centre, London, February 2013
27. Brighton Mini-Maker Faire, Brighton, October 2013
28. Open Source Hardware Camp, Hebden Bridge, September 2012
29. Open GDNM 2012, Rag Factory, London, June 2012
30. Self-Hacking, Hub Westminster, London, June 2012

31. Flossie, Open Source for Women, Queen Mary University of London, May 2012
32. Nano4Design, Nanoforce, Queen Mary University of London, March 2012
33. CultureCode, Centre for Life, Newcastle, February, 2012
34. CultureCode, Middlesbrough Museum of Art, February 2012
35. CultureCode, Live Theatre, Newcastle, February 2012
36. Quantified Self Europe, Amsterdam, November 2011

Workshops attended

1. Incorporating Energy Harvesting Design into Technology Workshop, ROCA Gallery London, January 2014
2. Peer Assisted Learning workshops, Goldsmiths, September 2013
3. Practice and Theory: Trajectories of Research Workshop, by Ernest Edmonds, January 2012
4. How do you present your 'practice' (of whatever kind) in your PhD, in what form and why? with Bill Gaver and Janis Jefferies December 2011
5. Make It, Sell It Day - for entrepreneur Makers and crafts people at the British Library, November 2011
6. Processing for Artists, taught by Eleanor Dare, Spring 2012
7. Physical Computing, taught by Brock Craft, Spring 2012

Group meet-ups attended

1. Thursday Club, show and tell, 2011–2016, Goldsmiths, London
2. ACT PhD Programme seminars 2011–2016, Goldsmiths, London
3. OSHUG, Open Source Hardware User group — monthly meet up, London
4. Quantified Self London group, monthly meet up, Google Campus, London

5. Dorkbot London, periodic meet up on arts and technology
6. E-stitches, wearable technology group, periodic meet-up, V&A, London

Exhibitions attended

1. Electricity: The spark of life, Wellcome Collection, London, April 2017
2. 'Soomi Park & collaborators: Technophilia & The Corrupt Body Exhibition' at the Mernier Gallery, London, March 2015.
3. 'Creative Machine', St.James, Hatcham Church Gallery Goldsmiths, November 2014
4. International Symposium on Wearable Computers Design Exhibition, EMP, Seattle, September 2014
5. MoMA, New york, New York, USA, September 2014
6. 'Universe of Particles', CERN, Geneva, September 2013
7. International Symposium on Wearable Computers Design Exhibition, Zurich, September 2013
8. Codebreaker: Alan Turing's Life and Legacy, Science Museum, London, March 2013
9. International Symposium on Wearable Computers Design Exhibition, Newcastle, July, 2012

Hackdays attended

1. BrainHack, Makerversity, London, March 2015
2. CERN Storymatter Hackathon in March 2014 I Geneva, Switzerland
3. Hondahack, Guardian Newspapers, London November 2011
4. Musichackday, Barbican, London, December 2011

Doctorial Colloquium

Participated in the International Symposium on Wearable Computers, Doctorial Colloquium for September 2014.

Competitions

June 2015 I reached the finals of the EPSRC UK ITC Pioneers 2015 Competition, held in October 2015 with research and practice investigating Emotive Wearables.

Scholarships, bursaries, and awards

June 2016 Awarded a travel bursary funded by the ESRC Advanced Training Initiative, to attend Cognitive Neuroscience Methods 4-day course (Certificate of Attendance), at The Centre for Integrative Neuroscience and Neurodynamics, University of Reading, UK.

June 2015 Awarded a travel scholarship from the Goldsmiths Graduate School for International Symposium on Wearable Computers to exhibit *ThinkerBelle EEG Amplifying Dress* in their Design Exhibition, and also exhibit a poster on my doctoral research in the Ubicomp Broadening Participation workshop, September 2015, Osaka, Japan.

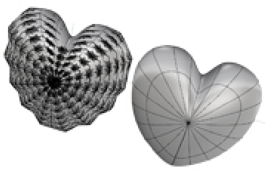
June 2015 Awarded a travel scholarship from the Goldsmiths Computing Department for the International Symposium on Wearable Computers to exhibit *ThinkerBelle EEG Amplifying Dress* in their Design Exhibition, and also exhibit a poster on my doctoral research in the Ubicomp Broadening Participation workshop, September 2015, Osaka, Japan.

September 2014 Awarded a travel scholarship by the International Symposium on Wearable Computers to participate in their Doctoral Colloquium, present poster and exhibit *Baroesque Barometric Skirt* in their Design Exhibition.

April 2014 Awarded a Convocation Trust Student Entrepreneurship Award to develop my *EEG Visualising Pendant*.

September 2013 Goldsmiths Computing Department travel bursary for the International Symposium on Wearable Computers, 2013 in Zurich, Switzerland, exhibited *EEG Visualising Pendant* in their Design Exhibition.

Bibliography



Adafruit (2013), 'adafruit/Adafruit-LED-Backpack-Library'.
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