A Conceptual Framework for Designing Wearable Technology

Jeremiah Nugroho
S.T., M. Des. Sci.

A thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

Faculty of Design, Architecture & Building
2013

UNIVERSITY OF TECHNOLOGY SYDNEY

CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis and data collection in this thesis was approved by UTS Human Research Ethics Committee (UTS HREC reference number: 2012-267A).

Jeremiah Nugroho

25 March 2013

ACKNOWLEDGEMENTS

First and foremost, I would like to express my highest gratitude to God Almighty for always guiding me through the journey. I would like to thank the following individuals who has kindly helped me in finishing this thesis:

- My supervisor: Professor Kirsty Beilharz for providing me with constant guidance in conducting this research. Her insightful and expert advice has been most substantial in completing this thesis.
- My gratitude extends to Dr. Sam Ferguson for being a great mentor in understanding technological issues; and Todd Robinson for his kind assistance of finding research participants; and to fellow PhD researchers within the DAB faculty at UTS for their genuine support.
- My research participants for generously providing time to participate in this research. This thesis would not be finished without your kind contributions.
- The administrative staff of the Design, Architecture and Building Faculty, University Graduate School, and International Office staff of the University of Technology Sydney for being very helpful and attentive.
- The informal and indispensable support from the following individuals: Rainda Rachmawyna Katili, Gracia Agatha and Dewi Taharuddin and friends whom I have worked with at Alpha60, Saxony and Ripples for supporting me through flexibility and understanding.

Last but not least, to my family: Samuel Nugroho and Gracia Anggraeni Nugroho- my siblings and also the rest of my extended family for believing in me. My parents: Cornelius Herman Nugroho and Sianni Kartika, who have been a constant source of support – emotional, moral and of course financial through my years of studies. It is thanks to my parents for teaching me that knowledge is infinite, constantly since I was young and therefore this thesis is dedicated to them.

Jeremiah Nugroho

25 March 2013

PREFACE

"…the designer's task is to produce 'the solution'." (Cross 2006, p. 7)

This thesis is the result of an almost 4 year period of research within the Faculty of Design, Architecture and Building at the University of Technology Sydney (UTS) where I was given the opportunity to grow as an academic researcher. The research discussed in this thesis is within the field of wearable technology by looking into its design process.

In the period between 2007-2008, I became deeply interested by the world of digital media while studying to complete my Master's degree at the University of Sydney. A particular course named Digital Culture was a pivotal subject as I experienced an epiphany of how digital technology has advanced, transformed and influenced our quotidian life. The discourse on pervasive and ubiquitous digital media pulled my interest towards the study of Cyborgism, where I encountered the possible physical representation of the future.

A small project in mid 2008 produced a pilot study on a performance piece titled *Wireless Gamelan*, which became part of the final research report in finishing my master's degree. This project was the beginning of my personal academic inquiry into the fusion between human and technology. Initially, I tended to value the extremity of embodying technology, thus physically representing the term cyborg. Human skin became a limiting boundary, which needed to be blurred (or permeated) as to efficiently transform oneself into a cyborg.

When this research project began, I explored literature and existing bodies of works closely related to Cyborgism, which led me to the inquiry: rather than penetrating the skin, why not embrace the skin as part of the integration between man and technology. This realization has extended to the point where I can clearly understand that integration does not necessarily mean embodiment. How do you achieve integration between man and machine? The answer possibly lies in understanding the design process of wearable technology, explored in this thesis.

TABLE OF CONTENTS

Certificate of Original Authorship ii
Acknowledgments iii
Preface iv
Table of Contents v
List of Figures ix
List of Tables x
Abstract xiv

1. INTRODUCTION 1

1.1. Motivation 1
1.2. Overview 4
1.3. Thesis Structure 4

2. LITERATURE REVIEW 6

2.1. Wearable Technology in Computing 7
2.2. Wearable Technology in Fashion 12
2.3. Wearable Technology in Art 16
2.4. Wearable Technology in the Discourse of Cybernetics 22
2.5. Wearable Technology in Popular Culture 27
2.6. Aesthetic Subjectivity vs. Wearable Technology Design 28
2.7. Art + Fashion + Computing=Wearable Technology? 32
2.8. Existing Theories in Designing Wearable Technology 33

3. DESIGN ATTIBUTES OF WEARABLE TECHNOLOGY 39

3.1. Design Attributes of Wearable Technology 40
3.1.1. Size/Dimensions 40
3.1.2. Device Positions 40
3.1.3. Power Source 40
3.1.4. Heat 41
3.1.5. Weight 41
3.1.6. Durability/Resistance 41
3.1.7. Washability 42
3.1.8. Enveloping/Fabrication 42
3.1.9. Functionality 42
3.1.10. Usability 43
3.1.11. Sensation 43
3.1.12. Connectivity 44
3.2. Interrelationships and Overlaps 45

4. INITIAL CASE STUDIES 48
4.1. Case Study on Personal projects 48
4.1.1. Case Study 1: Biomuse Performative Sonification 48
4.1.1.1. Case Study 1 Analysis 50
4.1.2. Case Study 2: GPS Data Logger 52
4.1.2.1. Case Study 2 Analysis 54
4.2. Case Study Conclusion 55

5. POSITIONING WEARABLE TECHNOLOGY DESIGNERS AND THE PHENOMENOLOGICAL APPROACH 57
5.1. Phenomenological Approach 60
5.2. Research Strategy Involving Participants 61

6. WHAT IS DESIGNING WEARABLE TECHNOLOGY LIKE? 66

6.1. Participant 1 66

6.1.1. Units of relevant meanings 71

6.1.2. Interview 1: relevant meanings in relation to the main research questions 88

6.2. Participant 2 90

6.2.1. Units of relevant meanings 92

6.2.2. Interview 2: relevant meanings in relation to the main research questions 107

6.3. Participant 3 109

6.3.1. Units of relevant meanings 111

6.3.2. Interview 3: relevant meanings in relation to the main research questions 126

7. DISCUSSION ARISING FROM RESEARCH FINDINGS 129

7.1. Aesthetics, visual aspects and people's reaction.....132

7.2. Design process, background research and time constraints 134

7.3. Technological issues or lack of previous training and designing as a group.....135

7.4. Design characteristics of Wearable Technology and emerging design attributes of Wearable Technology 137

8. CONCLUSION.....142

8.1. Significant Contributions of this Research.....142

8.1.1. Wearable Technology as a Multi Disciplinary Field.....142

8.1.2. Wearable Technology Design Attributes.....142

8.1.3. Wearable Technology Design Process.....143

8.2. Future Research Possibilities 144

APPENDICES 147

APPENDIX A: Research Participants Interview Transcripts. 147

APPENDIX B: Diagram Showing Interrelationships And Overlaps Within Design Attributes Of Wearable Technology 164

APPENDIX C: Glossary.....165

APPENDIX D: Conference Papers.....167

BIBLIOGRAPHY 179

LIST OF FIGURES

Figure 1. The ambient telepresence wearable computer prototype (Drugge et al. 2004) 8

Figure 2. ZYPAD WL1000 Wrist Worn Personal Computer (Parvus n. d.) 9

Figure 3. Vest with embedded computer for aircraft maintenance personnel (Nicolai et al. 2006) 10

Figure 4. Fashionable Wearables Range in Levels of Expressiveness versus Functionality (Seymour 2008) 12

Figure 5. Ying Gao's *Walking City* (2007) 13

Figure 6. Hussein Chalayan's shape-changing dress from his Autumn/Winter 2007 collection (Chalayan 2007) 14

Figure 7. *The M-Dress* by Cute Circuit (2011) 15

Figure 8. Kerri Wallace' *Motion Response Sportswear* (Henni 2008) 15

Figure 9. Joo Youn Paek's *Self-Sustainable Chair* (2006) 18

Figure 10. *My Trousers* (Ashuach 2003) 18

Figure 11. *The hipDiskettes* (Wilde 2008) 19

Figure 12. Imogen Heap at the Grammy Awards 2010 and the LED collar of the Twitter dress (Dybwad 2010) 44

Figure 13. Matrix diagram displaying the relationship between design considerations for Fashionable Technology and design attributes of Wearable Technology 45

Figure 14. Diagram showing interrelationships and overlaps within design attributes of Wearable Technology 46

Figure 15. Biomuse Performative Sonification 49

Figure 16. GPS logger 53

Figure 17. Research Strategy Diagram 62

Figure 18. Iterative use of design attributes in Wearable Technology design 139

LIST OF TABLES

Table 1. Inputs and Outputs Types of Fashionable Wearables (Seymour 2008) 34

Table 2. Guideline for the Construction of Fashionable Wearables (Seymour 2008) 35

Table 3. List of questions for semi-structured interviews with expected outcomes 63

Table 4. Prompts that were used in order to elicit more feedback during interview 64

Table 5. Field Notes Method 64

Table 6. Units of general meaning from Participant 1: Question 1, 1a and 1b 71

Table 7. Units of relevant meaning from Participant 1: Question 1, 1a and 1b 72

Table 8. Units of general meaning from Participant 1: Question 2 and 3 73

Table 9. Units of general meaning from Participant 1: Question 4, 4a and 4b 73

Table 10. Units of general meaning from Participant 1: Question 4, 4a and 4b 73-74

Table 11. Units of relevant meaning from Participant 1: Question 4, 4a and 4b 74-75

Table 12. Units of general meaning from Participant 1: Question 5, 5a and 5b 75-76

Table 13. Units of relevant meaning from Participant 1: Question 5, 5a and 5b 76

Table 14. Units of general meaning from Participant 1: Question 6 and 6a 77

Table 15. Units of relevant meaning from Participant 1: Question 6 and 6a 78

Table 16. Units of general meaning from Participant 1: Question 7 and 7a 78

Table 17. Units of relevant meaning from Participant 1: Question 7 and 7a 79

Table 18. Units of general meaning from Participant 1: Question 8 79

Table 19. Units of relevant meaning from Participant 1: Question 8 79

Table 20. Units of general meaning from Participant 1: Question 9, 9a and 9b 80

Table 21. Units of relevant meaning from Participant 1: Question 9, 9a and 9b 81

Table 22. Units of general meaning from Participant 1: Question 10 81

Table 23. Units of relevant meaning from Participant 1: Question 10 82

Table 24. Units of general meaning from Participant 1: Question 11, 11a, 11b and 11c 82-84
Table 25. Units of relevant meaning from Participant 1: Question 11, 11a, 11b and 11c 85-86
Table 26. Units of general meaning from Participant 1: Question 12 and 12a 85
Table 27. Units of relevant meaning from Participant 1: Question 12 and 12a 85
Table 28. Units of general meaning from Participant 1: Question 13 and 13a 86
Table 29. Units of relevant meaning from Participant 1: Question 13 and 13a 86
Table 30. Clusters of relevant meanings from Interview 1 87
Table 31. Units of general meaning from Participant 2: Question 1 and 1a 92-93
Table 32. Units of relevant meaning from Participant 2: Question 1 and 1a 93
Table 33. Units of general meaning from Participant 2: Question 2 and 3 94
Table 34. Units of relevant meaning from Participant 2: Question 2 and 3 94
Table 35. Units of general meaning from Participant 2: Question 4 and 4a 94-95
Table 36. Units of relevant meaning from Participant 2: Question 4 and 4a 95
Table 37. Units of general meaning from Participant 2: Question 5 96-97
Table 38. Units of relevant meaning from Participant 2: Question 5 97
Table 39. Units of general meaning from Participant 2: Question 6 97-98
Table 40. Units of relevant meaning from Participant 2: Question 6 98
Table 41. Units of general meaning from Participant 2: Question 7 and 7a 99
Table 42. Units of relevant meaning from Participant 2: Question 7 and 7a 99
Table 43. Units of general meaning from Participant 2: Question 8 100
Table 44. Units of relevant meaning from Participant 2: Question 8 100
Table 45. Units of general meaning from Participant 2: Question 9 101
Table 46. Units of relevant meaning from Participant 2: Question 9 101
Table 47. Units of general meaning from Participant 2: Question 10 102
Table 48. Units of relevant meaning from Participant 2: Question 10 103
Table 49. Units of general meaning from Participant 2: Question 11 103-104

Table 50. Units of relevant meaning from Participant 2: Question 11 104
Table 51. Units of general meaning from Participant 2: Question 12 and 12a 104-105
Table 52. Units of relevant meaning from Participant 2: Question 12 and 12a 106
Table 53. Clusters of non-redundant units of relevant meanings from the interview with participant 2 106-107
Table 54. Units of general meaning from Participant 3: Question 1 and 1a 111
Table 55. Units of relevant meaning from Participant 3: Question 1 and 1a 112
Table 56. Units of general meaning from Participant 3: Question 2, 3 and 3a 112
Table 57. Units of relevant meaning from Participant 3: Question 2, 3 and 3a 112-113
Table 58. Units of general meaning from Participant 3: Question 4, 4a-4f 113-114
Table 59. Units of relevant meaning from Participant 3: Question 4, 4a-4f 114
Table 60. Units of general meaning from Participant 3: Question 5 114
Table 61. Units of relevant meaning from Participant 3: Question 5 115
Table 62. Units of general meaning from Participant 3: Question 6, 6a-6c 115
Table 63. Units of relevant meaning from Participant 3: Question 6, 6a-6c 116
Table 64. Units of general meaning from Participant 3: Question 7 and 7a 116
Table 65. Units of relevant meaning from Participant 3: Question 7 and 7a 117
Table 66. Units of general meaning from Participant 3: Question 8, 8a and 8b 117-118
Table 67. Units of relevant meaning from Participant 3: Question 8, 8a and 8b 118
Table 68. Units of general meaning from Participant 3: Question 9 and 9a 118-119
Table 69. Units of relevant meaning from Participant 3: Question 9 and 9a 119
Table 70. Units of relevant meaning from Participant 3: Question 10 and 10a 119-120
Table 71. Units of relevant meaning from Participant 3: Question 10 and 10a 120
Table 72. Units of relevant meaning from Participant 3: Question 11, 11a-11e ...120-121
Table 73. Units of relevant meaning from Participant 3: Question 11, 11a-11e ...121-122
Table 74. Units of general meaning from Participant 3: Question 12, 12a and 12b 122
Table 75. Units of relevant meaning from Participant 3: Question 12, 12a and 12b ... 123
Table 76. Units of relevant meaning from Participant 3: Question 13 and 13a 123-124

Table 77. Units of relevant meaning from Participant 3: Question 13 and 13a 124

Table 78. Clusters of non-redundant units of relevant meaning from the interview with participant 3 125-126

Table 79. Clusters of relevant meanings from interview 1, 2 and 3 131

Table 80. Comparison between design attributes of Wearable Technology proposed in this research and design attributes of Wearable Technology raised by the participants during interviews 138

ABSTRACT

Previous studies showing the shortfalls of Wearable Technology demonstrate the lack of attention to aesthetics and the absence of an approach that positions the user importantly in the design process (Co 2000, Orth 2001, Boehner et al 2005, Dunne et al 2005, Waitier 2003, Viseu 2005). This thesis attempts to tackle this problem by understanding the design process in Wearable Technology. It explores the field of design thinking from the designer's perspective specifically in Wearable Technology, where interdisciplinary discourse integrating fashion, human-computer interaction, fine arts and the digital media culture merge and are intertwined.

Existing and related design theories of Wearable Technology have allowed extraction of design attributes of Wearable Technology that is holistic and flexible. These design attributes were then reflected on in semi-structured interviews involving designers who have experienced designing Wearable Technology. The resulting phenomenological analyses from the transcripts were then compared to the offered design attributes to further understand how these design attributes behave in the design process of Wearable Technology.

The research findings in this thesis offer a new conceptualization strategy for Wearable Technology designers that includes a set of design attributes and their characteristics in design process which are beneficial in understanding the design process itself. This conceptualization strategy and its application to Wearable Technology design render the possibility for designers to understand the user progressively during the design process.

CHAPTER 1

INTRODUCTION

1.1. Motivation

Everyday we make routine decisions, whether consciously or not in building a certain 'look' (or image or appearance) through our clothes. Fashion[1] as a form of self-expression embodies outward projection, reflecting an individual's personality (Mura 2004). Marshall McLuhan points out the power of clothing as a medium that carries another medium within (1994). It can demonstrate potential prowess in identifying with certain cultural movements, or differentiating socio-economic status, or simply for expressing subjective preference (Berzowska 2005). It becomes a significant part of the body which we construct daily as a personal identity system. Moreover, when we hear the word 'fashion', what often comes to mind is the idea of garments, textiles, and trends. If fashion is a form of artistic expression then its interpretation must rely in some way on a relationship to beauty and aesthetics rather than (mere) functionality.

The integration and vast development of technology in any industry is also seen through its adoption in multiple aspects of our everyday live, such as mobile phones, social media, computers, and of course in fashion. Advanced machinery that allows intricate garment construction and the vast array of high tech materials that become more adeptly integrated and visible in our lives. Transformative material processes have rapidly evolved in the past two decades, resulting in the development of advanced textiles, which have permeated all levels of the garment industry including mass produced fast fashion for the high street, everyday and extreme sports wear to couture. However, the fashion world has been rather reluctant to include technological and computational elements as part of its aesthetics. Its evidence is mostly only seen through garments or materials as witness to

[1] The decision to use the term fashion rather than 'garment' and 'clothing ' is linked to its history: It has always taken advantage of textile technology in its development process from primitive costume into more complex costumes, and later on gave birth to the field of fashion (Koda, as cited in Berzowska and Coelho, n. d.). It is also linked to its sensitivity to the current happenstances, which efficiently rejects the immediate past (Heller 2010). Thus, the choosing of the term fashion is also due to one of its main characteristics: responsive to the recent trend.

highly technological treatment. This is perhaps due to the lack of knowledge and research involving possible new technologies that can be embodied into what we wear. There is also a schism between the designed garment or whole form and materials that comprise it. Sabine Seymour, when introducing the term 'Fashionable Technology' avoids mentioning textile as an authoritative component, but rather defining it as the '*intersection of design, fashion, science and technology*' (2009, p. 12). She admits the influence of enhanced textiles and materials, along with other components (e.g. computing) have contributed to the development of wearable technology (Seymour 2009). This is further supported by the work seen in Berzowska's XS Labs[2], which focuses on the innovation of electronic textiles and reactive garment by questioning what type of information processing can be projected through the idea of wearing something on our bodies.

Screen-based desktop computers have transformed into mobile and peripheral electronic gadgetry, such as mobile/smart phones, MP3 players, game consoles and PDAs. Additionally, with the evolvement of technology and its miniaturization, the only differences between these devices and their larger deskbound counterparts, are the interface and the application software (Starner 2001) (as well as mobility/portability). Only very recently, these developments have affected how electronic technology is used to advance human abilities, thus shifting us from using to wearing the technologies. In example, a project from Hexagram named Wearable Absence, utilizes a PDA or a smart phone, which is connected to the internet and carried around by the user in the garments' pocket. The device is also connected to the embedded sensors in the garment via Bluetooth, transmitting readings from four different sensors: heart rate, temperature, rate of respiration and galvanic skin response (moisture). These readings reflect the emotional state of the wearer, thus triggering multimedia files from a database that are pre-uploaded by the user. Visual response from the device is then viewed on the PDA device / smart phone carried in the pocket, while audio response is played via embedded headphones in the garment (Jefferies 2012). Another example that leans to textile technology was featured in Science Daily (2012), covering the development of cotton fabric that has been

[2] http://www.xslabs.net/theory.html, n. d. (accessed 10 January 2014)

carbon activated and coated with nano-structured manganese oxide, enabling energy storage for powering electronic gadgets.[3]

The current advancements mentioned previously, give evidence to the current trend of an interdisciplinary approach in technology: the synthesis of textile (soft material) and electronic devices (hardware/computing) to a more seamless integration between the two (e.g. through chemical processing). Herbert Blumer in *Fashion: Critical and Primary Sources Volume 4, the Twentieth Century to Today* (ed. Peter McNeil 2009) wrote that new fashions are influenced by their immediate predecessors, thus creating a line of continuity, which is often customarily recognised as fashion trends. Its influencing factors are motivated by its sensitivity to current developments, as they occur in its own field, or other political and social shifts. Furthermore, in *Berg Encyclopaedia of World Dress and Fashion, Global Perspectives Volume 10*, the term 'trend' refers to: "*…fashion change (innovation) and fashion adoption behavior (diffusion)*" (Mackinney-Valentin 2010). Recent examples mentioned previously, along with works mentioned within the literature review (Chapter 2) have shown evidence of innovation and change in the adoption behaviour of fashion. However it is important to state that this research is not emphasized on fashion trend - which often relates to 'fast-fashion' (Mackinney-Valentin 2010), but rather it is positioned as a response to the arising trend of technological advances, which allows for the birth of Wearable Technology. This is further supported by the history of fashion and its rising as a valid academic inquiry in the 1960s, which reveals that in its growth, fashion has served as a pathway in understanding cultural, economic and social occurrence in history (Harte 2010).

Wearable Technology in this research challenges this nomenclature by shifting emphasis towards usability, ergonomics and user-centred perspective rather than focusing on the technology itself, looking towards engagement, usefulness, ease and enjoyability of use (i.e. human factors). It could be said that human engagement and satisfaction are metrics of aesthetic 'success' in Wearable Technology design. Hence, the central issue in Wearable Technology in this research is comprehension from the designer's perspective of

[3] http://www.sciencedaily.com/releases/2012/06/120629211540.htm, 29 June 2012 (accessed 10 January 2014).

the user, i.e. both comprehensibility of content and also of controls, manipulators and other interactive elements of the interface and representation (display).

This thesis attempts to augment understanding in the field of Wearable Technology by elaborating how the synthesis of fashion and computing invite multiple considerations, therefore challenging designers in creating successful outcomes. A set of specifications for approaching and integrating these required considerations in process of designing Wearable Technology is developed and examined in this research. How does the designer's understanding of design attributes affect the design process of Wearable Technology? How do different designs purposes that have different types of functionality and usability requirements affects design process in Wearable Technology? How can an understanding of the interdisciplinary iterative design process of Wearable Technology provide a new conceptual understanding of the field? These are the questions addressed through this research.

1. 2. Overview

This thesis reviews historical surveys of existing Wearable Technology from the perspective of different fields that converge in Wearable Technology design, including fashion, computing, arts, pop culture and cybernetics culture, discussing their influence and overlaps with one another, reflecting the interdisciplinary nature, and thus defining the new design field that needs to be explored. A set of design attributes for smart Wearable Technology is introduced and then situated through interviews with design students that catalyse ideas for understanding the design process of Wearable Technology.

1. 3. Thesis Structure

The first chapter of this thesis acts as an introductory chapter explaining the research motivation, an overview of the research and thesis structure. Chapter 2 of the thesis discusses relevant literature and body of works of wearable technology existing in several different fields, including Computing, Fashion, Popular Culture, Art and Cybernetics Discourse. From this exploration, a discussion on what constitutes Wearable Technology, its

relevant design theories and the discussion on aesthetics is necessary as part of understanding the design problems of wearable technology, aligning with how it has been discussed by other researchers as an influential issue. Existing theories and literature on designing Wearable Technology are also discussed which acts as a starting point to a set of design attributes that in this research, creates part of the research justifications.

Relevant design theories reviewed in Chapter 2, produced a set of newly formed design attributes, which acts as a foundational theory of the research discussed in Chapter 3, followed by a discussion on its interrelationships and overlaps. Chapter 4 includes initial case studies of personal pilot projects are included as part of the analysis in observing how the design attributes are applied to a design process, thus giving greater understanding in conducting further interviews using research participants who has experienced the design process of wearable technology. The practice of designing and design pedagogy, more specifically in the context of fashion design, design integrating new technologies, and other forms of wearable technologies, have both motivated the research questions and provided the forum for their investigation. In this way, this research fits within the established paradigm of Practice Based Design (Scrivener 2002).

Chapter 5 explains phenomenological approach taken for this research, which acts as research strategy involving research participants. In Chapter 6, phenomenological process of semi-structured interviews with three designers who have experienced designing Wearable Technology, are included, each followed by reflective analysis towards the main research questions. Chapter 7 discusses the research findings of the thesis, which then manifested themselves in chapter 8 (conclusion) along with possible future research inquiries in the field of design thinking in Wearable Technology and how this research contributes to the knowledge of the field.

CHAPTER 2

LITERATURE REVIEW

The term Wearable Technology itself is very often misunderstood. If one is to etymologically dissect this, the word "Technology" originated from a Greek word: "*tekhnologia*" which is a derived from "*tekhno*" and "*logia*". The original Greek definition is: systematic treatment of an art, craft, or technique (Merriam-Webster 2013).

Merriam-Webster Online Dictionary (Merriam-Webster 2013) definitions:

1. A: The practical application of knowledge especially in a particular area. B: A capability given by the practical application of knowledge.
2. A manner of accomplishing a task especially using technical processes, methods, or knowledge.
3. The specialized aspects of a particular field of endeavor.

As one can see there are significant shifts in the meaning of the word 'technology'. These days, we commonly think of technology as something that allows us to execute tasks faster and more efficiently. There are numerous aspects that are embedded into the word of 'technology' in real life such as, crafts, logical hierarchy, systems, etc.

Combined with the word 'Wearable', the understanding becomes much more complex and layered. Technology that is worn on a user's body: the complexity lies in the interwoven aspects of considering the user as a part of the technology for it to function properly.

Referring to the etymological nature of the word 'technology', art is included in the definition. Today we know that art can have many meanings, which makes it difficult to define the bearing of art, as there is a sense of contextualising and liberating art according to its medium. Alongside formal freedom, art that is worn on the body seems to have a disconnection from cohesive practice (Ryan 2008) that is distinct from more conventional or

traditional forms of art practice. In order to gain a multi-angled perspective and achieve greater understanding of Wearable Technology, it is important to include in the literature review the different areas where it can be significantly found. Thus, Wearable Technology in its early development is espoused in science fiction with the notion of cyborg-ism and steampunk literature. Since then, it has ventured into the fields of Fashion, Pop Culture, Cybernetics Discourse, Art and Computing.

2.1. Wearable Technology in Computing

Wearable computing is attributed to have originated with the development of Edward O'Thorp's and Claude Shannon's pocket-sized analogue computer in 1961, which functions as a roulette results predictor (Rhodes n. d.).

> *"A wearable computer is a computer that is subsumed into the personal space of the user, controlled by the user, and has both operational and interactional constancy, i.e. is always on and always accessible" (Mann 1988).*

The above definition by Steve Mann describes the heavy emphasis upon absolute functionality, which, in addition reinforces a less body-based nature of wearable computers. Other authors have stated the definition of wearable computers through sets of characteristics, such as Rhodes (2000) who stated that wearable computing provides portability during operation; enables hands-free or hands-limited use; attempts to sense the user's current context, and can run continuously. This set of characteristics aligns with the criteria by Kortuem et al. (1998 p. 60), but he uses the term *augmented reality* to discuss *"the user interface technique that allows focusing on the user's attention and presenting information in an unobtrusive, context dependent manner"*.

Since the early age of its development, wearable computing takes form in hand-held gadgets and does not refer much to the body-based nature of Wearable Technology (Ryan 2008). The existing works of wearable computing allow the user convenience in the notion

of “wearing” the technology only. The smartness of the system in sensing the user is often confronted and overridden with the device function and capabilities.

It is very important to comprehend the field of wearable computing and its development in the context of computational miniaturization (which allow technology or computing capability to be subsumed into the user’s personal space), and which thus enables greater wearability. Embedded technology in the form of physical computing also influences numerous aspects of wearability, for example comfort and aesthetics. The main components of physical computing include: Interfaces, microprocessors, inputs, outputs, software, energy and materials (O’Sullivan & Igoe 2004). These components clearly excluded user’s comfort and appearance appeal.

Figure 1. The ambient telepresence wearable computer prototype (Drugge et al. 2004).

As recently as 2002, the aesthetics of Wearable Technology were still considered to be influenced by the image of the ‘*borg*’ (Rhodes & Mase 2005). The ‘*borg*’ aesthetic may possibly be one of the causes behind the lack of consumer take-up for everyday life usage.

This is evident in many works of wearable computing, such as the project developed by Mikael Drugge et al (2004) in Sweden, which is a prototype containing a backpack computer, a hand-held keyboard, a head-mounted display and a webcam that are connected to a wireless network (Figure 1). The prototype project provided a platform for exploring the experiences of immersive ambient telepresence and remote interaction by "wearing" the computer. Several problems that arose from the prototype include the system not being sonically responsive to the user's surrounding conditions (volume controls and the immersive quality of the telepresence), inefficient set up time and also navigational difficulties that emerged from multiple control buttons (non-user friendly) (Drugge et al 2004).

The *ZYPAD WL1000 Wrist Worn Personal Computer* (Figure 2) offers user's efficiency in completing computational tasks in hands-free necessary conditions (Parvus n.d.). The device is embedded with smart tilt sensors to detect the user's hand movements and position, allowing for on/standby recognition. The Zypad WL1000 considers the user as part of the design with its ability to sense the user's hand movements, which impacts the smart system navigation of the device.

Figure 2. ZYPAD WL1000 Wrist Worn Personal Computer (Parvus n. d.).

In the aviation field, there have been many wearable computers developed in the context of aircraft manufacturing, maintenance and operation. This is evident through projects such as the Boeing initiated project to support technicians in the assembly of wires by utilizing augmented reality (AR) technology to eliminate paper documentation in the field (Mizell 2001). In 2004, the research project *wearIT@work,* funded by the European government, was established to investigate possible implementation in four different industrial application settings, with the maintenance of commercial aircraft being one of the applications.

A project developed by Nicolai et al (2006) is a vest to be worn by aircraft maintenance personnel, embedded with a computer, which allows data access and wireless network connection. However, the computer itself still needs to be "uncovered" by the user (Figure 3). The vest provides the personnel more body efficiency while allowing both hand movements while not using the computer.

Figure 3. Vest with embedded computer for aircraft maintenance personnel (Nicolai et al. 2006).

Starner (2001 p. 44) stated that: *'wearable computing can be described as the pursuit of a style of interface as opposed to a manifestation in hardware'*. This strengthens the perception that not only does the user interface play an integral part in a wearable

computer, but also becomes the main emphasis in the design considerations. Even though the desktop metaphor of a user interface in wearable computing has been recognized and is evident, it is not suitable for tackling the particular challenge of proper user interface design (Starner 2001). The lack of manifestation in hardware creates challenges for more adaptable designs that may result in further public adoption.

A discourse within computing that concentrates closely on the smart characteristics of Wearable Technology is Situated Computing, which concerns the ability of computational devices to detect, interpret and respond to aspects of the user's local environment (Hull et al. 1997), i.e. with situated, contextual, user-relevant knowledge that allows a customized or contextually appropriate, (sometimes locative) and specific response. The ability of sensing (detecting, interpreting and responding) a user's local surroundings creates a conceptual platform that illustrates the two-way interaction between a user and a device, and thus creates a premise - the signifying characteristic of 'smart' Wearable Technology. If compared with the static nature of desktop computers, this ability translates the wearability of a device into flexible functionality, sensitive and responsive to the user's needs.

After investigating several examples of wearable computing, it is evident that each of them was built to perform its allocated functionality. However, there is a common theme that runs through all, namely the user interface. These examples managed to transform the static form of desktop computers by miniaturizing the device elements, to allow more mobility. The 'wearing' aspect of the user experience was addressed comparatively simplistic by merely attaching or embedding a machine into wearable items. The aircraft maintenance vest and the ambient tele-presence vest adopted this idea, thus having a substantial consequential effect on the user's appearance. The Zypad wrist device has the ability to sense the user's hand movements but, given its rather large dimensions and clunky appearance, it lacks designed visual and ergonomic appeal and perhaps its size and weight further influence arm gestures and mobility.

One might argue that these devices are not meant for everyday usage and not built to cater to untrained professionals. From the design perspective, these devices were built for a specific purpose. They may not necessitate sleek appearance or small dimensions. However, the reason why these examples are discussed in this section is to develop foundational principles for conceptualizing the design characteristics of smart Wearable Technology discussed in this research.

2. 2. Wearable Technology in Fashion

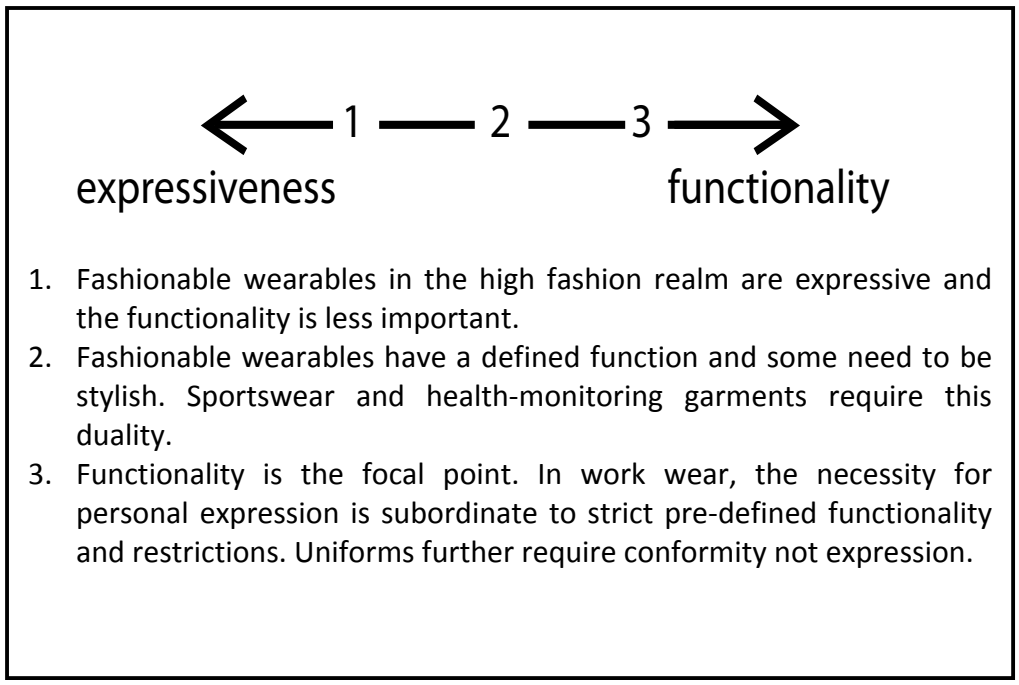

Figure 4. Fashionable Wearables Range in Levels of Expressiveness versus Functionality (Seymour 2008).

In 2000, Sabine Seymour coined the term for Fashionable Technology, in which she defined it as "'*designed' garments, accessories, or jewelry that combine aesthetics and style with functional technology*" (Seymour 2008, p 12). It is important to underline that in her definition, Seymour prioritised the term 'designed garments' at the beginning and clarifies

that design activity is involved in what constitutes 'fashionable wearables'. Andrew Bolton in his book *The Supermodern Wardrobe* mentioned that '*all clothes have psychological and physical functions'* (2002, p 10). The two statements above create an understanding of how fashion is a contextual matter, which is underlined by Malcom Barnard, who stated that there are various functions of clothing, including material functions (protection, concealment, attraction) and cultural function (communication, individual expression, social status, political/religious affiliation) (2002, p 49-71). The contextual nature of fashion and its inevitable connection with technology creates a range in levels of expressiveness versus functionality (Seymour 2008, p 14).

In Figure 4, functionality and expressiveness exist in an opposite/bipolar manner, which are exemplified in the following works. Hussein Chalayan's Spring/Summer 2007 collection titled *'One Hundred and Eleven'* (Figure 5) and Ying Gao's body of work (Figure 6) that includes a series of pneumatic garments that react to embedded electronic sensors, are all more related to level 1 of Sabine Seymour's axis of Fashionable Technology.

Figure 5. Ying Gao's *Walking City* (2007).

Figure 6. Hussein Chalayan's shape-changing dress from his Autumn/Winter 2007 collection. (Chalayan 2007).

Fashion form operates according to a similar paradigm to Sabine Seymour's expressiveness levels of Fashionable Technology, as can be observed in *Haute Couture*. This form of fashion emerged from the nineteenth century concept of dresses or clothing that were bespoke and specifically tailored for clients (Schaeffer 2001). In contemporary parlance, there is a significant shift in its understanding. *Haute Couture* now refers to fashion that has the tendency not to be 'ready to wear' but which is highly regarded as an art form and as a "one-off". Hence, these are close to individually crafted pieces tailored to meet a specific client's requirements or requests (see example on Figure 6). There is also a sense of idealistic nature in terms of design in the world of *Haute Couture* that involves the user within the process of altering the pieces to fit/suit a particular client's body type. Thus, other than the high price point, there is a level of exclusivity in who can own something from a *Haute Couture* collection since each garment is custom made and involves detailed bespoke tailoring.

In observing existing similarities between the aforementioned examples and the world of *Haute Couture*, Hussein Chalayan's and Ying Gao's works exhibit a similar kind of exclusivity and idealism as found in *Haute Couture.* The aforementioned body of works

crossed into the realm of fashion as sculptural pieces, thus making it not exactly ready-to-wear. Along with the evolution of modernism and the advance of technology, there are other works that adopt heavier emphasis on functionality, such as *The M-Dress* (Mobile Phone Dress) by Cute Circuit (2007) that transformed a hand held mobile phone device into a dress to purposefully shift the way a user interacts with a mobile phone and to avoid missing calls (Figure 7). Another example in the area of sports-gear is the Motion Response Sportswear developed by Kerri Wallace includes a conceptual series of garments that aim to integrate newly evolving smart-printed textile technology (Figure 8). These examples exhibit less exclusive idealism and emphasize more wearable functionality. Thus, one can say that *Haute Couture* inevitably touches on Wearable Art, which will be discussed more in the following section.

Garments and technology have consistently influenced one another throughout the 20th century and manifest a persistent dialogue, such that a certain garment style is able to stay connected with its previous forbears and its imagined future possibilities (Ryan 2008). Technological inventions in history have propelled pivotal developments in fashion. For example, the result of research into elastics in the 1930s drove rapid changes in the industry of womens' undergarments and eventually into non-gender specific clothing items. Moreover, the rise of mass media in the post-World War II era and industrialization has evidently reflected culture's fascination with technology.

Figure 7. *The M-Dress* by Cute Circuit (2011).

Figure 8. Kerri Wallace' *Motion Response Sportswear* (Henni 2008).

Numerous examples of fashion literature refer to authors dating from Baudelaire (1859-1861) to Giles Lipovetsky (1994), who constantly refer to the culture of modernism (a fact present in the French terms *mode* and *modern*). Modernism in itself encompasses different cultural influences, including industrialization, technology, art, architecture and so on. The condition it has heralded includes technological advances towards industrialization, mass-media-driven marketing, and urbanized culture (Lehmann 2000). So, fashion, modernism and technology have grown and are bound together.

Ryan (2008) drew the link between fashion and art by mentioning Baudelaire (an archetypal modernist figure) in the mid 19th century who wrote extensively of fashion and art (Baudelaire 1859-1861). The connection is followed by a French poet Stephane Mallarme, a French symbolist poet who in 1874 edited a fashion magazine, *La Derniere Mode* (Furbank 2004). Adolf Loos in 1907 made the statement that his own fellow Austrians are not modern enough as they utilize fashion imagery that still depends on ornamented attire similar to the previous tribal societies in the growing industrialization age (Munz, et al. 1966). In *The Arcades Project*, Walter Benjamin commented that fashion is the mold of modernity (Benjamin 1999), followed by Mark Wigley in *White Walls, Designer Dresses* who argues that fashion (in terms of dress) was the model for Le Corbusier's writings about modernism in architecture (Wigley 1995). The aforementioned writings present the perspective that fashion is inextricably tied to modernism and shares similar characteristics in its growth and expansion, which is supported by the growth of technology and is also constantly affected, influenced and in conversation with art.

2. 3. Wearable Technology in Art

Fashion and Art have always had close connections that can be seen dating back as far as Paul Poiret, a founder of the French couture, who started mentioning to his clients that he produces art and his shop is the studio. However a more serious form of art worn on the body, instead of presented on a wall or in a space, emerged in the 1950s and 1960s propelled by interest amongst the art world in the body and time-based performance such

as video and performance (Ryan 2008). For example, works such as artist Atsuko Tanaka's *Electric Dress* (1956) showcased wearable art. Further developed throughout the 1980s and 1990s, wearable art became more of a common theme with the help from the art world's interest in fabric as a medium and the feminist art movement. Despite increasing appearance, it was still not entirely acceptable and its marginalization was perhaps well portrayed by Hunter Reynolds' Patina Du Prey's *Aids Memorial Dress* (1993-2007), which has names of people who died from AIDS silk-screened onto the dress. The piece has been showcased numerous times around the world but is still rather unknown.

The issue of the museum space invaded by fashion and rarely by wearable art demonstrates a clear distinction in the perception and acceptance of the different modes. Diana Vreeland's exhibition in 1984 at the Metropolitan Museum of Art in New York showcasing her Yves Saint Laurent retrospective received frequent hangings at that time and was sponsored by the Met Costume Institute. A similar, more recent example of such an exhibition is Daphne Guinness' exhibition at the Fashion Institute of Technology in New York showcasing the heiress' wardrobe archive, shown for the purpose of education. However, the transition of high fashion entering the museum space has not always met with acceptance. In the late 90s, Guggenheim Museum's director, Thomas Krens, was criticised for utilizing the connection between art and fashion as an agenda behind Guggenheim's brand for shows such as *Art/Fashion* in 1997 and *Giorgio Armani: Retrospective* in 2000 (Ryan 2008).

Even with criticism providing some insight to the unacceptance of fashion by the arts world, the connection between fashion and art is remains consequently reinforced. Fashion's actual agenda, which is commercial, is seemingly opposed by the arts. However, the arts bring an agenda that is filled with subjective notions while mixed with market driven motives and pop art famously deconstructs artistic paradigms by ascribing artistic merit to everyday and non-valuable objects through interpretation, reframing, contextualisation or other forms of commentary, plying the tension between commerce, market-force, patronage and pure artistic motivations. Wearable art, on the other hand,

occupies a unique position with the ability to comment on the culture that we live in while providing a dynamic platform for expressing the way we live our lives.

Figure 9. Joo Youn Paek's *Self-Sustainable Chair* (2006).

Figure 10. *My Trousers* (Ashuach 2003).

The involvement of technology in fashion and art is visible through works by artists who include any form of mechanism or scientific knowledge applied in artforms for practical purposes. For instance, Joo Youn Paek's *Self-Sustainable Chair* (2006) combines fashion design and furniture design (Figure 9). The wearable art piece is actually a pair of trousers with attached air pumps attached to the sole part of the wearer/user. As the user walks, air is pumped into the back of the trousers, inflating a form of surface for the wearer to sit on.

Assa Asuach's work title *My Trousers* (2003), which is a pair of jeans that transforms into a seat when the wearer goes to sit down (Figure 10); Danielle Wilde's *hipDiskettes* (2008) (Figure 11) which is '*a self contained wearable sonic output system for performance and play*' (Wilde 2008, p. 2) are further examples of ways in which Wearable Technology exists within the world of art. The idea of extending the body, as aligned with the notion of cyborgism also has perforated art, with works such as Leigh Bowery's performance costumes that extend and distend his body in all directions (Bowery & Greer 2005); and also the works of Stelarc and also Marcel Li Atunez.

Figure 11. *The hipDiskettes* (Wilde 2008).

A series of collaborative works by Laura Beloff present the concept of a new being called the *Hybronaut*, which she described as: "*a figure, a person, or a body, coupled with a peculiar-looking wearable device*" (2008). Her *Hybronaut* works include several wearable pieces embedded with different types of technologies, such as *Heart Donor* from 2007, *Seven Mile Boots* from 2004-2004 and *The Head* from 2004-2006, which all encompass the theme of virtual versus physical realms of life (Beloff 2008). Beloff also argues that the *Hybronaut* is a user-turned-performer as a result of the body worn devices, which sparks the curiosity of the public (2008).

Stelarc (2011), an Australian artist who has performed extensively in Japan, Europe and the USA, has built his repertoire including new music, dance festivals and experimental theatre. He has used medical instruments, prosthetics, robotics, virtual reality systems and the Internet to explore alternative, intimate and involuntary interfaces with the body. He has performed with a third hand, a virtual arm, a virtual body, a stomach sculpture, and exoskeleton, and a six legged walking robot. His work as an artist is very much themed with the bodily prosthetic issue.

One of Stelarc's works is *The Third Hand* (1980). In this work, he mimics the substitution of the body by a technological construct. *The Third Hand* may be regarded as a form of physical extension of the body, which is connected to an attempt to represent discomfort of this kind of technology (Clarke 2002).

Another very interesting aspect of this piece is the interpretation of computer technologies as sterile and non-organic which have evolved by their pairing with the human body. In addition, the human body is seen as increased and augmented by its attachment to technology (the Cyborg notion). In this project, Stelarc viewed *The Third Hand* as a prosthesis of his own body, thus exposing the human body as a structure that may be assembled or disassembled. These extra 'body parts' somehow evoke a new questioning of prosthetic body parts as a means of articulating loss (Clarke 2002). The idea of extending the body by using *The Third Hand* in Stelarc's work reflects the sensation of adding bodily functions and ability.

These examples show ways in which artists have adopted Wearable Technology as their medium. On the other hand, history has shown that artists in general, who utilized technology whether electronic or digital media as part of their core practice, had faced rather lukewarm acceptance from the art world. In example, C. P. Snow's 1959 Lecture "The Two Cultures" exhaustively described the rising of two different and opposing cultures: science and art, both suffering from the communication breakdown between them (Snow 2008). More recent writings and works such as Christiane Paul's *Digital Art* (2003) and Oliver Grau's (ed.) anthology, *Media Art Histories* (2010) have become pioneering literature that managed to describe the infusion between art and technology. This shows the separation between art and technology is perhaps diminishing and that works by prominent artists such as Stelarc and Orlan have helped garner interests in the subject.

However, works by artists who utilize technology as their medium, even though thought provoking, often dwell far from diurnal reality and have found their audience in alternative creative spaces (Ryan 2008). Perceptibly, through examples of Wearable Technology in art, the act of the user (in this case, the artist) turning into performer is anchored with the performance-based nature of the artistic expression it gives. Thus, one can say that in the discourse of wearable art, technology is perceived as a medium for assisting artistic expression, and therefore it somehow marginalizes the physical human factors (such as the user's/artists' comfort) in its designed objects.

> "*It is the beginning of the new century…. We want to imagine ourselves anew. If visual art, hopelessly stuck in recycling its recent history over and over, can no longer help us, where can we turn? Enter fashion. Fashion is everything contemporary art is not: it is concerned with beauty; it is well aware of its history over many centuries, rather than just recent decades; it is more semiotically layered than the most complex Photoshop composite you ever worked on; and it has one ever present constraint (and only constraints can lead to great art) — the human figure. This constraint gives the art of fashion its vitality, its optimism and its inventiveness.*" (Manovich 2001)

The above paragraph from new media guru, Lev Manovich, provided the realization of fashion (broadly defined) as art and thus potentially banished the opposition between fashion and art, and rather embraced the adjoining of both. Works mentioned in the previous section (Wearable Technology in Fashion) such as Hussein Chalayan's *111* (2007) translated fashion's interest in technology and art. ACM Siggraph's fashion shows have transformed from Goth-rock inspired runways into more refined runway shows that include a catalogue of various works by individual designers and artists, exhibiting how art is embraced by such a technology-driven community.

The advancement of mobile media and the miniaturization of technology have also propelled the growth of Wearable Technology in art. Works from Laura Beloff and Danielle Wilde effectively adopted technology by consciously embracing its mobile quality. Wearable Technology in art also embrace the somatic aspect of the body as interface in its practice, therefore developing the understanding that pervasiveness in mobile media is at the same time challenged by wearable art's fascination with the tangible and physical body.

Wearable Technology in art invites multiple disciplines into its practice: fashion/dress, technology, science, performative art: all combined and enfolded into each other in a non-derogatory manner rather than that shown in the past. However, it is essential to clarify that the performative nature of wearable art should not be confused with how Wearable Technology is perceived in this research. The reviews of exemplar works and literature are used to magnify the understanding of ways in which Wearable

Technology infiltrates the realm of wearable art and to decipher the distinguishing characteristics of Wearable Technology in this research: its possible adoption in a quotidian non-performative context.

2. 4. Wearable Technology in the Discourse of Cybernetics

One of the essences of Wearable Technology is the "wearing" aspect of technology, which centres on the user/wearer as the main focus and motivation for the technology. An exploration of Wearable Technology including the discourse of cybernetics studies, in particular cyborg theories, is necessary since the term itself embodies an understanding of part human-part machine coexistence.

One of the first discussions of cyborgs originated out of cybernetics studies in the 1960 when Manfred S. Clynes and Nathan E. Kline helped coin the term as a concept that would allow man to maximize his internal regulation to suit the environment he may seek in outer space. On the other side of history, in this case popular culture, cyborgs originated from a character in Mary Shelley's Frankenstein (2005). The monster is often cited as the first cyborg and was not born out of a woman's womb but assembled on the operating table from different parts of human body corpses (even derivative of ancient Promethean mythology).

These two distinct origins emerged as two different types: one is the cyborg as a conceptualized post-human body which is able to extend his capabilities by using extensions and prosthetics (whether social or physical) and cyborg as a monstrous man-made being; both have human body parts. It is necessary to explain that the first type itself actually consists of two different concepts. The first is the concept of human with social prosthetics and the second concept is a human with physical prosthetics or extensions. With the rapid growth of popular culture and its nature of being easily accepted and socially adapted or assimilated, the second kind of cyborg seems to overshadow the first in contemporary times.

Nevertheless, the first type of cyborg that has emerged in historic fiction seemed to be nothing more than merely conceptual or visionary conjecture at the time, mostly aimed at the world of astronomy and outer space life. If we observe current experience, the reality speaks of its own growth from vision to fact. Based on Andy Clark's (2003) and William James Mitchell's (2003) definitions, being a cyborg does not necessarily mean being able to survive in outer space by maximizing internal regulations, but it means to have connections with functioning external regulations to survive but not necessarily environmental features, such as conditions in outer space.

Based on an article in *Wired Magazine*, Hari Kunzru (1997) wrote that the first real cyborg existed for more than 50 years. It was a white lab rat, part of an experimental program in the late 1950s at New York's Rockland State Hospital. The rat had an implant in its body, which is a tiny osmotic pump that injected precisely controlled doses of chemicals to alter several of its physiological parameters. It was part-organism-part-machine. Even though this study aims to learn more about human-machine integration, this experimental program should be considered a breakthrough milestone in the world of cyborg studies, since the word organism from 'cyborg' could also be interpreted and extended to animals as well.

To touch on Clark's definition of a cyborg, the historical period of a cyborg stretches back much earlier than the digital era, since he states that humans became cyborgs million of years ago (2003). For example, when the first known human alive in the paleontological world invented tools to hunt, they could already be considered to be cyborgs, since they were able to control that period's everyday life technology, which were their hunting tools. Another example is the use of prosthetic body parts for disabled people, which were instigated centuries ago. It is very interesting to examine this particular example further. In the children's story of Peter Pan by J. M. Barrie (2003), for example, there is a villain pirate character named Hook, who has a fake (prosthetic) wooden leg and a hand hook made of steel. The wooden leg and the steel hand hook could be regarded as everyday life technology in the story, since they are used for everyday life. The function of the wooden

leg is of course to replace the missing leg and the hand hook to replace the missing hand. Even though these replacements only act as a substitute of missing body parts, the functions of the hook itself can be the equivalent of a prosthesis that offers an extension. For instance, with a bare hand someone would find it hard to scar someone else physically, while with a hook scarring another person's skin is not a hard task to fulfil. An even more interesting part is the placement of the character as a villain of the story because of the other characters' fear of his notorious hand hook. Moreover, Hook can be considered to be one of the first and most famous cyborgs ever mentioned in the world of popular children's literature that has been a prominent part in indoctrinating the public's view of cyborgs (Shanks 2006).

In 1960, Manfred E. Clynes and Nathan S. Kline coined the first term cyborg as human-machine hybrid that has the ability to survive in extra-terrestrial conditions. Originating from the words "cybernetics" and "organism", the second syllable of the word *cyborg* refers to humans as the host of the technology (O'Mahony 2008). Furthermore, O'Mahony also stated that the cyborg movement is generated by the desire of achieving eternal life (2008). Danielle Wilde also discussed a similar stream of an idea between the two definitions mentioned above, that is the notion of extending the body through technology, through her works as an artist (2008). Marshall MacLuhan, media theorist, wrote: "*The wheel is an extension of the foot. The book an extension of the eye. Clothing an extension of the skin. Electronic circuitry an extension of the nervous system"* (1994). The enhancement of bodily functions acts as a very direct and cogent translation of how technology is adopted to reassess the corporeal quality in art, fashion and computing.

> "*…hybrid identities made of, first, ourselves and other organic creatures in our unchosen 'high-technological' guise as information systems, texts, and ergonomically controlled, labouring, desiring, and reproducing systems. The second essential ingredient in cyborgs is machines in their guise, also, as communications systems, texts, and self-acting, ergonomically designed apparatuses."* (Haraway 1991, p. 1)

Another key thinker in the field of posthumanism, Donna Haraway (1991), described the image of cyborgs in four different ways. The first is as a cybernetic organism. The second is as a hybrid of human and machine. The third is as a creature of lived social reality and the fourth is as a creature of fiction. She used these images as an anchoring metaphor, thus creating a complex argument that at its root, a cyborg is a political construct.

N. Katherine Hayles' (1999) described the correlation between the posthuman and the cyborg as an analogy to the existence of an imaginative discourse sphere, of the posthumanism discourse: in which another sphere exists, that is the cyborg discourse. Thus, one can say that cyborgism is a form of posthumanism. The discourse of cyborgism is also fueled by public fear, caused by the successful indoctrination of the media and entertainment industries, for example in *Terminator* (1984), *Eve8* (1911) and *iRobot* (2004), to name a few, that incorporate aspects of fear towards this emerging, impending technology.

Andy Clark in his book *Natural-Born Cyborgs* (2003), states that we are all actually cyborgs, even without embodied machines in our organic systems. The fact that we are the powerful controllers of everyday life technologies, such as mobile phones, personal computers, etc. means that we are all cyborgs. He believes that humans have been cyborgs since we existed million of years ago and its evolution, the city, in the concept of urbanized culture, creates a borderless and pervasive system in which humans interact with.

> "*Consider, if you will, Me ++. I consist of a biological core surrounded by extended, constructed systems of boundaries and networks. These boundaries and network structures are topological and functional duals of each other. The boundaries define a space of containers and places (the traditional domain of architecture), while the networks establish a space of links and flows. Walls, fences, and skins divide; paths, pipes, and wires connect*." (Mitchell 2003, p.7)

Clark's notion is corroborated by the similar definition of cyborgs in William J. Mitchell's book *Me++: The Cyborg Self And The Networked City* (2003), in which he defines himself (and each of us) as a cyborg. In this definition, Mitchell does not clearly define what

a cyborg is, but rather, views himself as a cyborg. By stating that he has a biological core with systems of networks and boundaries, he reiterates and reinforces Andy Clark's definition. There is a strong correlation between the two definitions, and in the case of Mitchell's, the cyborg is inseparable from its networks of connection, which is related to ubiquitous computing, wireless network connectivity of body-worn devices and also urban architecture.

The fading line between the body and its surrounding inhuman environment is also translated by Anthony Vidler who stated that the boundaries between the organic and the inorganic are blurred by cybernetic and biotechnologies which cause the body to be corrupted and enveloped by technology, thus confusing the body's depiction of the border that constitutes the inner and the outer whether visually, mentally or physically (1990). The permeating ability of technology to thoroughly encapsulate the human body is also translated by Tiziana Villani who stated: "*The body-territory* (corpo-terrorio) *poses a problematic form of corporeal identity that in becoming ever more routinized has tended to dissolve the distinctions that formerly existed between the organic and the inorganic*" (1995, p. 118). Such statements attempted to navigate the spatial and territorial borders of the body by acknowledging the obscure gap between the body and the non-body.

These definitions display different purposes in translating ideas of the cyborg as a discourse. While Haraway and Hayles look at the cyborg as a political construct, Clark and Mitchell talk about them from a technological point of view. Villani and Vidler use the cyborg construct as a vehicle for translating issues in material and social practice. However, the authors argue along the same baseline: namely that, in a sense, we are all already cyborgs, and the very idea of "cyborg" offers a platform to critique and rethink society, including the interdependencies between society's and technology's evolution. Since its development as a critical intellectual concept in the 1980s, the cyborg metaphor has been used in strategizing scientific and technological studies, infused with greater understanding of the relationship between culture and nature.

Human ability to utilize his/her surroundings as a form of prosthetic or extension, whether technologically, socially, or even as a platform of critique, provides evidence of how Wearable Technology performs as a physical rendition of cybernetics theory. Thus, the challenge for designers lies in incorporating or referring to these theories that have the potential to enhance their intellectual reasoning in executing good Wearable Technology design practice in.

Existing literature of the cybernetics discourse has also been interchanging nuances and ideas with works in popular culture and media. In the following section, the dialogue between them will be discussed to understand more of the Wearable Technology phenomenon.

2. 5. Wearable Technology in Popular Culture

In science fiction popular culture, the figure of the cyborg is represented not necessarily as an automated robot but advanced creations that continuously reiterate and also threaten our understanding of what it means to be human. One of the most famous and earliest cyberpunk science fiction literary works mentioning and describing Wearable Technology is William Gibson's *Neuromancer* (2007)- first published in 1984, which tells the story of a character named Henry Dorsett Case. In the story, an augmented "street samurai" named Molly Millions, who owns and utilizes numerous gadgets, including wearable devices, helps Case. An interesting aspect of the novel is that the storyline centres on the idea of merging the physical body and the machinery and flowing data. Thus, intrinsically woven layers between the three create and shape a complex "DNA"-like web of elements. Another pivotal science fiction literary work in the subgenre of Cyberpunk is titled *Snow Crash* by Neal Stephenson (1992), which narrates a rather similar storyline of human/machine hybrid. Mary Shelley's *Frankenstein* also developed a similar narration in which the main character was built by assembling body parts of human corpses and made alive by the help of a mechanical system.

Furthermore, in Science Fiction movies or motion pictures, there are many examples in which conceptual wearable technologies are seen, such as wearable computer packs in *Star Trek* (2009) and *2001: A Space Odyssey* (1968), *Wired Gloves in Iron Man* (2008) and *Minority Report* (2002), Head-Up displays in *Star Trek* (2009) and *GI Joe: The Rise of Cobra* (2009), etc. An interesting phenomenon found in these fictitious wearable technologies or devices is that most of them have built-in networking capabilities, extending the powerful functionality and usability for the wearer.

Human-Computer Interaction (or HCI) in these fictional wearable devices is crucial in that most of the storylines exhibit characters that are seen to be having some sense of bargaining interaction with the computers/wearable devices/machines. It is arguable that Science Fiction motion pictures and literature impose a significant impact on the development and invention process of wearable technologies in real physical life. These examples also intersect with theories from the cybernetics discourse where the human body is seen to be merging seamlessly with technology and thus augmenting the capability of the body. It is intriguing that most of our experiences in dealing with technological devices are collectively similar and include at some point, moments of "bargaining/negotiating" with the functionality and the usability of a device or the machine and network it inhabits. If one is to locate cyborgs as an idea in popular culture, it is arguable that it is clearly identified with our fascination with the fusion between human and technology but is nonetheless integral to our way of thinking about the world.

2. 6. Aesthetic Subjectivity vs. Wearable Technology Design

It is important to understand how Wearable Technology is interpreted in the context of this research. As the result of a critical reading of selected literature and existing examples, it is inevitable that Wearable Technology permeates and draws upon several fields, ranging from computing, fashion, textiles, pop culture, to cybernetics discourse. The term Wearable Technology itself is often depicted in a broad and loose manner and its definition varies accordingly to each field it relates to.

In her book Fashionable Technology, Sabine Seymour defined 'fashionable wearables' as: "*'designed garments', accessories, or jewellery that combine aesthetics and style with functional technology*" (Seymour 2008, p. 12). This definition falls closest to the way in which Wearable Technology is depicted in this research, however the words 'aesthetics' and 'style' question the design practice in Wearable Technology. Wittgenstein stated, "*an aesthetic explanation is not a causal explanation*" (Wittgenstein 2007, p. 18). This signifies the subjectivity in aesthetics that is responsive to individuals. Subjectiveness in fashion relates to its function as a mode for self-expression, which varies from one person to another. In order to create an aesthetically pleasing smart Wearable Technology that caters to each individual's subjectivity requires careful consideration by the designer in their understanding of the user. What does 'aesthetically pleasing' mean? How does it relate to designing smart Wearable Technology?

Emmanuel Kant in the *Critique of Power Judgement* stated that the subjective principle is the foundation of judgment of taste, but it has universal validity. This subjective principle determines what pleases or displeases us from a beautiful object only through feeling, not through concepts (Kant 2000). Beautiful, according to Kant is "*cognized without a concept as the object of a necessary satisfaction*" (Kant 2000, p. 240). Kant also points out that subjectivity in aesthetic judgment is not based on the principles of our will (Kant 1997). Further on, he stated that universal or general acceptability in the idea of aesthetics is achieved through the principle of common sense - *sensus communis.* It is very important to underline that Kant's understanding of *sensus communis* is based on the cognitive capacities that everyone has and exists in a universally objective manner.

Referring to Nigel Cross in his paper 'Natural Intelligence in Design', this ability in designing is part of human intelligence and it exists naturally in every individual (Cross 1998). This concurs with Kant's understanding of subjective aesthetics that exists in each person sourced from 'inner feeling'. However, Cross also stated that some people are better designers than others due to the variety of possible genetic endowment or through social and educational development. This clearly signifies that there is a form of conceptual

structure that can explain the ability to design better but the ability itself exists in every individual. Beauty, according to Kant, is filled with personal taste and there is no way to value it with a conceptual universal principle. In addition, there is no empirical ground to challenge the judgment of taste as it relates to individual aesthetics.

Therefore, a clear differentiation between subjective aesthetic judgement and design activity that responds to individual aesthetics is necessary. Subjective aesthetic judgement exists on the base of non-empirical grounds and origins in the human necessity of beauty (that cannot be exhausted as a particular exemplar of a principle or of a concept). On the other hand, design activity is not based on feelings, but rather, it comprises a mixture of creativity and analytical reasoning (Dorst 2006). According to Kees Dorst in his paper, 'Layers of Design: Understanding Design Practice': "*a good design practice is strong and consistent in its intellectual core (in its meaning-giving and value statements), pervasive and all encompassing in its expression*" (2009, p. 163). This statement shows that design requires a form of structuring of information in its activity and that this information does not rely on the 'inner feeling' of each individual.

How does subjective aesthetic judgement in fashion relate to the design process of smart Wearable Technology discussed in this research? Referring again to Kant's idea that aesthetic necessity, i.e., judgement of taste, differs from one person to another but objectively exists in each person as common sense, in relation to design activity, this understanding of Kant's aesthetic theory creates the idea that not only the user, but also the designer, has individual subjectivity in aesthetic judgments. What differentiates the user and the designer is the definition of design itself: "the creation of objects, information, environments, services etc. that afford the opportunity for people to create value in their use" (Meijkamp 2000, Lancaster 1991). This definition indicates that the purpose of design activity is focused on the user and done by the designer.

Kant has stated it is not plausible to conceptualize the structure of beauty (Kant 2000) and therefore designers are not challenged to do so, but rather, utilize their own

aesthetic subjectivity as intuition in implementing design activity. Nigel Cross (1999) in his paper 'Natural Intelligence in Design' listed what expert designers say about design:

- Design is rhetorical: in constructing a design proposal, constructs a particular kind of argument, in which a final conclusion is developed against both known goals and previously unsuspected implications.
- Design is exploratory: in the process, designers seek out to find new solutions to the given problem rather than return with already familiar example or solution.
- Design is emergent: in its process, the solution-concept might be developed together in relevancy with the problem concept.
- Design is opportunistic: the decision that is taken during design process is influenced by what is learned along the way, which may include possible future problems. This means the exploration path cannot be predicted other than by going through the process itself.
- Design is abductive: the reasoning process in design is intuitive and different from the more familiar concepts of inductive and deductive reasoning. The emphasized role of 'intuition' in reasoning involves the necessary step from function to form.
- Design is reflective: the designer has to have a form of medium in expressing partly formed ideas and to be reflected upon (consider, revise, develop, reject and return).
- Design is ambiguous: it tends to have early tentative solutions that are kept uncertain and open. These are often prepared by designers as necessary solution-concepts that may be imprecise and inconclusive.
- Design is risky: design is often uncomfortable and requires risk-taking.

The aforementioned list can be regarded as a set of characteristics that comprise design. These characteristics reveal how the design process necessitates problem solving to achieve a solution and impart minor subjective aesthetic judgements in its intuitive reasoning. Aesthetic subjectivity as part of human perceptive ability that is influenced by time, culture and other various sociological grounds, affects universally accepted aesthetic

judgement (Ford 2009). Thus, the role of design is to incorporate these influences by transforming abstract ideas into objects that fulfil the user's necessity. It is arguable that in smart Wearable Technology, the more successfully designed for its purpose an object is, the more appealing it is to the user. The term 'successfully designed' invites multiple questions as to what constitutes such quality, especially in Wearable Technology with its body-worn nature and interdisciplinary nature.

2. 7. Art + Fashion + Computing = Wearable Technology?

Works and literature reviewed in the previous sections provide background knowledge of existing examples of Wearable Technology from many disciplines. A few, not yet all, characteristics have been swiftly touched upon but still require further elaboration in order to clarify the constitution of Wearable Technology in this research.

In the field of computing, Wearable Technology is able to progress its development naturally through the advancement of mobile computing and media, which is typified by the miniaturization of hardware. Its shortfall in incorporating the user's corporeal quality is evidenced by a strong emphasis on functionality, which results in the 'borg' aesthetics. The idea of merely embedding technology to pre-existing garments contrasts the approach found in the discipline of fashion.

On the other hand, fashion, which has 'wearing' as part of its institutional belief, incorporates technology by approaching it as a part of its designed aesthetics. Thus, the role of technology in this discipline places more emphasis on technology as an ornamental element. In the field of wearable art, technology is adopted as a medium in assisting artists to deliver their practice. This induces another understanding of how the emphasis on technology in wearable art is as a 'tool' and is adopted according to the purpose of its artistic and performative expression.

Reiterating Kees Dorst's statement that good design needs to encompass all-round aspects of intellectual meaning-giving value statements and to be pervasive in the end product, it is then crucial to explore how Wearable Technology also permeates the

discourse of cybernetics as part of the humanities field and its relationship to popular culture. The studies of cybernetics and popular culture portray the cultural reflection of Wearable Technology and correspond strongly to the field of fashion, art and computing.

Examining Wearable Technology in the fields of fashion, computing, art, cybernetics and popular culture, it is evident that Wearable Technology is an interdisciplinary field and in order to elaborate the position of this research across those fields, a justifying definition is necessary that encompasses these design challenges. Hence, smart Wearable Technology here may be construed as *a wearable device with the ability in sensing a user contextually in its functional and expressive qualities*. Thus, *the challenge is in designing a device that values expressiveness and functionality equally while coordinating a level of smartness embodied to the system*.

2. 8. Existing Theories in Designing Wearable Technology

Over its development, several theories providing guidelines for designers in the stages of designing Wearable Technology have emerged as the result of on-hand practice and experiments. Each of these guidelines has attempted to formulate certain design attributes to help designers engaging with the interdisciplinary process in designing Wearable Technology.

O'Sullivan and Igoe (2006) listed overall components that are important in the construction of physical computing, which are then used as categories for consideration by Sabine Seymour (2008) in her book as the technical components of Fashionable Wearables: Interfaces (connectors, wires, antennas, etc.), Microprocessors, Inputs, Outputs, Software, Energy and Materials. Furthermore, she also stated that the required interaction dictates the choice of inputs and outputs types (Seymour 2008).

The examples of inputs and outputs mentioned clarify the link with the field of physical computing or more precisely 'ubiquitous computing'. Mark Weiser at the Xerox Palo Alto Research Centre coined this term, which means that the presence of computing is seamlessly everywhere (1991). In the 1990s IBM coined the term 'pervasive computing',

which, over the years, was often used in parallel to ubiquitous computing. Wireless communication as part of these fields has imparted the advance of seamless data transfer from embedded inputs to outputs and vice versa (e.g. via UMTS, Wi-Fi, GPS, GPRS, Bluetooth, infrared, etc.).

Table 1. Inputs and Outputs Types of Fashionable Wearables (Seymour 2008).

<table>
<tr><td rowspan="2">Inputs</td><td>Active
Consciously controlled by a wearer whether by using tactile or acoustic feedback system that allows an intuitive use of the garment.</td><td rowspan="2">Examples:
Pressure, bend, motion, biometric data, sound, visuals, humidity, proximity, orientation, displacement, smell, acceleration, etc.</td></tr>
<tr><td>Passive
Typically biometric data gathered from the body or automatic data feeds via wireless transmission using environmental data.</td></tr>
<tr><td>Outputs</td><td>The many output options can simulate all five human senses:
- Touch - Scent
- Sound - Taste
- Visual</td><td>Examples:
LEDs, thermochromatic inks, photochromatic inks, speakers, conductive fabrics, scent capsules, etc.</td></tr>
</table>

Seamless data transfer is also enhanced through current research in nanotechnologies, electronic textiles, biotechnologies and digital technologies, which will lead to true integration between functionality and aesthetic design (Seymour 2008). Furthermore, Seymour stated that in order to create successful wearable designs, designers

need to comprehensively understand the purpose, the user, the interaction and the right price point (in a commercial context) (2008). Within the designing activity of Fashionable Wearables itself, Seymour provided a set of the following guidelines:

Table 2. Guideline for the Construction of Fashionable Wearables (Seymour 2008).

Factor	**Considerations**
Body ergonomics/wearability	Placement, form language, human movement, proximity, sizing, attachments, weight, accessibility, heat, body shape, comfort, cut of garment, compartments
Perception	Aesthetics, look & feel, design, cultural and psychological functions
Functionality	Usable interaction with the system (inputs & outputs), wearer's control, modular construction for multi-purpose
Technology	Ubiquitous computing, sensor technology, embedded systems design, physical computing
Materials	Interactive or reactive materials/textiles, electronics textile, washing/cleaning, shielding, durability
Energy	Batteries, solar, kinetic, fuel cells
Recycle	Ecological, biodegradable, modular construction for dissemble

In the design process, designers are also required to factor in the influence of embedded technology in the garment and integrated functionality in electronic textiles towards 'wearability'. Francine Gemperle et al (1998) have created a set of design guidelines for wearability, which include: placement, form language, human movement,

proxemics, sizing, attachment, containment, weight, accessibility, sensory interaction, thermal, aesthetics and long-term use (1998). However, not all of these guidelines can necessarily be applied to all design of Wearable Technology and only the first six are considered appropriate in a generalizable context, while the rest relate to specific design problems (Gemperle et al 1998).

Within the field of computing, several attempts have also been made to establish attributes/characteristics and guidelines for designing wearable computers. Thad Starner (2001) argued that wearable computers requires several key attributes:

- *Persist and provide constant access to information services*: The device is designed to serve the user continuously, thus providing quick access, mobility and minimal physical disturbance for the user.
- *Sense and model context*: The device needs to embed smart system that is intuitive in placing its context and able to correspond or reactive to user's interactive input by providing cues and feedbacks. The device also requires malleability for the user in the context of its adjustable setting.
- *Adapt interaction modalities based on the user's context*: The device requires adaptability to the user's environment and is able to deliver tasks from the user with minimal desktop-computer based type of interaction and adjust its feedback accordingly to the user's privacy needs.
- *Augment and mediate interactions with the user's environment*: The wearable device needs to be able to detect and compile universal information relevant to the user's context and environment, thus providing filtration according to the user's preferences.

The set of attributes by Starner emphasizes the function of wearable computers as a form of mediator between the user and the user's environments (physical and virtual) and provides assistance through its interface. Furthermore, Starner also acknowledged several challenges for designing wearable computers that include: power use, heat dissipation, networking, privacy, interface design and wearable computer as intellectual tools (2001).

Kortuem et al have also listed four fundamental elements of wearable computing, which can be seen as a set of characteristics that define wearable computing design (Kortuem et al 1998):

- Hands-free or one-handed operation. The design needs to enable the user for single-handed interaction requiring alternative input and output interface.
- Mobility. The device enables the user to depart from static or desktop based interaction and allows the user to move freely while wearing the device.
- Augmented-Reality. The device is able to present information in a non-obtrusive manner to the user, depending on the required context.

The aforementioned attributes of the wearable computer create the idea of locating its role in Wearable Technology. The challenges found in wearable computers are embraced as part of the design guidelines for Fashionable Wearables (Seymour 2008). Furthermore, Gemperle's design guidelines for wearability are taken as part of Seymour's holistic approach. Several other 'requirements' in the design needs of Wearable Technology have also emerged in recent years. Tao's (2001) categorization of these requirements includes: functionality, connectability, durability, maintainability, usability in combat, manufacturability, wearability, and affordability. Cho (2004) clustered her analysis and concluded the requirements of Wearable Technology (or in her term 'digital clothing') include: durability, easy care, comfort, safety and aesthetic satisfaction.

Along with acknowledging multiple design guidelines and theories existing in the field, it may be valuable to understand the design process employed in the development of Wearable Technology. The question of when and how designers can use these design attributes in a design process reveals further understanding of its characteristics and qualities. In the process, design activity draws upon a series of problem-solving procedures whereby designers allocate problems, synthesize research findings and implement solutions in (visual) [or material] forms (Lee et al 2010). Each design process is recognizably different and unique, relative to its specific design features and demands. As an interdisciplinary field, the complexity of Wearable Technology invites multiple design considerations that are

tied in with different disciplines. A comparative study by Lee et al, elaborated differences between design processes of various disciplines, resulting in a design process model for smart clothing, a type of apparel that combines electronic engineering and apparel design (2010). The smart clothing design process model comprises of an experimental stage in which an initial design prototype is developed and then utilized as an analytical tool in realizing design problems, which leads to context-specific design considerations. Moreover, the smart clothing design process also includes reliability and performance testing before entering the final production stage (Lee et al 2004). This particular design process model displays added layers of complexity in its development stage, so much so that a set of simplified design attributes is necessary.

CHAPTER 3

DESIGN ATTRIBUTES OF WEARABLE TECHNOLOGY

The previously mentioned design attributes, guidelines, challenges and requirements existent across a range of fields contribute to our understanding of the way in which Wearable Technology intertwines multiple disciplines and if the design of Wearable Technology is successful, no predominant discipline overrides another. Based on observation of different examples from this array of fields, it is apparent that wearable computing is an essential part of creating a successful user interface. A fashionable approach to designing plays an equal role in accomplishing comprehensive design practice of Wearable Technology.

This research attempts to develop a set of design attributes for Wearable Technology drawing from the examination of multiple theories and their different fields. The initial motivation for developing these new design attributes was a response to the complexity of assimilating existing design theories and the multi-layered decisions required to effectively design Wearable Technology. The apparent relationship between a technical approach to wearable computing and a design-based approach from fashion adds complexity that calls for a more simplistic, yet holistic, and flexible approach, i.e. that allows designers to understand and detangle the steps of the design process, while simultaneously remaining context-aware.

Therefore, for the purpose of categorizing and evaluating the design process of Wearable Technology, the proposed design attributes recognize significant interactions between them with the objective of delineating general strata of design considerations in the whole process of designing Wearable Technology. This design paradigm works closely with the needs of the user (influenced by user centred design), which may lead to the design of more comfortable, intuitive, aesthetically-pleasing, helpful and ultimately wearable outcomes. It is important to state at the outset that these attributes do not

oppose each other and the researcher acknowledges that there are significant overlaps or interplays.

3. 1. Design Attributes of Wearable Technology

3. 1. 1. Size/Dimensions

The dimensions of the device play a significant role in the design of Wearable Technology. Levisohn argues that an integral element of interactive systems should be the body (Levisohn 2007). Therefore, the wearable device dimensions should not exceed the user's expectation and anatomy otherwise the design could be considered a failure. Adding load to the body may affect the user's physical factors. The mechanics of the musculoskeletal system is altered immediately once load is added to the user's body (Baber et al. 1999). Moreover, the effects of the device on the user's comfort and freedom of movement plays an important part in making the design fabrication decisions.

3. 1. 2. Device Position

The positioning of the device is one of the most important attributes in designing Wearable Technology, since this may strongly affect the user's comfort, appearance, and sensation. In addition, it affects the interactivity in its input and output qualities (voice recognition, buttons, vibro-tactile, visible, etc.). The design approach to positioning should consider ergonomics and anatomy of the human body. An example from one of the simplest designs of Wearable Technology is the wristwatch. It is worn on the user's wrist, which provides basic comfort and ability to effectively view time information for the user. Despite various attempts in history, including the pocket-watch or clocks worn elsewhere on the body, most Wearable Technology examples return to the wrist-worn device.

3. 1. 3. Power Source

The power source, which is the probably the most limiting factor in Wearable Technology (Starner 2001), has several points of consideration. The first one is the type of device power source. This first element also determines the following essential

characteristic, which is longevity. It is also very important to consider whether the device power source is rechargeable or not. Another element, which should not be overlooked, is the question of whether the device power source requires a power point in order to function. In other words, the question of corded or cordless power source strongly corresponds to issues of usability and function and mobility.

3. 1. 4. Heat

This is a crucial design attribute that needs careful consideration since heat affects the user's comfort (and ultimately safety) in wearing the device. The device's position and enveloping material largely affect proximity between electronic components and the user's body, while its power source will influence heat dissipation.

3. 1. 5. Weight

The weight of the wearable device affects the user's comfort. This particular issue is interwoven with other issues: power source, size/dimensions and device position. The size and type of power source determines the size and dimensions of the device, and also the positioning of the device affects the user's comfort.

In order to illustrate the effect of weight, Graves et al. (1998) and Miller et al. (1987) discovered that using wrist-weights (of 2.3 kg and 1.3kg, respectively) would increase muscular and physiological activity to move the arm about the elbow. A greater amount of muscular activity is obviously needed to move the elbow once the weight is increased. The issue of physical constraints of a human body affects the success of Wearable Technology designs.

3. 1. 6. Durability/Resistance

The resistance and durability of the device(s) worn on the user's body is strongly dependent upon the quality and the robustness of the enveloping material. There are a few elements that require thoughtful design decisions, such as: flexibility, absorbency of user's

body natural excretion, heat distribution and robustness, for example water resistance for designs intended for outdoor use, e.g. GPS devices, sports devices, etc.

3. 1. 7. Washability

The washability factor should be considered in the process of making design decisions or while evaluating Wearable Technology devices in order to respond to hygiene issues that arise as a consequence of usage. Several exemplary alternatives that provide a solution to this issue are detachable or possibly, waterproof encased electronical components.

3. 1. 8. Enveloping/Fabrication

The choice of the enveloping or fabricating housing material for a wearable device is relevant to the two factors mentioned before. Washability and durability need to be anticipated by design decisions about the enveloping material selected for a wearable device. Enveloping/fabrication includes the choice of materials, flexibility, and the way in which it covers the internal electronics, and provides accessibility to controls or sensors and displays.

3. 1. 9. Functionality

The Functionality of a Wearable Technology device is contextual depending on its purpose. According to Rens Meijkamp (2000) design can be defined as the creation of value for people. Kelvin J. Lancaster (1991) defined it as '*the creation of objects, information, environments, services, etc. that afford the opportunity for people to create value in their use*'. Therefore, 'value creation' or functionality is obvious and important in any kind of design field in order to acknowledge and fulfil the client's need. In the case of Wearable Technology, it is very important for a device to serve its purpose upon creation. For instance, if the user is intending to use a wearable GPS sensor that is able to monitor heart rate, then it is very important for the device to deliver the results demanded by the user

while wearing or using the device. Safety and health products, for example, also expect a higher degree of accuracy and reliability than entertainment and playful-purpose devices.

3. 1. 10. Usability

The Usability of a Wearable Technology device can be correlated with the word "navigation". A user's ability to navigate his/her way in using the device influences the user's engagement and impression of interactivity and responsiveness of the device. Therefore, it is very important for designers of Wearable Technology to observe simplicity in creating a user- friendly device. There is always a balance between control and simplicity. An increase in number/granularity of controls increases complexity and runs the risks of creating increased confusion.

John Maeda's *Laws of Simplicity* (2006) is applicable for providing guidelines for designing Usability in Wearable Technology. For instance, four out of the (total of) ten 'Laws of Simplicity' would already create quite a demanding set of design guidelines: Reduce (size, waste, visibility and 'clunkiness'), Organize (structure and hierarchies), Time [reduce and use time efficiently to achieve a goal or task], and Learn. The idea of reducing controls to achieve the purposed task of a wearable will benefit the user with simplicity. In order to achieve a thoughtful reduction in design, the designer must carefully organize the functions of each control. The fourth law, which is Time, suggests that the amount of time needed for a task to be performed or executed affects simplicity in design and can be leveraged to maximise efficiency and pleasure of experience and responsiveness. In designing Wearable Technology, it is very important for the device to be able to deliver the task for which it is purposely designed within an effective period of time, and especially considering the fact that the device is worn on the body.

3. 1. 11. Sensation (Seeing, Hearing, etc.)

The idea of enhancing the body's functionality and ability is often the purpose of wearable expressions. It is essential to consider what kinds of sensations the user might

receive while using the device. These sensations could be in many and various forms creating levels of engagement and interactivity between the user and the Wearable Technology device. For instance, the sensation of hearing, seeing, touching, vibrating and perhaps one day, smell.

3. 1. 12. Connectivity

With the rise of the Internet age and wireless communication technology, it is impossible to separate this factor from the design of Wearable Technology. Levels of connectivity achieved by the user while wearing Wearable Technology have the potential to increase levels of engagement between the user and the device and also with the social sphere. The development of mobile media, pervasive and ubiquitous computing propels mobility of device, thus increasing potential functionality and usability for the user.

To elaborate this idea, consider the social micro-blogging website, Twitter. It has spawned a new way of communicating and socializing among its users and Twitter can create social connectivity via a Wearable Technology device. A recent example of the synthesis between software platform (medium) and Wearable Technology is the Twitter Dress worn by artist, Imogen Heap from collaborating with Moritz Waldemeyer, during the Grammy Awards 2010 (Dybwad 2010).

Figure 12. Imogen Heap at the Grammy Awards 2010 and the LED collar of the Twitter dress (Dybwad 2010).

Walter Moritz and Imogen Heap created the Twitter dress. It allows Imogen Heap to receive tweets from her fans and the messages are displayed on the LED collar of the dress and images are displayed on an iPod Touch built into a purse she carries. The wearable device is connected to a wireless router that, in turn, connects the Twitter Dress to the virtual world. The idea of 'including the fans' on the Grammy Awards stage aims to create a two-way connection between the fans and the artist, through the medium of the Wearable Technology device. The fact that, in order to create the new level of engagement with her fans, she was wearing a form of Wearable Technology that evokes a sense of engagement and generates levels of sensation between the wearer and her fans.

3. 2. Interrelationships and Overlaps

	Design Attributes of Wearable Technology												
Design Considerations for Fashionable Technology (Seymour 2008)		Function	Sensation	Usability	Device Position	Power Source	Weight	Size/Dimension	Enveloping/Fabrication	Heat	Connectivity	Durability/Resistance	Washability
	Body ergonomics/wearability	•	•	•	•		•	•	•	•			
	Perception	•	•	•	•		•	•	•		•		•
	Functionality	•	•	•	•	•	•	•	•	•	•	•	•
	Technology	•	•	•	•	•	•	•	•	•	•	•	•
	Materials	•	•		•		•	•	•			•	•
	Energy	•	•	•	•	•	•	•		•	•		
	Recycle					•			•			•	•
• = related													

Figure 13. Matrix diagram displaying the relationship between design considerations for Fashionable Technology and design attributes of Wearable Technology.

Comparing design attributes of Wearable Technology in this research to Sabine Seymour's design considerations for fashionable Technology, there are multiple overlaps displayed on the matrix diagram below. These overlaps explain the importance of a more designerly approach to attaining a comprehensively user-focused Wearable Technology.

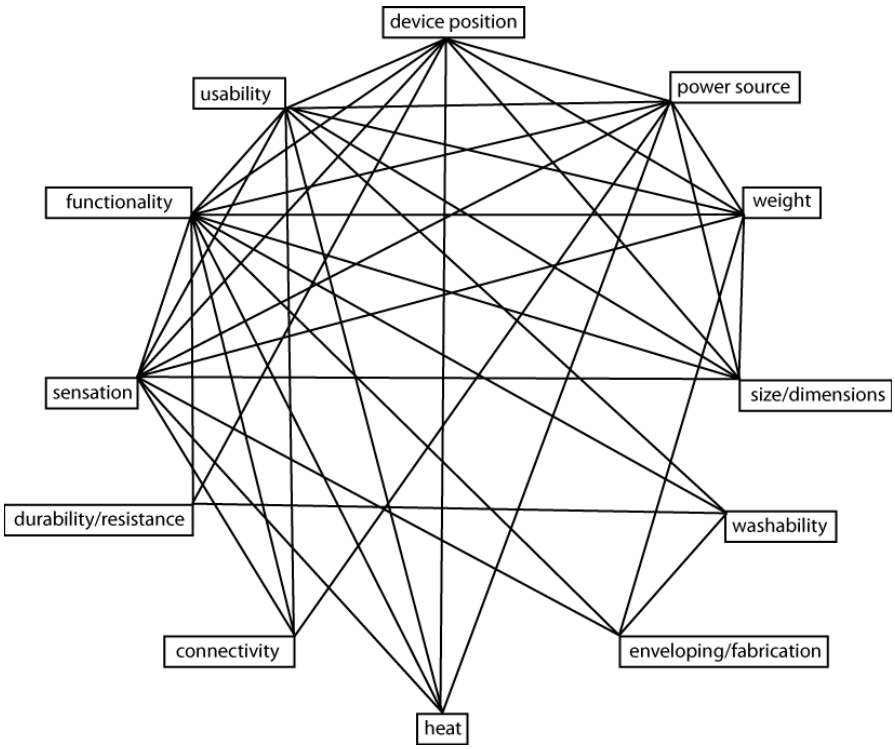

Figure 14. Diagram showing interrelationships and overlaps within design attributes of Wearable Technology.

In the previous diagram (Figure 13), Functionality and Technology play an important role by overlapping all the design attributes of Wearable Technology. Perception and Energy also require attentive consideration by the designers, while the Recycle design consideration signifies only a minor proportion in the design attributes relevant to Wearable Technology. Function, Weight, Sensation, Size/Dimensions and Enveloping/Fabrication overlap with most of the design considerations set out by Seymour. Moreover, by comparing the two, it becomes apparent how design attributes of Wearable

Technology in this research attempts to unravel the condensed list of design considerations for Fashionable Technology, thus providing a simplified approach for designing Wearable Technology. Functionality and Technology (from Seymour's list) prove to be the core ingredients in designing Wearable Technology, thus clarifying that good design is executed in accordance with a full understanding its design purpose and a thorough mastering of the supporting technology on the part of the designer, thereby playing a prominent part in achieving successful design in Wearable Technology.

Within the set of design attributes for Wearable Technology, there are also overlaps and interrelationships between each of them (shown in Figure 14) and it is important to state that these overlaps do not mean that one is more important than the other, nor should it be mistaken as a form of hierarchal system. However, one (or several) factor(s) may be more dominant in the design process, according to the particular context and constraints of the specific design problem/context/user needs.

Figure 14 shows that, not only these design attributes are linked to one another, but also that they provide a thinking map that may assist designers within the design process or problem space. The links drawn in Figure 14 are not constructed with a particular design project in mind but rather they are connected in a neutral way, where the purpose is to show how these interrelationships are complex and nuanced and require holistic (or top-down, whole-project, as well as detailed) consideration. Moreover, this set of design attributes can potentially also be used as an evaluation tool for designers. This complex array of design attributes has the potential of being utilized as criteria for assisting designers, by functioning as a non-hierarchal design consideration checklist.

CHAPTER 4
INITIAL CASE STUDIES

4. 1. Case Study on Personal Projects

During the development of this research, pilot projects were developed in order to study possible implementations of Wearable Technology design attributes within a design process. The pilot projects summarized in this section do not form the basis of the main thesis methodology as their significance and contribution were largely formative, providing the opportunity for systematically analysing the design attributes discussed in the previous chapter in the context of a real-life design process. These pilot projects provided initial insights in understanding the way a designer's thinks through design considerations in the iterative process of developing and refining an outcome.

4. 1. 1. Case Study 1: Biomuse Performative Sonification

This project was a continuation of an earlier project (Wireless Gamelan in 2008), which was done as part of a previous degree (see Appendix D) and was done in February 2010. The idea of capturing human biological data and projecting this externally through audio feedback is widely prevalent within the bio-medical field as audification. However, in the medical field these biological data remain in its captured form, only used to analyse a certain health condition with diagnostic or alert functionality and not aesthetic quality as the objective. The potential of bio-data processing as the basis for generating a performative artistic work was seen as an opportunity to represent something that is normally an internal (and possibly private) activity of a human body in an extrovert way.

The choice of data was initially based on the rhythmical quality found though biological pulses, such as the human heart rate. A practical survey of consumer-available sensors to capture human heart rate also led to the inclusion use of Electromyography (EMG) and Electroencephalography (EEG) sensors in order to multiply strands of audio feedback. The data captured from iCube-X sensor technology was transmitted via Bluetooth

to a software program for systematic data processing developed in Max/MSP on a desktop computer. The processed data was used as parameters to activate various Gamelan (Indonesian metal gong) sound samples (actuated according to datafeed from the different sensors) and distributed to a spatial (multi-channel, multi-speaker) audio display system. The data variation affected volume, tempo (speed of onset and movement) and notes (frequencies) of Gamelan sound samples. These sensors are wired from different parts of the body to the transmitter unit (worn on the chest, from around the neck). This Bluetooth transmitter unit, while small in size, requires a 9 Volt battery in order to function.

Figure 15. Biomuse Performative Sonification

In order for the entire system to function, it requires four separate components: the set of sensors and Bluetooth transmitter attached to the user's body; the computer as data processor; the network connecting the sensors and base computation; and the audio system through which audio feedback is projected.

4. 1. 1. 1. Case Study 1 Analysis

The functionality of the design remains true to the design purpose itself, which is a performance medium. In order to function well, the data processing system required refinements, especially addressing the issues of latency and data range inconsistency that initially resulted in the system seeming non-responsive if there was perceptibly (> 15 ms) delay between a physical actuation and audible processes result. These refinements were principally related to data processing or the software part of the system.

The very specific hierarchical system activation also influenced usability of the system, as it demanded a very methodical protocol by the user. Ease of use becomes almost non-existent due to this factor (i.e. expert knowledge to operate and program the data processing is requisite). Furthermore, the user also experienced difficulties in recognizing or distinguishing which sensors were related to certain sounds, aimed at allowing minimal user navigation ability of the system. The abstract input method through galvanic type sensors also created a strong bargaining-sense between the user and the system, almost to a point of reinforcing muscular activity in order to trigger sounds. To clarify, heart rate, muscle conductivity and so on, would normally be subconscious non-deliberate artefacts however the creation of an extroverted display invited actuation and confirmation and deliberate manipulation of the displayed outcome, i.e. natural bio-signals were soon adopted and integrated as performative ingredients in the interface.

Testing the working prototype, it was found that close proximity was required between the computer as data processor and the user wearing the sensors which constrained the distance for data transmission, thus limiting the user's movement to a rather static location when using the system. Excessive movement that affects skin contacts also affects and adds unwanted 'noise' to electrophysiological signals. However, this issue was not considered problematic for this context as the system was intentioned to be a performative piece, not for daily wear.

While most of the sensors could be compactly embedded into a figure-hugging garment, the EEG sensor requires direct contact with the user's forehead. Possible

implementations in designing may include a form of headpiece or a type of hat, which seamlessly covers electronic sensors. The wires that connect each sensor to the transmitters also affects usability and functionality by demanding the user to 'attach' each sensor one by one, rather than one single motion of 'wearing'. The issue of fragility was also seen to affect usability and functionality for the user. The limited lengths of these wires created constraint by limiting the user's movements while using the system, however this could be adjusted. It can be noted, however, that while the transmitter itself is 'wireless' there remains connecting wires between this transmitter and the sensors which have specific sites on the body, sometimes peripheral, e.g. arms, forehead, finger, etc.

These limiting issues can be partially solved through the correct use of enveloping materials or integrating the electronics into a garment that embodies (obscures and joins the) electronic sensors and components. In order for sensors to gain data, direct, firm, continuous skin contact is required, which indicates that the body-worn garment or type of clothing needs to be figure-hugging (i.e. the enveloping material needs to be of flexible and durable nature). Appropriate and adjustable wire-length measurements are beneficial for increasing functionality and usability.

The transmitter's battery life is very dependent on the system's overall activity, thus creating difficulty in predicting its power and longevity. The placement of battery compartment therefore needs to be carefully considered to allow easy replacement. The use of one 9 Volt battery was beneficial as rechargeable types are available at reasonable cost for this specification.

Heat and overall weight of the sensors did not affect the user's comfort during the testing phase therefore these issues were negligible. Hygiene or washability also need further development for electronic components in direct contact with the user's body, such as detachability or disposable and replaceable parts, and acknowledging the selection of enveloping material from proximity to the wearer's body.

Functionality and usability emerged as dominant attributes to be considered during the process as they overlap and influence other design attributes. This reveals how

designers must fully understand the importance of a defined design purpose and to take into account its requirements or demands when making design decisions.

As the project was in a prototypical phase, the system appeared to be fragile and required specific hierarchical steps in order to be activated. However, as mentioned earlier, the reasoning behind analysing the project closely in its early development stage was to gain insights into ways in which Wearable Technology design attributes could be adopted as a mind-mapping means for other designers, strategic attributes for designers of wearable technologies more generally.

By using the set of design attributes as a mind-map, not only are designers assisted in producing solutions to the self-defined design problems but they are also forced to consider an elimination process of unfeasible design solutions. The benefit here lies in the development of a methodical and efficient workflow process, effective even for new unfamiliar design scenarios and new technology integration.

4. 1. 2. Case Study 2: GPS data logger

The motivation behind this pilot study project was to explore possibilities of designing a device with GPS capability that demanded a standalone operational system with independent power source (by comparison with the previous prototype that was base-computer and network dependent). In addition, this prototype provided a vehicle to develop the researcher's familiarity with electronic components, which are integral to designing Wearable Technology in this research. The study was done in September 2010.

A simple approach to selecting electronic components was to use pre-packaged and pre-made kit components and build the device using online documentation manuals. This project was not initialized as functionality-driven but more as an open-platform exploration to refine mind mapping design processes using the researcher's Wearable Technology design attributes.

An SD memory card is used to record GPS data captured by a mini GPS antenna (parts are available at ladyada.net). The chosen enveloping material for electronic

components (seen in Figure 16) is a 1 mm thick plastic compartment, sufficient to contain one 9 Volt battery as power source. The plastic compartment was attached to a lanyard allowing it to be worn around the neck.

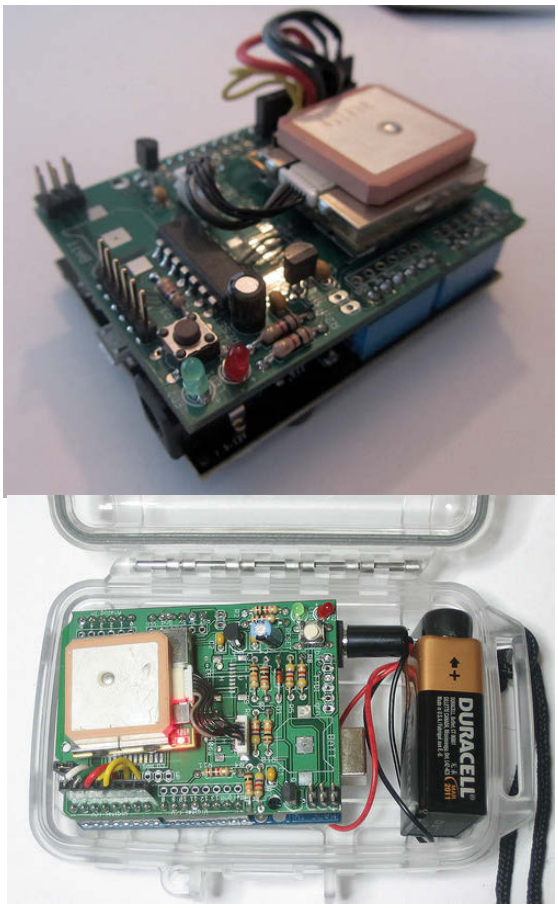

Figure 16. GPS logger

After a few test runs, it became apparent that initial GPS synchronization (the initial satellite lock on before location could be tracked) often required several attempts and was not robust to be sustained through urban landscape with multiple storey buildings and interference. However, after the device establishes GPS reception, it is able to store data contingent on the memory card capacity. These data are static in NMEA (National Marine Electronic Association) sentences forming GPS coordinates, thus requiring a computer for further subsequent data processing.

4. 1. 2. 1. Case Study 2 Analysis

The choice of plastic case with translucent quality as enveloping material has proven to be beneficial as it provides clear visibility and indication of successful/unsuccessful GPS synchronization. In addition, the lightness of the plastic compartment (weighing in total of 75 g along with all electronic parts) also increases the possibility of easy embodiment in a garment and does not interrupt user's comfort.

As it requires almost constant user supervision in order to ensure correct functioning, the issue of device positioning is limited to certain areas of a user's body. An alternative positioning is on a user's shoulder, which allows easier GPS satellite synchronization. However this positioning does not allow easy user supervision, which leads to a more effective possible alternative: on a user's wrist (which is seen in GPS sports watches, for example).

The device durability also introduces the issue of weather durability. Since the GPS logger was intended to be mobile and to allow outdoor usage, the electronics compartment needs to be weather shielded. The mobility of the device is also affected by its power longevity, which after a few test runs, was found to be approximately 5 hours on optimum synchronized functioning.

Initial GPS synchronization was found to be rather difficult as the urban landscape interrupts signal acquisition, thus affecting the prototype's usability. Replacing the GPS module with one with stronger reception may possibly resolve this problem; indicating that further investigation into potential available alternatives is necessary. More robust processors tend to be larger, more power consuming and more costly or require an aerial protuberance. Ease of battery replacement procedure is advantageous as the device is intended to be independently operational (cordless), which benefits the usability attribute of the design.

When placed on a user's shoulder, the device's overall dimensions do not seem to interrupt comfort but may possibly invite reactions from the surrounding environment due

to slight but noticeable alteration on a user's visual appearance. In contrast, when placed on a user's wrist, the device provides easy visual monitoring but felt slightly uncomfortable due to its relatively large proportions. In addition, this feeling of slight discomfort is affected by the continuous reflex of wanting to protect or shield the device from being physically in contact with other things.

It is to be acknowledged that this GPS logger is not a Wearable Technology device, as it does not have any 'wearing' notion. However, the application of the design attributes and the evaluation of mindmapping during the design of a mobile electronic device (which has further potential in becoming an element of a Wearable Technology device), provided insights into the potential flexibility of its application and the fluidity of these design attributes, even when applied to just the mobile electronic elements of a Wearable Technology device.

The analysis of this GPS logger prototype suggested that in Wearable Technology design, functionality and usability overlap with one another and also to some extent with the device's positioning and dimensions. Physical sensation experienced by trial-wearing the device also revealed that its wearability is very much influenced by size, weight and dimensions. Furthermore, the set of design attributes also provides a pathway for designers in dissecting design problems in an eloquent way by inviting solution ideas to appear progressively. However, an assessment of these emergent solution ideas would also be insightful as the invented, and even the rejected, solutions in the design space all contribute to the formulation of the 'primary generator' in the design process (Dorst 2006).

4. 2. Case Study Conclusion

It is important to state that these formative case studies were used to provide reflective 'self-journal'-like foundations in exploring the design process of Wearable Technology. They contributed to understanding several emergent characteristics of the way in which these design attributes work within the design process:

- Each design attribute of Wearable Technology influences and affects others in a determinative manner.
- They assist designers in creating a more steady and fluid workflow.
- They perform well as a method for formulating ‘primary generators’ in a design process.
- They assist in recognizing possible future design problems by forcing designers to acknowledge, understand and consider multiple different aspects of the design concurrently together.

CHAPTER 5

POSITIONING WEARABLE TECHNOLOGY DESIGNERS AND THE PHENOMENOLOGICAL APPROACH

"…the designer's task is to produce 'the solution'." (Cross 2006, p. 7)

Earlier studies showing forms of dissatisfaction towards the aesthetic experience of Wearable Technology (Co 2000, Orth 2001) have assisted the development of a more user-centred approach in design and also serve to bridge the disconnected reality between the initial purpose concpet of the designers and the actual experiences in use (Boehner et al 2005, Dunne et al 2005, Watier 2003, Viseu 2005). O'Mahony (2008, p, 10) also argues that cyborg-related technologies have continuously *'forced designers to think carefully about how the consumer will use such interactive products as the more basic question of why they would want to use them'*. Starner (2001) states that researchers have not thoroughly consulted the design trade-offs of the area in Wearable Technology, it advocates a more designed approach to wearable computing.

The idea of garments as a communicating medium (Seymour 2008) propelled the necessary perforation of interaction design in tackling one of the main challenges in wearable computing, which is the importance of user interface (hardware and software), and also the lack of design aesthetic values (Starner 2001). According to Kees Dorst in his paper, '*Layers of Design: Understanding Design Practice'*: "*a good design practice is strong and consistent in its intellectual core (in its meaning-giving and value statements), pervasive and all encompassing in its expression*" (2009, p. 163).

These powerful statements clarify the need of designers to be fully cognisant of the user and also provide a sketch describing the *reciprocating* nature between the user and the designer. Within this research of the design process in Wearable Technology, the pivot lies in the word: "*reciprocating*". In order to bring the abstract sketch to a more concrete and solid form, this research aims to develop a framework for designers to understand and

discuss the quality of their Wearable Technology design by integrating the user as a reflective input (instead of being directly engaged in the design process), in the process to which the framework of design attributes is applied. Thus, it is important to state that this is not user experience research, but rather, research that emphasizes a design process that recognizes the essential and influential role of users for Wearable Technology designers.

The designer is positioned in between the technology itself and the potential users of the wearable device. The key to good designing lies in the fulfilment of the user's needs whether this is achieved aesthetically or in a functional manner. This creates a complex array of design decisions and considerations for designers, hence the complexity and an intricately woven nature of designing for wearable technologies.

Designing for the user, who may bring many different qualities, cultural experience and values or even expectations, requires the designer to be attentive in ways of evaluating the design. Thus design attributes to help designers evaluate their Wearable Technology devices, positioning the user as a prominent element in design considerations, serve as a flexible mind-mapping method in designing for a more human–centred approach. This is, however, distinct from a participant-design or user-initiated design approach, which, though useful in research concerning usability, dissipates the role of the designer and designer-led aesthetic and materials expertise in the chosen medium. It is important to state that this set of factors will hopefully induce discussion amongst designers in evaluating and solving design deficits and problems.

Unlike the way in which scientists solve problems through analysis, designers solve problems through synthesis, thus discovering multiple solutions to a design problem and then apply a series of elimination processes until they find an acceptable one (Lawson 1980). Thus, the working emphasis for designers leans towards a solution-focused strategy, whereas scientists adopt a problem-focused strategy, which usually results in comprehensive analysis of a problem and a distilled hypothetical solution (Lawson 1980; Cross 2006).

Cross (2006) also states that a central feature of design activity lies in producing effective and immediate satisfactory solutions rather than focusing heavily on problem analysis. Furthermore, Lawson (1980) wrote that this is a result of the design education and training, where time constraints are introduced in design projects to reflect real-life situations. The project time frame difference between scientists and designers are considered to be a key element of this behavior. Scientists are often required to refrain from making final conclusions or statement until further information on the research subject is known and "further research necessary" is a common and justifiable solution to a scientific exploration (Cross 2006).

This brings designers' approach to tackling design problems into question. How are immediate solutions to design problems regarded as acceptable when analyses of the design problems are often constrained to a specific amount of time? This is most likely assigned relative to the design task. Rittel and Webber (1973) revealed that design problems are ill-defined, ill-structured or 'wicked'. Designers often enter a design project without having the necessary information provided to them, unlike the way in which scientists work. Thus making designers more likely to focus on the solution rather than the problem itself. Rather than indulging an exhaustive analysis of design problems, designers tend to seek the 'primary generator' (Darke 1979) which: "…*both defines the limits of the problem and suggests the nature of its possible solution*" (Cross 2006, p. 7).

In finding solutions to design problems in Wearable Technology, designers must be able to find the primary generator in the design activity. The encountered problems mentioned earlier, is already a start for designers in comprehending the nature of the problem, thus put in light possible solutions in tackling them. The set of design attributes explained in this research is derived not only from previous theories and guidelines, but also from an attempt to define, redefine and change the aforementioned design problems thus suggestion possible and satisfactory solutions.

Hillier and Leaman (1976) suggested that design activity is similar to learning an artificial 'language', the purpose of which is to transform abstract thoughts into concrete

patterns on an actual object. Wearable Technology and its multi disciplinary nature creates an abstract dimension for designers in recognizing multiple problems and challenges, thus it is necessary to develop an 'artificial' language for understanding, defining and providing solutions.

5. 1. Phenomenological Approach

"*A determinate method of inquiry (directed towards) attaining a rigorous and significant description of the world of everyday human experience as it is lived and described by specific individuals in specific circumstances*."

(Pollio et al. 1997, p.28)

The term Phenomenology originates from the Greek words: *phainomenon* and *logos*, which mean: "*…the activity of giving an account, giving a logos, of various phenomena, of the various ways in which things can appear*" (Sokolowski 2000, p. 13). This research uses a Phenomenology-inspired approach to look into the design process of Wearable Technology. The decision to utilize this research methodology is due to the nature of the design process, which involves an iterative process with open-ended goals. It is important to clarify that this research is bound to explore the designer's perspective in designing their Wearable Technology device, which includes his or her organizational functioning and interactional relationships within the understanding of the design brief, the concept generation stage and the design self-evaluation stage that lies within the design process.

The research was conducted by using semi-structured interviews that include a set of questions about the design process of Wearable Technology. Following the true aim of Phenomenology to always return to the concrete, the interviews are rigorously documented and critically analysed in order for the research to understand the 'lived experience' of designing Wearable Technology (Gronewald 2004). The questions in the interview assimilate the researcher's set of design attributes not in a blunt manner, but

rather by taking on a suggestive prompting approach. The 'themes' gained from the interviews help answer the research question.

The 'themes' mentioned above are the design attributes of Wearable Technology explained in the previous section. These design attributes do not operate as a hypothesis but rather as a medium for abstracting the themes in order to understand the meaning of the lived experience of design attributes in use when designing Wearable Technology.

The choice of research participants follows Hycner's theory that it is the phenomenon that dictates the method (not vice-versa) and that includes the decision made when choosing participants (1999, p. 156). Kruger also stated that when looking for research participants, the researcher must find people who have gone through experiences related to the phenomenon being researched (1988, p. 150). UTS design students that have undertaken the subject Interdisciplinary Design Lab were selected as suitable candidates for participation in the research as they have some experience designing Wearable Technology in the context of a broader three-year undergraduate design education.

5. 2. Research Strategy Involving Participants

The research strategy follows the process outlined by Collaizi (1978) with alterations in accordance to the research topic. The selected research participants were interviewed using a semi-structured interview method, providing interview transcripts that were analysed by the researcher. The researcher proceeded to extract significant statements from the interview and to formulate meanings from them. The meanings are a result of analysing the interview transcripts, in order to find recurring themes, by using the set of design attributes of Wearable Technology explained previously as a reflective literature tool. The next stage involved revisiting participants in order to elicit opinions on the resulting themes of design attributes, to validate the interpretations.

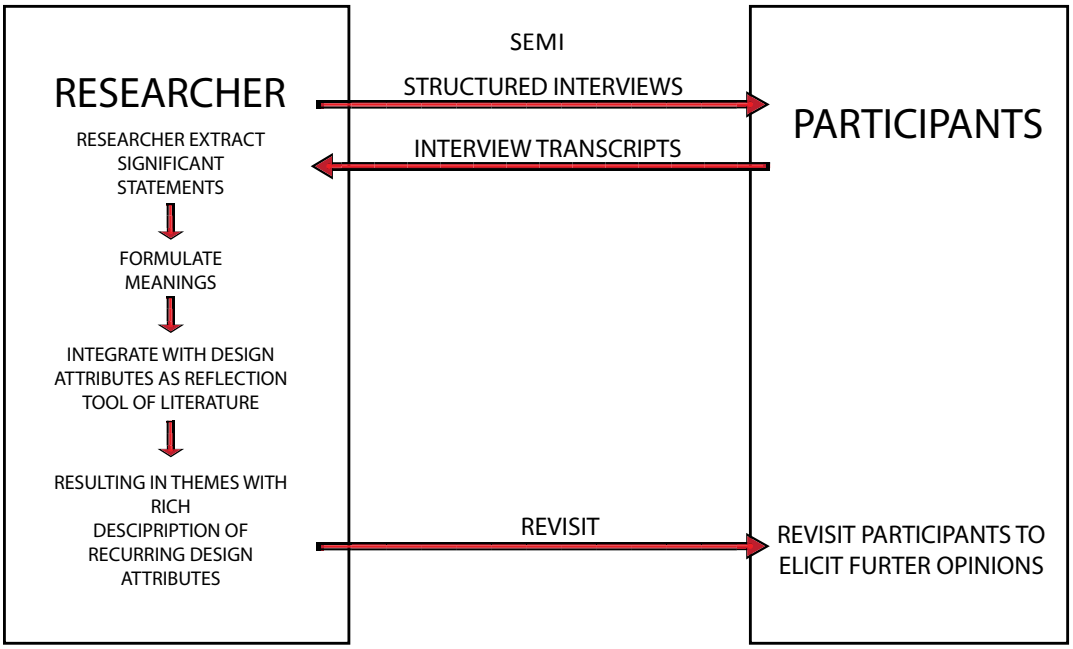

Figure 17. Research Strategy Diagram

Bentz and Shapiro (1988) and Kensit (2000) stated that the researcher must allow the data to surface or emerge, which means it is important for the interview questions to be different from the actual research questions. This is supported by Kvale (1996) who draws a similar distinction between the research questions and the interview questions. Thus, in order to avoid any such leading or seeding, and to allow openness for research possibilities, the following questions were used in the interviews:

Table 3. List of questions for semi-structured interviews with expected outcomes

No.	Questions	Expected Outcomes
1.	Please describe your Wearable Technology project.	A description of their project, hopefully includes a certain keyword in explaining their initial design brief
2.	How many people were involved in the project?	The number of people in the project. This helps clarify whether the work was collaborative or not.
3.	Did they come from different fields of practices?	Clarify if the project is a result of a collaboration across different fields
4.	According to your background of practice, what are the challenges of the project?	Explain more of the person's background training
5.	Please describe how you approached the design brief.	To see if the person's background practice affected his/her approach to design process
6.	How do you describe your personal initial design-related challenges on the project?	
7.	What design attributes lead to design considerations for the project?	To look for the possibilities of design attributes that affected the design
8.	What are the difficulties of approaching the design brief of the project?	
9.	Within the design process, what recurring design problems appeared?	To look for keywords related to researcher's own design attributes
10.	How did you approach these design problems?	The understand more of how the participant went through the design process and look for keywords signalling design attributes that affected the design dominantly
11.	How do you describe the design process in designing for the project?	To get an idea of how the experience of the design process was like
12.	If you could fix (a) certain design aspect(s) of the project, what or which aspect would it (they) be?	To look for more in-depth design aspects that affected the project
13.	Would there be a set of general guidelines in designing Wearable Technology, in what form of would you describe them to be?	To see if the participants have any inputs regarding possible future personal projects related to wearable technologies, by reflecting to their own past experiences.

The blue coloured section is the first stage of interview where the researcher looked to engage with the participants and to gain more knowledge in regard to the participant's background training. In the following section (red) were questions that attempted to reveal more of the participant's experience in regard to designing Wearable Technology. The interviews were in semi-structured form. Following is a list of prompts that were used if necessary to reveal information relating more closely to the research question.

Table 4. Prompts that were used in order to elicit more feedback during interview

PROMPTS
Function?
Sensation?
Usability?
Power source?
Weight?
Size/dimensions?
Enveloping/fabrication?
Heat?
Social Connectivity?
Durability/resistance?
Washability?

The interviews were tape-recorded which generated the first type of data storage utilized in the research. After each interview, the researcher proceeded with data transcription, which followed the field notes method, based on a model/scheme developed by Leonard Schatzman and Anselm Strauss (1973), supplemented by Alan Bryman and Robert Burgess (2002):

Table 5. Field Notes Method

Observational Notes (ON)	'What happened notes' deemed important enough to the researcher to make. Bailey (1996) emphasizes the use of all the senses in making observations.
Theoretical Notes (TN)	'Attempts to derive meaning' as the researcher thinks or reflects on experiences.
Methodological Notes (MN)	'Reminders, Instructions or critique' to oneself on the process.
Analytical Memos (AM)	End-of-field-day summary or progress reviews.

The field note method mentioned previously is a step toward data transcription and also data analysis, that allows the researcher to dissect information to reveal findings via the following stages:

1. Transcription
2. Bracketing and the phenomenological reduction

3. Listening to the interviews for a sense of the whole
4. Delineating units of meaning
5. Delineating units of meaning relevant to the research question
6. Eliminating redundancies
7. Clustering units of relevant meaning
8. Determining themes from clusters of meaning
9. Writing a summary for each individual interview
10. Return to the participant with the summary and themes: Conducting a second interview
11. Modifying themes and summary
12. Identifying general and unique themes for all the interviews
13. Contextualization of themes
14. Composite summary

These stages are used in the phenomenological process of interpreting semi-structured interviews with selected research participants and therefore resulting research findings of the way Wearable Technology design attributes perform in a design process.

CHAPTER 6

WHAT IS DESIGNING WEARABLE TECHNOLOGY LIKE?

The resulting interviews with participants produced research findings that reveal rich information in helping to understand how designers work through the design process of Wearable Technology. There are 3 research participants who participated in the interviews. Rigorous analysis of the interview recordings and transcriptions examined through phenomenological process included the steps described in the previous chapter.

6. 1. Participant 1

This interview was conducted on 27 September 2011. When asked to describe the Wearable Technology project, the first participant clarified that it falls into the definition of Wearable Technology in this research, thus validating their participation in this research. These projects are purposed for assisting the user by providing enhanced navigational ability as pedestrians exploring the cityscape in an urban context. The first participant foregrounded the foundational purpose of their project, which was to explore the possible use of design to enhance walking etiquette. This purpose surfaced as a result of their observation of how pedestrian lanes have disappeared on Sydney's George Street, thus also drawing on a localized observation of the urban context.

Reflecting on the first participants' Wearable Technology project, her understanding of design activity aligns with the definition of a designer's task given by Kees Dorst (2006), which is to provide solutions. The resulting observation that there is a lack of etiquette of walking in a city space, created the main problem that the designers attempted to solve via designing a Wearable Technology device. The participant also revealed the collaborative nature of the project by stating that a group comprising two fashion design students (including the first participant) and one industrial design student collaborated on the design. This collaborative effort in solving the design problem reveals further knowing that in order to provide solutions, designers in Wearable Technology often work collectively and

collaboratively. Moreover, it reflects a characteristic of Wearable Technology: the interdisciplinary overlap of different fields.

Difficulties in understanding the process of designing an object that includes electronic elements embedded into garments were also mentioned in the first interview, in which assistance from the subject's tutors was essential in pushing the project forward to completion. The first participant's fashion design training was also a substantial reason why the design process was viewed as an exploration into an unknown field. The lack of knowledge in available electronic elements that can potentially be used for the garment was considered an absent component in her training in fashion.

It is also apparent that the first participant's approach to the project was by perceiving the final designed object to be a 'garment'. This is because of the preliminary design training received and it was admitted that previous introductory training to electronic components would have been beneficial for the project. Moreover, this also explains that a designer's background training influences the use of design vocabulary in approaching or describing a design project.

The knowledge gap in electronic component that can be embedded in a garment led to the notion that it was a challenging aspect of the design activity. The fact that the design student continuously referred to the Wearable Technology object as garment also gave probable evidence that the electronic elements problem in this design was encountered after the initial project idea was conceived. This was supported by a statement that the group already had the idea of how the Wearable Technology object would function and operate, but the group had to make the project simpler and attainable to complete, due to the time constraint and limited knowledge of electronic elements. This reflects the way designers work within a design process: limited to specific time constraints and the designer's ability and obliging necessity to redefine design problems in achieving the solution (Dorst 2006).

The first participant also touched upon stages within design process, by stating that the end design did not have to be a final design product, but rather an acceptable

functioning prototype. Thus, describing again the time limitation of the project and the difficulty in tackling a multi-disciplinary design project in a short period. The initial approach in the design process involved researching the background to the design problem through videos and literature, which then transgressed into dividing workload for each member of the group. The first participant was given the task of designing the aesthetics, or the 'look' of the garment, thus working through the initial sketching process. Afterwards, the sketch was broken down by figuring out possible approaches for transforming its concept into physical reality. This reveals further how a designer's background training affects flow in a design activity, and also the iterative nature of the process. The importance of aesthetic in its design was also highlighted and further reinforced the understanding that her fashion design background informs her approach to designing in the project. Even though the design brief was to design an object that augments and assists the activity of walking in the city, the group had to define their own design problems by researching literature, as well as creating and analysing video documentation.

The group also went through a brainstorming and mind-mapping process which they said helped them in discussing who the possible user of the Wearable Technology may be; hinting that user scenario studies were also developed during the design process, indicated by investigating which group of people are struggling most with the lack of etiquette in walking through the city. Thus, reflecting on functionality while designing Wearable Technology emerged through defining its possible audience and identifying who may find the device useful. Furthermore, the group decided to base the design on a type of garment that is versatile. A premade blazer was chosen due to limited time for the project and also the wearable appeal to a wide audience of potential adopters.

The premade blazer was then embedded with the electronic components (power, hardware, cables, lights, etc.). The order in which a type of clothing was chosen first, and then embedded with electronic parts, describes a kind of approach similar to that found in fashion where electronic elements become part of ornamental embellishment rather than having a more integrated functional ability. The use of lights as a medium for providing

visual feedback (whether ornamental or for other functionality) for the user and her/his surroundings also affects its positioning, described by the designer in the interview. The group also had to alter the design in order to ensure usability: easy accessibility and intuitive activation, influenced by effective positioning and hardware selection of the activating trigger.

The designer's first reaction when testing the prototype was described as 'interesting' and the group was fascinated by how people in the user's individual surroundings were 'generally surprised' by the blazer's visual feedback. The group recognized this 'surprised' effect to be caused by the unfamiliarity of similar Wearable Technology in the everyday life. Moreover, the group also discovered that the user's individual surroundings find the design prototype to be 'funny'. However, this is not only related to the look of the prototype but also the idea of the project and the visual feedback it gives.

When asked about the possibility of revisiting and developing the design prototype, the designer mentioned that the group would possibly like to create more prototypes with more than one type of visual feedback. She mentioned that having more than just one visual feedback that says STOPPING, but also other directional sayings or phrases, will increase the likelihood of its enhanced reception and functionality. The designer stated they would also like to explore different visual feedback positioning and gauge how it may affect effective usability. The emphasis of redesigning the non-electronic components was also raised by the designer, by saying she would like to come up with more of an original design, with the hope of broadening its appeal to the user.

The designer also mentioned that transforming initial sketch idea into reality was seen as a dominant challenge as it included electronic components with which they were unfamiliar. Functionality and usability very much influenced this design as they included user scenario studies as part of their design purpose. This indicated that by placing possible users within process of making design decisions significantly affects the end product. The choice of enveloping material was also mentioned as quite a challenge as the team wanted

the material to have sufficient strength and structure to provide adequate physical support for the electronic components, while maintaining visible visual feedback. The choice of power source was also a design consideration that influenced the overall weight of the garment and the electronic components.

Reflecting on the first interview with a Wearable Technology designer revealed an iterative design process similar to other fields of design. The integration between non-electronic and electronic elements became a dominant challenge and interleaved with multiple other design considerations that mostly positioned the user as the central argument in making design decisions. The multi-disciplinary nature of Wearable Technology also reveals that in order to maintain successful design, a collaborative working method is often necessary.

Several design attributes of Wearable Technology explained in this research also emerged from this case study, discussed relative to their importance and overlap with one another. Functionality and usability were regarded as the main design challenges and must result from comprehension of available and possible electronic parts and sensible (pratical, feasible) user scenario study. The choice of the enveloping material was also said to affect its durability and device positioning and may affect the visibility of device feedback, thus further impacting on functionality and usability.

The way in which a user's surrounding environment (people) reacts to extraordinary visual feedback also influences Wearable Technology design. Elucidating from the data gained in the first interview, the first interviewee's background reveals that training works in parallel with her task description of the project, which involved designing the aesthetics. Her approach to designing also reflected her fashion design training, thus her concern for aesthetics in the interview further supported her concern about the reaction of people in the user's surrounding environment to the device or garment. The designer's wish to redesign in order to broaden its appeal also indicated the ambition of creating seamless integration between the user, the device and the surrounding environment.

In the following section, units (concepts) of general meaning are listed and filtered to extract units of meaning that are relevant to the research question. This phase of reduction is essential in the phenomenological approach for allowing the eliminating of redundant units of relevant meaning. The decision to unpack these units for each question was made consciously in order to avoid any misinterpretation of the interview transcripts.

6. 1. 1. Units of relevant meanings

Several units of meaning emerged during analysis of the first question, shown in the following table:

Table 6. Units of general meaning from Participant 1: Question 1, 1a and 1b.

Questions	Answers	Units of general meaning
Question 1. Please describe your Wearable Technology project	*OK…so [1]the project that we did, which is [2]a bit of a while ago now, we [3]had to design something that would assist with walking in the city…the [4]final design that me and my group came up with was a jacket that had indicators on it and [5]also had lights showing messages and [6]we wanted to document kind of how this would affect walking through a congestion in the city, [7]essentially using the blinkers, [8]people would know and [9]move out of your way or look at the sign, [10]we had like, a red light saying stopping at the back or if you [11]press the button that says stopping people would know through that and [12]they would be able to navigate easier around you.*	1. The project they did 2. A bit of a while ago 3. Had to design something that assists walking in the city 4. The final design they came up with was a jacket with indicators 5. Had lights showing messages 6. They wanted to document 7. By essentially using the blinkers 8. So that people would know 9. And move out of the way by looking at the signs 10. The jacket had a red light saying stopping at the back 11. By pressing the button, people would know 12. People would be able to navigate easier around the user
Question 1a. So you practically become a walking traffic light?	*[13]Yes, and we also…. [1]a lot of our ideas behind it was thinking about like [15]how on the road there were so many rules and how pedestrians, [16]is kind of like free for all, [17]do what you want, and [18]there are no actual set rules and [19]we*	13. Yes 14. A lot of their ideas behind it was thinking on 15. There were so many rules for pedestrians 16. It is kind of like free for all

	were looking at how George street [20]used to have pedestrian lanes, [21]they have, like where to walk…[22]down the right or left and [23]how that's kind of disappeared and [24]it's all just a jumble now and [25]there's no, like etiquette	[17.] Do what you want [18.] There are no actual set rules [19.] They were looking at how George Street [20.] Used to have pedestrian lanes [21.] They have "… like where to walk" [22.] Down the right or left [23.] How those things have disappeared [24.] It's all a jumble now [25.] There's no etiquette
Question 1b. So basically it's almost like trying to bring the etiquette forward through the design?	[27]*Yes.*	[27.] Yes

After reducing 27 units of general meaning from question 1, there were 11 units of relevance that align with the research question, including:

Table 7. Units of relevant meaning from Participant 1: Question 1, 1a and 1b.

Units of relevant meaning	
Question 1	[3.] Had to design something that assists walking in the city [4.] The final design they came up with was a jacket with indicators [10.] The jacket had a red light saying stopping at the back [11.] By pressing the button, people would know [12.] People would be able to navigate easier around the user
Question 1a	[19.] They were looking at how George Street [21.] Used to have pedestrian lanes [23.] How those things have disappeared [24.] It's all a jumble now [25.] There's no etiquette
Question 1b	[27.] Yes

The next table includes units of general meaning from questions two and three:

Table 8. Units of general meaning from Participant 1: Question 2 and 3.

Questions	Answers	Units of general meaning
Question 2. How many people were involved in the project?	*Um…. [28]in our group there were three of us [29]that specifically worked on the project.*	28. There were three of them in the group 29. Who specifically worked on the project
Question 3. Did they come from different fields of practices?	*There were [30]2 fashion students and [31] 1 industrial design student.*	30. Two fashion students 31. One industrial design student

After reducing four units of general meaning from question 2 and 3, there were three units of relevant meaning that align with the research question, including:

Table 9. Units of relevant meaning from Participant 1: Question 2 and 3.

Units of relevant meaning	
Question 2	28. There were three of them in the group
Question 3	30. Two fashion students 31. One industrial design student

Units of general meaning from question 4 are seen in the following:

Table 10. Units of general meaning from Participant 1: Question 4, 4a and 4b.

Questions	Answers	Units of general meaning
Question 4. According to your background of practice, what are the challenges of the project?	*[32]I guess, [33]since we were kind of taught to design for the body and like aesthetics and stuff as well…[34]I think were the challenges, especially…. like, [35]cause we don't really know much about how to…[36]in the terms of how to actually making it, [37]we don't really know much about how to put together, like the electrical side of it and the lights and [38]how that would work in a garment and [39]putting the technology into it.*	32. They guessed 33. Since they were taught to design for the body and aesthetics 34. She thinks those were the challenges 35. They don't really know how 36. In terms of how to actually making it 37. They don't know much how to put together the electronical side and the lights 38. How that would work in a

		garment 39. By putting technology into it
Question 4a. So it's more of the idea of embedding the technology that was quite a challenge because you say coming from a fashion background when everything pretty much don't have the electronic element in a way?	*[40]Yes, [41]but I guess they're trying to encourage that a little bit more now, [42]but we never really cover that in our lessons. [43]So, we didn't really know what kind of products or things that we could use to put into it [44]so it was kind of hard to design with…. [45]we kind of knew what we wanted [46]but we don't know what was available to use..*	40. Yes 41. She guessed they're trying to do it a little bit more now 42. But they never covered that in their lessons 43. So they didn't really know what kind of products or things they could use 44. It was kind of hard to design with 45. They kind of knew what they wanted 46. But they don't know what was available to use
Question 4b. So, given the fact that you haven't been trained that way, do you reckon if you had known more, it would be much easier?	*[47]Yes. [48]If we had known more of the electrical side of it, [49]it would've really helped us and [50]it would help us create a better design probably in the end…[51]because we kind of had to make it a little bit simpler for us to actually produce the design [52]but for the actual project [53]we needed to have a prototype [54]but it didn't have to be the working product.*	47. Yes 48. If they had known more of the electronical side of it, 49. It would've really helped them and 50. It would help them create a better design probably in the end 51. Because we kind of had to make it a little bit simpler for them to actually produce the design 52. But for the actual project 53. they needed to have a prototype 54. But it didn't have to be the working product.

Here, only thirteen units were relevant to the research question, including:

Table 11. Units of relevant meaning from Participant 1: Question 4, 4a and 4b.

Units of relevant meaning	
Question 4	33. Since they were taught to design for the body and aesthetics 34. She thinks those were the challenges 37. They don't know much how to put together the electronical side and the lights 38. How that would work in a garment 39. By putting technology into it

Question 4a	43.	So they didn't really know what kind of products or things they could use
	45.	They kind of knew what they wanted
	46.	But they don't know what was available to use
Question 4b	48.	If they had known more of the electronical side of it,
	50.	It would help them create a better design probably in the end…
	52.	But for the actual project
	53.	They needed to have a prototype
	54.	But it didn't have to be the working product.

Units of general meaning from question 5 are listed in the table below, followed by a table containing its units of relevant meaning.

Table 12. Units of general meaning from Participant 1: Question 5, 5a and 5b.

Questions	Answers	Units of general meaning
Question 5. Please describe how you approached the design brief.	*[55]We did have some assistance from different tutors who are more experienced [56]and we had a few lessons showing us different things that we could use [57]but because everyone in the class were doing such different things, [58]it was kind of, like, we didn't have much time [59]and everyone kind of wanted a one on one time [60]but, is that what you were asking for, or?*	55. They did have some assistance from different tutors who are more experienced 56. They had a few lessons showing them different things they could use 57. But because everyone in the class were doing such different things 58. They didn't have much time 59. Everyone wanted a one on one time 60. Is that what was being asked?
Question 5a. Yes, but I 'm really interested in looking into how you approach the design brief…	*[61]First of all of course we did the research and [62]we came up with the idea from looking at videos [63]and finding what the main problems were and…. [64]so we went about it that way first and [65]I myself did a lot of designing like fashion model [66]which is the way I've been taught of [67]and a lot of my ideas came out that way [68]when I would sketch down how I want it to look first [69]and then work out how it would work afterward.*	61. First of all they did the research 62. They came up with the idea from looking at videos 63. And finding what the main problems were 64. They went about it that way first 65. She did a lot of designing like fashion model 66. Which is the way she's been taught 67. A lot of the ideas came out that way 68. When she would sketch down how she wants it to look

		69. And then work out how it would work afterward
Question 5b. So would you say, in terms of your background training, which is fashion design, how it looks is what concerns you the most when you were approaching the design brief?	*70Yes…71we had like the background idea of how we want it to do (its task) 72but being taught that way, 73aesthetics is quite important when designing it and that was…. 74in my group we had different jobs and 75my job was to design the aesthetic of it and then 76the industrial girl did a lot more work with like putting it together and yeah, 77a lot of it was sketching and 78that's the way I work.*	70. Yes 71. They had like the background idea of how they want it to do (its task) 72. But being taught that way, 73. Aesthetics is quite important when designing it 74. In the group they had different jobs 75. Her job was to design the aesthetic of it 76. The industrial girl did a lot more work with putting parts together 77. A lot of it was sketching 78. That's the way she works

Table 13. Units of relevant meaning from Participant 1: Question 5, 5a and 5b.

Units of relevant meaning	
Question 5	55. They did have some assistance from different tutors who are more experienced 56. They had a few lessons showing them different things they could use 57. But because everyone in the class were doing such different things 58. They didn't have much time
Question 5a	61. First of all they did the research 62. They came up with the idea from looking at videos 65. She did a lot of designing like fashion model 66. Which is the way she's been taught 67. A lot of the ideas came out that way 68. When she would sketch down how she wants it to look 69. And then work out how it would work afterward
Question 5b	70. Yes 71. They had like the background idea of how they want it to do (its task) 73. Aesthetics is quite important when designing it 75. Her job was to design the aesthetic of it 77. A lot of it was sketching 78. That's the way she works

In the following two tables are the units of general meaning and units of relevant meaning from question 6:

Table 14. Units of general meaning from Participant 1: Question 6 and 6a.

Questions	Answers	Units of general meaning
Question 6. How do you describe your personal initial design-related challenges on the project?	[79]*We had to think of who would actually wear the design and* [80]*who struggled the most with that….* [81]*who are the kind of people that need to be somewhere and* [82]*we had like shoppers and business people and uni students that wanted to walk fast,* [83]*so we wanted something that kind of versatile, and* [84]*because we didn't have much time,* [85]*we needed to have a prototype that we could just create and* [86]*we probably would've liked to have created something little bit more 'designed' but* [87]*we ended up using a kind of, not like a blazer but a kind of, a premade jacket and* [88]*we put the electrical lights into it.*	79. They had to think of who would actually wear the design 80. Who struggled the most 81. Who are the people that need to be somewhere 82. They had like shoppers and business people and university students that wanted to walk fast 83. They wanted something that is versatile 84. Since they didn't have much time, 85. They needed to have a prototype to create 86. They probably would've liked to have created something little bit more 'designed' 87. They ended up using a premade jacket 88. They put the electronical lights into it
Question 6a. So, basically, when you were thinking of it the design attributes, one of them being the user him self and how they will wear it?	[89]*Yes.*	89. Yes.

Table 15. Units of relevant meaning from Participant 1: Question 6 and 6a.

Units of relevant meaning	
Question 6	[79.] They had to think of who would actually wear the design [80.] Who struggled the most [81.] Who are the people that need to be somewhere [82.] They had like shoppers and business people and university students that wanted to walk fast [83.] They wanted something that is versatile [85.] They needed to have a prototype to create [86.] They probably would've liked to have created something little bit more 'designed' [87.] They ended up using a premade jacket [88.] They put the electronical lights into it
Question 6a	[89.] Yes

Table 16. Units of general meaning from Participant 1: Question 7 and 7a.

Questions	Answers	Units of general meaning
Question 7. What design attributes lead to design considerations for the project?	*[90]We had to change our design a little bit because of the constraints of these things, [91]one of the main factors was how people would react to it and [92]how we would be able to document it and [93]also at the end, it has a lot to do with how the user would be able to activate the signals [94]and the usage of lights.*	[90.] They had to change the design a little bit due to several constraints [91.] One of the main factors was how people would react to it [92.] How they would be able to document it [93.] In the end, with how the user would be able to activate the signals [94.] And the usage of lights.
Question 7a. Ah, the trigger?	*[95]Yes, so we had to …use…. [96]a lot of the design was based around that like, how we would get the switches and [97]how they would be able to do that without knowing too much about technology and [98]how we would be able to…get those lit down to somewhere that the person could activate it, [99]so that kind of changed our design a little bit.*	[95.] Yes [96.] The design was based around how they would get the switches [97.] How the user would be able to do that without knowing too much about technology [98.] How they would be able to position the lights somewhere that the user could activate [99.] That changed their design a little bit.

Displayed in the following table, are units of relevant meaning from question 7:

Table 17. Units of relevant meaning from Participant 1: Question 7 and 7a.

Units of relevant meaning	
Question 7	90. They had to change the design a little bit due to several constraints 91. One of the main factors was how people would react to it 92. How they would be able to document it 93. In the end, with how the user would be able to activate the signals 94. And the usage of lights.
Question 7a	96. The design was based around how they would get the switches 97. How the user would be able to do that without knowing too much about technology 98. How they would be able to position the lights somewhere that the user could activate 99. That changed their design a little bit.

In the next table, units of general meaning from question 8 are listed, followed by the units of relevant meaning**.**

Table 18. Units of general meaning from Participant 1: Question 8.

Questions	Answers	Units of general meaning
Question 8. What are the difficulties of approaching the design brief of the project?	*[100]As I've said before, [101]it was kind of…. mainly figuring out how all the electrical parts are going to work…[102]and also knowing what I could use in the design, [103]cause I kind of…. we kind of had an idea of what we wanted [104]but we didn't know if it was possible for us to pull it off.*	100. She had said before 101. It was mainly figuring out how all the electronical parts are going to work 102. Also in knowing what she could use in the design 103. They had an idea of what they wanted 104. They didn't know if it was possible to pull off

Table 19. Units of relevant meaning from Participant 1: Question 8.

Units of relevant meaning	
Question 8	101. It was mainly figuring out how all the electronical parts are going to work 102. Also in knowing what she could use in the design 103. They had an idea of what they wanted 104. They didn't know if it was possible to pull off

Units of general meaning and those relevant from question seven are shown in the following two tables.

Table 20. Units of general meaning from Participant 1: Question 9, 9a and 9b.

Questions	Answers	Units of general meaning
Question 9. Within the design process, what recurring design problems appeared?	*[105]Maybe when we went out to like demonstrate it, [106]we didn't expect people's reaction to be what they were so [107]that was kind of, came up and….*	105. When they went out to demonstrate it 106. They didn't expect people's reaction to be what they were 107. That reaction came up
Question 9a. So, is it recurring?	*[108]Yes, [109]it did happen when we were testing but yeah, [110]we didn't have enough time to like… [111]we changed a little bit of how we walk and the places we went to [112]but it wasn't kind of like a…. recurring problem [113]but an interesting find.*	108. Yes 109. It did happen when they were testing 110. They didn't have enough time 111. They changed a little bit of how they walk and the places they went to 112. It wasn't a recurring problem 113. It was an interesting find.
Question 9b. How would you describe people's reactions to that, in general?	*[114]A lot of them generally surprised and [115]they thought it was funny [116]and I guess this was to be expected because it's something that hasn't been seen before [117]and it would probably be different with a lot of people using it [118]and it becomes more mainstream or like, acceptable [119]but I guess with this kind of thing you can't really expect this to happen.*	114. A lot of people were generally surprised 115. People thought it was funny 116. She guessed this was to be expected because it's something that hasn't been seen before 117. It would probably be different with a lot of people using it 118. It becomes more mainstream or acceptable 119. She could not expect it to be mainstream

Table 21. Units of relevant meaning from Participant 1: Question 9, 9a and 9b.

Units of relevant meaning	
Question 9	105. When they went out to demonstrate it 106. They didn't expect people's reaction to be what they were
Question 9a	108. Yes 109. It did happen when they were testing 111. They changed a little bit of how they walk and the places they went to 112. It wasn't a recurring problem 113. It was an interesting find.
Question 9b	114. A lot of people were generally surprised 115. People thought it was funny 116. She guessed this was to be expected because it's something that hasn't been seen before 117. It would probably be different with a lot of people using it 118. It becomes more mainstream or acceptable 119. She couldn't expect it to be mainstream

Answers from question 10 produced several units of general meaning and also units of relevant meaning shown in the next two tables:

Table 22. Units of general meaning from Participant 1: Question 10.

Questions	Answers	Units of general meaning
Question 10. If you could fix (a) certain design aspect(s) of the project, what or which aspect would it (they) be?	*[120]I think we've talked about this, [121]saying we would like to create more of them [122]and kind of set them out in different places [123]and we also would've like to design a few different…. [124]in the end we'd like to have a few more different signals on the jacket [125]but we would like to have a few more different saying, [126]cause we only had 'stopping' at the end, [127]we would've like to have like a few different directional sayings on the jacket [128]and maybe something on the front [129]and maybe tried different things and see how that would've worked*	120. I think we've talked about this 121. They would like to create more of them 122. Set them out in different places 123. They also would've liked to design a few different ones 124. They would like to have a few more (different) signals on the jacket 125. They would like to have a few more different sayings 126. They only had 'stopping' in the end design 127. They would've liked to have few different directional sayings on the jacket 128. Maybe something on the front 129. Maybe tried different things and see how that would've worked

Table 23. Units of relevant meaning from Participant 1: Question 10.

Units of relevant meaning	
Question 10	121. They would like to create more of them 122. Set them out in different places 124. They would like to have a few more (different) signals on the jacket 126. They only had 'stopping' in the end design 127. They would've liked to have few different directional sayings on the jacket 129. Maybe tried different things and see how that would've worked

Question eleven provided a number of units of general meaning along with a small quantity of the relevant meaning, shown in the following two tables:

Table 24. Units of general meaning from Participant 1: Question 11, 11a, 11b and 11c.

Questions	Answers	Units of general meaning
Question 11. How do you describe the design process in designing for the project?	[130]*It was quite an enjoyable process* [131]*but we end up…we had a lot of time to brainstorm* [132]*and brought up proposals* [133]*and do a lot of research so,* [134]*I think that was good that we had quite an amount of time to do background research* [135]*which we really needed to do because we all went out to do different things* [136]*there were also different perspectives and it's also a good thing.* [137]*All the visuals, like the videos of people on the street and photos and documenting were really helpful…* [138]*We also did a lot of mind mapping* [139]*which kind of led us to our final idea,* [140]*like writing down all the key points that were the problems that people had encountered whilst walking* [141]*and like things that could be improved* [142]*and what we wanted to see happen.*	130. It was quite an enjoyable process 131. They ended up having a lot of time to brainstorm 132. They brought up proposals 133. They did a lot of research so, 134. She think that was a good thing to have a lot of time for background research 135. She felt that was needed as they went and do different things 136. There were also different perspectives which she felt to be a good thing 137. She found all the visuals, including videos of people on the street and photos and documenting it to be helpful 138. They did a lot of mind mapping 139. The mind mapping led them to a final idea 140. The mind mapping includes writing down all the key

		problems people encountered whilst walking 141. They also listed things that could be improved 142. Along with things they want to see happen
Question 11a. This will seem like I'm repeating the question but then again it is quiet important, what are the main design concerns when you were designing it in the process?	[143]*Um…I'm just trying to…. cause it's been a while…*[144]*um…do you mean the concerns of like…. when, like?*	143. She was trying to remember as it has been a while 144. Do you mean the concerns?
Question 11b. OK, so it could either be, like you have the initial sketch of the idea and the other part of the group will be thinking of how to embed all the electronics nicely and then of course you will have design concern, ok how are we going to do that? Is it the size that matters or maybe you were thinking would it weight too much on the jacket? Or what about the dimensions? On/off?	[145]*Yeah when we put it together we had quite a few concerns like,* [146]*taking the sketch into a reality* [147]*and we were concerned about what kind of jacket that we're going to put it into,* [1147]*as I've said before we wanted something that was…wouldn't stand too much out from the crowd* [148]*and something that would be ….can be used everyday.* [149]*Essentially that was where our design was heading,* [150]*but we found it really quite difficult to find an item of clothing or like a designer item that would work for everyone so that was one of our main problems…* [151]*also implementing them into the shoulders,* [152]*we needed them to be seen* [153]*and we had the concern of putting it in the back or the shoulders where would be the most visible…*[154]*same with the lights we needed to have a material that would support them* [155]*but we also needed them to be seen also…. that was a bit of the concern as well* [156]*and how that jacket would support the battery packs and things like that* [157]*and the weight and how that would work with the fabric*	145. They had a few concerns when putting things together including taking the sketch into reality 146. They were concerned about what kind of jacket to use 147. She said before they wanted something that wouldn't stand too much out from the crowd 148. They wanted something that can be used everyday 149. Essentially that was where their design was heading 150. One of the main problems was they found it really quite difficult is to find an item of clothing or a designer item that would work for everyone 151. Also the implementation of electronic parts 152. They needed the electronic parts to be seen 153. They had the concern of putting it on the back or the shoulders where it would be most visible 154. Similar for the lights, they needed to have a material that would support electronic parts 155. They also needed the electronic parts to be seen, which was a bit of the concern 156. How that jacket would support the battery packs and electronic

		157. parts They were concerned on the weight and how that would work with the fabric
Question 11c. So, meaning the weight of the electronics and how the weight of the garments and how it would support that?	*Yes*	158. Yes

Table 25. Units of relevant meaning from Participant 1: Question 11, 11a, 11b and 11c.

Units of relevant meaning	
Question 11.	130. It was quite an enjoyable process 131. They ended up having a lot of time to brainstorm 132. They brought up proposals 133. They did a lot of research 134. She think that was a good thing to have a lot of time for background research 135. She felt that was needed as they went and do different things 136. There were also different perspectives which she felt to be a good thing 137. She found all the visuals, including videos of people on the street and photos and documenting it to be helpful 138. They did a lot of mind mapping 139. The mind mapping led them to a final idea 140. The mind mapping includes writing down all the key problems people encountered whilst walking 141. They also listed things that could be improved 142. Along with things they want to see happen
Question 11a.	144. Do you mean the concerns?
Question 11b.	145. They had a few concerns when putting things together including taking the sketch into reality 146. They were concerned about what kind of jacket to use 147. She said before they wanted something that wouldn't stand too much out from the crowd 148. They wanted something that can be used everyday 149. Essentially that was where their design was heading 150. One of the main problems was they found it really quite difficult is to find an item of clothing or a designer item that would work for everyone

	151.	Also the implementation of electronic parts
	152.	They needed the electronic parts to be seen
	153.	They had the concern of putting it on the back or the shoulders where it would be most visible
	154.	Similar for the lights, they needed to have a material that would support electronical parts
	156.	How that jacket would support the battery packs and electronical parts
	157.	They were concerned on the weight and how that would work with the fabric
Question 11c.	155.	Yes

In the following tables are shown units of general meaning and units of relevant meanings from question 12 and 13, respectively.

Table 26. Units of general meaning from Participant 1: Question 12 and 12a.

Questions	Answers	Units of general meaning
Question 12. If you could fix (a) certain design aspect(s) of the project, what or which aspect would it (they) be?	[156]*I would personally change the actual jacket that we used* [157]*because it probably wasn't the best design for what we were trying to go for…* [158]*if we like had more time, it would've been nice to actually create an original design that would kind of suit all different types of people that would need this product, I guess…*	156. She would personally change the actual jacket they used 157. Because it probably wasn't the best design for what they were trying to do 158. If they had more time, she felt it would've been nice to create an original design that would suit all different types of people that would need this product
Question 12a. So changing the jacket to something that would appeal broader?	[159]*Yeah, more appealing …*	159. Yes, more appealing.

Table 27. Units of relevant meaning from Participant 1: Question 12 and 12a.

Units of relevant meaning		
Question 12.	156.	She would personally change the actual jacket they used
	157.	Because it probably wasn't the best design for what they were trying to do
	158.	If they had more time, she felt it would've been nice to create an original design that would suit all different types of people that would need this product
Question 12a.	159.	Yes, more appealing.

Table 28. Units of general meaning from Participant 1: Question 13 and 13a.

Questions	Answers	Units of general meaning
Question 13. Would there be a set of general guidelines in designing Wearable Technology, in what form of would you describe them to be?	*I'm not sure if we had a specific guideline that we needed to sit down to, it was a pretty creative environment that we were in and because it wasn't something that we had to produce…it was more of a kind of conceptual and looking at how people would react, we weren't sent with that many guidelines but we did have to do something that would change the way people were walking or how they would interact with the environment*	160. She's unsure if they had a specific guideline to use 161. They were in a pretty creative environment 162. Since it wasn't something that we had to produce, it was conceptual and to look at how people would react 163. They weren't provided with many guidelines 164. They had to do something that would change the way people walk or how people would interact with the environment
Question 13a. Through the design…	*So it needed to integrate the people with the environment, I guess that was something that was one of the main points…I don't know if I'm going a bit off topic here…but…*	165. It needed to integrate people with environment 166. She guess that was one of the main points 167. She's unsure if she's gone off topic

Table 29. Units of relevant meaning from Participant 1: Question 13 and 13a.

Units of relevant meaning	
Question 13.	160. She's unsure if they had a specific guideline to use 161. They were in a pretty creative environment 162. Since it wasn't something that we had to produce, it was conceptual and to look at how people would react 164. They had to do something that would change the way people walk or how people would interact with the environment
Question 13a.	165. It needed to integrate people with environment 166. She guess that was one of the main points

Based on the findings shown in the aforementioned tables of units of general meaning and the delineations extracted, on the basis of the first interview, there were 167 units of general meaning and after delineation, 126 units of meaning emerged that were relevant to the research question. The following analysis repeats this observation of the

interview as a whole in order to eliminate redundant units followed by using the method of clustering themes that emerged from the interview.

Table 30. Clusters of relevant meanings from Interview 1

Clusters of relevant meanings
Aesthetics - Since they were taught to design for the body and aesthetics - Aesthetics are quite important when designing it - Her job was to design the aesthetic of it
Lack of knowledge in electronic components - They don't know much how to put together the electronic aspects or the lights - So they didn't really know what kind of products or things they could use - If they had known more of the electronic side of it - And the usage of lights. - It was mainly figuring out how all the electronical parts are going to work - Also the implementation of electronic parts - They needed the electronic parts to be seen
Usability - In the end, with how the user would be able to activate the signals - How the user would be able to do that without knowing too much about technology
Device positioning - How they would be able to position the lights somewhere that the user could activate - They were concerned about what kind of jacket to use - They needed the electronic parts to be seen - They had the concern of putting it on the back or the shoulders where it would be most visible
Background research - First of all they did the research - They had to think of who would actually wear the design - They did a lot of research - She think that was a good thing to have a lot of time for background research - She found all the visuals, including videos of people on the street and photos and documenting it to be helpful
Design process - A lot of it was sketching - They brought up proposals - They ended up having a lot of time to brainstorm - The mind mapping led them to a final idea - The mind mapping includes writing down all the key problems people encountered whilst walking - They had a few concerns when putting things together including taking the sketch into reality
Time constraints - They didn't have much time - If they had more time, she felt it would've been nice to create an original design that would suit all different types of people that would need this product

People's reactions
- One of the main factors was how people would react to it - They didn't expect people's reaction to be what they were - A lot of people were generally surprised - People thought it was funny - She said before they wanted something that wouldn't stand too much out from the crowd

Table 30 shows that there are eight themes that emerged from the first interview including: aesthetics, lack of knowledge in electronic components, usability, device positioning, background research, design process, time constraints and people's reactions. Thus, it became clear that the essence of the central theme revealed through the clustering of meanings was: the design process and its challenges.

6. 1. 2. Interview 1: relevant meanings in relation to the main research questions:

From the first interview, there emerged eight themes of relevant meanings and each influenced the others. These themes were then filtered through the questions asked by this research, expounded in the following:

1. How does the designer's understanding of design attributes affect the design process of Wearable Technology?

In order to elaborate relevance between findings from the first interview and the research question above, it is necessary to clarify that a designer's understanding of design attributes is included as an internal factor, which is very much influenced by the first participant's background training. The project purpose forced her (and the group) to do background research, which included the development of user scenarios. This means that their understanding of usability was foregrounded as one of the main concerns in their design process, signifying its importance as a design attribute. Through their background research, functionality also became another main concern, through their attempt to define their own unique design problem that emerged from expediting background research appropriate to the given design brief. Moreover, the unique definition of functionality also influenced considerations in device positioning, which affected usability, and in turn affected the overall design and the reaction from the user's surrounding environment.

2. How do different designs purposes that have different types of functionality and usability requirements affect the design process in Wearable Technology?

From the first interview, it became apparent that functionality was driven by the design purpose and arose as a result of the designer's background research exploring and explicating the specific design brief. Usability requirements were also driven by the designer's background research and were defined initially through brainstorming and mind-mapping. However, additional requirements may arise during the process, which may be driven by certain implications from particular elements of the design, such as limitations of electronic components, characteristics of the enveloping material etc. The issue of designing its appearance was also contingent upon the definition of functionality in accordance with the unique design purpose.

3. How can an understanding of the interdisciplinary iterative design process of Wearable Technology provide a new conceptual understanding of the field?

The collaborative project (between 2 fashion design students and 1 industrial design student) described by the first interviewee reflects the interdisciplinary nature of Wearable Technology, further explained by the way in which the designer (and her group) approached difficulties in embedding electronic parts into their design, and thus required assistance from external sources (tutors). The iterative nature of the project was also seen by the sketching activity performed by the group, which resulted in the proposal of multiple ideas and subsequent elimination of unsuitable ideas according to the intended solution.

These findings provide pathways for understanding that Wearable Technology in its design process requires collaborative effort, which corroborates its interdisciplinary nature. The iterative nature in its design process is almost unavoidable since multiple elements (such as: electronic circuitry, fashion, user studies, etc.) automatically synthesize and converge as the design activity starts, thus generating almost limitless possibilities of design

solutions that require a critical elimination process in order to achieve a refined final design.

6. 2. Participant 2

The second participant revealed in the interview (conducted on 29 September 2011) that her project matched the definition of Wearable Technology as used in this research. The brief for this project was the same as the first participant's. However, the two designers approached the problem with distinct different perspectives and methods. This was useful to augment and reinforce the understanding of the Wearable Technology design process.

The second participant described the main qualities of a car as the features they initially attempted to incorporate into their design for walking etiquette in the urban environment. Blinkers, a car horn, screeching brake sounds, and LED light signage were embedded into a blazer type garment to elicit public reactions to the wearer. She further agreed that these features were intentionally driven to transform the wearer into a car navigating in a pedestrian environment.

The project was executed by a group of three design students, including one industrial design student and two fashion design students (including the second interviewee). The challenges in the projects mentioned arose due to unfamiliarity with technological requirements of the design, due to lack of previous training in this design area. Her background training in fashion design contributed to this unfamiliarity. She admitted that this lack of knowledge impacted the design suggesting a simpler approach than that initially conceived in the group's ideas.

Approaching the given design brief, it was mentioned that her group needed to undertake sufficient background research for the project as they were briefed to not place too much emphasis on the aesthetic aspect of the project. This would seem to have steered towards a more technical and less aesthetic solution than they would have found intuitive. This became a challenge in the process, as the group were previously trained to do the opposite. Thus, functionality became the driving force, or in Darke's (1979) term, the

'primary generator' in designing the project as the group attempted to integrate technological elements in order to elicit public reactions. Thus, the design problems for the project were defined through the designer's background research conducted to support the project.

Within the process, the group followed through a series of elimination processes of design solutions that included the potential technology to be embedded, and visual and aesthetic aspects. This is similar to Lawson's (1980) theory, which explains that the way in which designers work very much emphasizes a solution-focused strategy. Furthermore, the second participant as a designer for the project also mentioned the group's intention to create a less avant-garde visual appearance, which may translate as avoiding 'borg' aesthetics described previously by Rhodes and Mase (2005). This evidenced a conscious effort to achieve seamless embodiment of technological elements by the group. The second participant further mentioned that they had chosen a premade blazer as a base of garment choice due to its versatile nature and due to the time constraints for the project itself, which prompted her group to consciously choose a quick and executable design solution.

The weight consideration emerged as an important design problem as it was determined by the choice of power source for the design. The overlap between the problems of weight and power source further affects the usability of the design as the second participant admitted it became almost too heavy to wear for the user. By increasing usability, the second participant also mentioned that her group would have liked to reassess manual operational controls and possibly alter it by enhancing automatic capabilities to require only a minimal triggering system and automated sensor activation, that is, to create a more natural and intelligent user interface design. The group suggested a preference for different types of blazer according to different age groups, gender, etc. of the intended wearer, which was perhaps related to her own background training in fashion.

In describing the process of designing Wearable Technology, the second participant found the initial process already differed from her previous design experience. She was used to approaching ideas in a very conceptual and visual manner, whilst for this particular

project, she had to cast aside her usual approach and adjust to the project's technological nature. She also found it daunting and frustrating as she felt her previous background training in fashion was of minimal advantage towards the project.

When further asked if she could suggest conceptual guidelines for designing Wearable Technology, a balanced visual and technological approach was mentioned, as she believes a user's surrounding environment plays a substantial part in determining the usability of Wearable Technology. She stated that social conventions, the potential visual response from the user's surroundings, and understanding of the body contribute to versatility of a Wearable Technology.

To further develop our understanding of the design process of Wearable Technology based on the feedback from the second participant, following is the phenomenological process of eliciting units of relevant meanings and a summary and reflection of its bearing on the main research questions.

6. 2. 1. Units of relevant meanings

In this section, units of general meaning from the second interview are listed, followed by a process of elimination and eliciting units of relevant meaning.

Table 31. Units of general meaning from Participant 2: Question 1 and 1a.

Questions	Answers	Units of general meaning
Question 1. Please describe your Wearable Technology project	[1]*It was in response to how peak hour pedestrian traffic can get a bit chaotic* [2]*and everybody kind of does their own thing,* [3]*so in response to that we kind of took a humorous approach* [4]*and took features that would be associated with a car* [5]*and see what would happen if they suddenly got kind of injected in a pedestrian environment… umm…* [6]*so the project itself is a jacket with blinkers attached into transparent shoulder pads* [7]*so the wearer could*	1. It was in response to how peak hour pedestrian traffic can get a bit chaotic 2. Everybody kind of does their own thing 3. They took a humorous approach 4. They took features that would be associated with a car 5. To see what would happen if car features are suddenly put in a pedestrian

	activate the right or left shoulder to blink according to which direction they wanted to go [8]and we also had speakers sewn into the jacket [9]so there were just noise every time the blinker would activate.. Umm...a very loud blinker noise would come on [10]and we also kind of threw in some other sounds such as screeching brakes... umm... a horn tooting... [11]so in addition to the product itself, the project was more about people's reactions, like in real life [12]rather than how the jacket would work itself.	environment 6. The project is a jacket with blinkers attached into transparent shoulder pads 7. The wearer could activate the right or left shoulder to blink according to which direction they wanted to go 8. They had speakers sewn into the jacket 9. There were noise every time the blinker would activate, a very loud blinker noise would come on 10. They also put in other sounds such as screeching brakes and a horn tooting 11. The project was more about people's reactions in real life 12. Rather than how the jacket would work.
Question 1a. So it's almost like you become a car?	[13]*Yes*	13. Yes

Table 32. Units of relevant meaning from Participant 2: Question 1 and 1a.

Units of relevant meaning	
Question 1.	1. It was in response to how peak hour pedestrian traffic can get a bit chaotic 4. They took features that would be associated with a car 5. To see what would happen if car features are suddenly put in a pedestrian environment 6. The project is a jacket with blinkers attached into transparent shoulder pads 7. The wearer could activate the right or left shoulder to blink according to which direction they wanted to go 8. They had speakers sewn into the jacket 9. There were noise every time the blinker would activate, a very loud blinker noise would come on 10. They also put in other sounds such as screeching brakes and a horn tooting 11. The project was more about people's reactions in real life
Question 1a.	13. Yes

Table 33 and 34 show units of general meaning and units of relevant meaning from questions 2 and 3 of the interview with participant 2.

Table 33. Units of general meaning from Participant 2: Question 2 and 3.

Questions	Answers	Units of general meaning
Question 2. How many people were involved in the project?	[14]*There were three in our group.*	14. There were three in the group.
Question 3. Did they come from different fields of practices?	[15]*Two were fashion design including myself* [16]*and 1 was industrial design.*	15. Two were fashion design including the 2nd participant 16. The other person is from industrial design.

Table 34. Units of relevant meaning from Participant 2: Question 2 and 3.

Units of relevant meaning	
Question 2.	14. There were three in the group.
Question 3.	15. Two were fashion design including the 2nd participant 16. The other person is from industrial design.

Following are units of general meaning and units of relevant meaning from question 4.

Table 35. Units of general meaning from Participant 2: Question 4 and 4a.

Questions	Answers	Units of general meaning
Question 4. According to your background of practice, what are the challenges of the project?	[17]*Definitely the technology side of things we kept it quite lo fi.* [18]*We found it was even a challenge for the industrial girl as well to kind of get our head around this.* [19]*That's why we kind of make the project more about people's reaction rather than technology itself.* [20]*It was all battery operated and manually operated as well* [21]*so yeah that was definitely the challenge*	17. The technology side of things were the challenge, thus kept lo fi 18. They found it was a challenge for the industrial design student 19. That's why they made the project more about people's reaction rather than technology itself. 20. It was all battery operated and manually operated 21. That was definitely the

		challenge
Question 4a. So, continuing with the previous question, the fashion design background, it was hard to embed the technology into the garment. Would you say that if you have gotten some sort of training like in a previous subject, do you think that would help you?	[22] *Yes definitely for that particular subject*	[22.] Yes

Table 36. Units of relevant meaning from Participant 2: Question 4 and 4a.

Units of relevant meaning	
Question 4.	[17.] The technology side of things were the challenge, thus kept lo fi [19.] That's why they made the project more about people's reaction rather than technology itself. [20.] It was all battery operated and manually operated
Question 4a	[22.] Yes

Question 5 produced 16 units of general meaning and 12 units of relevant meaning shown in table 37 and table 38.

Table 37. Units of general meaning from Participant 2: Question 5.

Questions	Answers	Units of general meaning
Question 5. Of course when you were given the design brief, you have a certain approach as a fashion design student. Please try to describe to me how you approach that initial design brief for this subject	[23]*We were kind of encouraged to not think of it as an aesthetic project* [24]*we were all very much encouraged to embrace technology even though we kind of didn't have the training more as a...* [25]*I guess the tutors kind of had the vision that you'll never really get the chance to do this again with technology* [26]*so they were kind of pushing from that angle* [27]*so we all kind of went into it a little bit blindly.* [28]*When we tried to kind of make the aesthetic, we were encouraged to not think too much about that* [29]*but I guess the only way it would've formed was to kind of think of ways we could hide the technology.* [30]*I also forgot the feature that we included in LED lights we also made the sign follow me at the back.* [31]*That was in response to how people…. things like if there's a lot of people waiting on the side of the road to cross, one would only cross if other people start to do it,* [32]*even that the lights don't go on so that was just kind of a play on that.* [33]*Um, the fashion design helped in, you know, thinking about materials that would cover the sign when it wasn't lit but will still shine through when it was, um...* [34]*just knowledge about the garment so where the different switches could go,* [35]*but aesthetically didn't really… We didn't really have scoped to kind of allow it...* [36]*it wasn't...it was more about reactions.* [37]*We didn't have the time or the expertise to kind of think how aesthetic and technology can kind of be merged together.*	23. They were encouraged to not think of it as an aesthetic project 24. They were encouraged to embrace technology even though they didn't have the training 25. The tutors had the vision that they'll never really get the chance to do this again with technology 26. The tutors were pushing the subject from that angle 27. They all went into it a little bit blindly 28. When they tried to make the aesthetic, they were encouraged not think too much about that 29. She guessed the only way to form it was to think of ways to hide the technology 30. Another feature included in LED lights is they made the sign 'follow me' at the back 31. The lights was in response to how when there's a lot of people waiting on the side of the road to cross, one would only cross if other people start to do so 32. Even if the lights don't go on 33. The fashion design helped in thinking about materials that would cover the sign when it wasn't lit but will still shine through when it was 34. Knowledge about the garment so where the different switches could go 35. They didn't really think of the aesthetics 36. It was more about reactions. 37. They didn't have the time or

	the expertise to think how aesthetic and technology be merged together.

Table 38. Units of relevant meaning from Participant 2: Question 5.

Units of relevant meaning	
Question 5.	23. They were encouraged to not think of it as an aesthetic project 24. They were encouraged to embrace technology even though they didn't have the training 27. They all went into it a little bit blindly 29. She guessed the only way to form it was to think of ways to hide the technology 30. Another feature included in LED lights is they made the sign 'follow me' at the back 31. The lights was in response to how when there's a lot of people waiting on the side of the road to cross, one would only cross if other people start to do so 32. Even if the lights don't go on 33. The fashion design helped in thinking about materials that would cover the sign when it wasn't lit but will still shine through when it was 34. Knowledge about the garment so where the different switches could go 35. They didn't really think of the aesthetics 36. It was more about reactions. 37. They didn't have the time or the expertise to think how aesthetic and technology be merged together.

The following tables show units of general meaning and units of relevant meaning from question 6.

Table 39. Units of general meaning from Participant 2: Question 6.

Questions	Answers	Units of general meaning
Question 6. Moving on, how do you describe...so we spoke about how your background	*[38]I found definitely very daunting… umm... I kind of... [39]My first ideas were kind of projects that were not very feasible to make to somewhat my expertise... Umm... [40]And then the process became more about toning it back and how it could be*	38. She found it definitely very daunting 39. Her first ideas were projects that were not very feasible to make to somewhat her expertise

training affected the way you approached the design brief and how it's slightly different and you're encouraged to embrace the technology itself. What about you personally, as a fashion designer when you were given that design brief, what was the first thing that came to your mind?	*possible.... [41]but yeah, that's probably what I first thought it was... [42]cause we had the choice to either keep it as something conceptual or make it real.. Umm... [43]and definitely my first impressions were to keep it conceptual [44]because I just had no idea where to start; [45]my ideas were really big...*	40. The process became more about toning it back and how it could be possible 41. That's probably what she first thought it was... 42. They had the choice to either keep it as something conceptual or to make it real 43. Her definite first impressions were to keep it conceptual 44. She had no idea where to start 45. Her ideas were really big

Table 40. Units of relevant meaning from Participant 2: Question 6.

Units of relevant meaning	
Question 6.	38. She found it definitely very daunting 39. Her first ideas were projects that were not very feasible to make to somewhat her expertise 40. The process became more about toning it back and how it could be possible 42. They had the choice to either keep it as something conceptual or to make it real 43. Her definite first impressions were to keep it conceptual 44. She had no idea where to start 45. Her ideas were really big

Table 41 includes units of general meaning and table 42 shows units of relevant meaning from question 7.

Table 41. Units of general meaning from Participant 2: Question 7 and 7a.

Questions	Answers	Units of general meaning
Question 7. Of course in the design process there are certain design attributes that came up when you were trying to design the jacket or when you were trying to design the visual feedback...what were the design attributes that emerged during the process which became part of the considerations that made, design wise?	[46]*We definitely considered keeping it very normal, if that make sense.* [47]*So visually we didn't want it to be anything avant-garde,* [48]*it was something that very much had to blend in with what people were wearing,* [49]*so instead of designing something from scratch, we used a blazer and then we altered it from there,* [50]*so it wasn't really...the visual side of things wasn't really designed at all.* [51]*It was more how we incorporate the technology.* [52]*That was the only designed part.*	46. They definitely considered keeping it very normal 47. Visually, they didn't want it to be anything avant-garde 48. It was something that very much had to blend in with what people were wearing 49. Instead of designing something from scratch, they used a blazer which was then altered 50. The visual side of things wasn't really designed at all 51. It was more how they incorporate the technology 52. That was the only designed part
Question 7a. Oh ok. So the embodiment of technology into the garment, that's the main consideration?	[53]*Yes*	53. Yes

Table 42. Units of relevant meaning from Participant 2: Question 7 and 7a.

Units of relevant meaning	
Question 7.	47. They definitely considered keeping it very normal 48. Visually, they didn't want it to be anything avant-garde 49. It was something that very much had to blend in with what people were wearing 50. Instead of designing something from scratch, they used a blazer which was then altered 51. The visual side of things wasn't really designed at all 52. It was more how they incorporate the technology 53. That was the only designed part
Question 7a.	54. Yes

The following two tables show units of general meaning and units of relevant meaning from question 8.

Table 43. Units of general meaning from Participant 2: Question 8.

Questions	Answers	Units of general meaning
Question 8. Is there any difficulty when you were trying to embed that technology? What would be the concrete example you encountered when you were trying to embed technology into the garment itself?	*[55]Definitely a power source [56]and cause everything was battery operated it was very heavy [57]and we had the LED sign that was made out of 42 Christmas lights which needed about 6 AA that needed to be put into the back of the jacket plus the speakers [58]so it was very heavy to wear [59]and that was probably something that would have never made it usable in real life situation.*	55. Definitely a power source 56. Since everything was battery operated it was very heavy 57. They had the LED sign that was made out of 42 Christmas lights which needed about 6 AA that needed to be put into the back of the jacket plus the speakers 58. So it was very heavy to wear 59. That was probably something that would have never made it usable in real life situation.

Table 44. Units of relevant meaning from Participant 2: Question 8.

Units of relevant meaning	
Question 8.	55. Definitely a power source 56. Since everything was battery operated it was very heavy 57. They had the LED sign that was made out of 42 Christmas lights which needed about 6 AA that needed to be put into the back of the jacket plus the speakers 58. So it was very heavy to wear 59. That was probably something that would have never made it usable in real life situation.

Question 9 has produced 10 units of general meaning with 8 units of relevant meaning, which are shown in the following two tables.

Table 45. Units of general meaning from Participant 2: Question 9.

Questions	Answers	Units of general meaning
Question 9. Within the process itself, were there any design problems that kept on recurring? For example: ok we decided we're going to use Christmas lights, we tested it, there were certain problems and you changed it again, or as you've said before the ideas were big, and you started moving backwards and you try to turn it down. Were there recurring design problems that you encountered during the process itself?	*[60]Probably, how big we could take it was the biggest problem… Umm… [61]Yeah, it was just very hard with kind of, limited resources and limited time; [62]I think we only had about three weeks to do this and 1 day a week… [63]I mean we had our whole semester but in terms of actually making it when it got down to it, that's how much was allowed for the physical making of the jacket… Umm. [64]Yeah like we did want to take it to a grander scale [65]and put more features that would have elicited a bigger reaction from the public, [66]possibly things like, you know, small signs coming out from shoulders or something like that, [67]but it just ended to be toned down or kept conceptual. [68]So, yeah that's probably one design thing, [69]cause we didn't have the expertise we couldn't carry out the design.*	[60.] Probably, how big they could take it was the biggest problem [61.] It was just very hard with limited resources and limited time [62.] They only had about three weeks to do it and 1 day a week [63.] They had a whole semester but in terms of actually making it that's how much was allowed for the physical making of the jacket [64.] They wanted to take it to a grander scale [65.] To put more features that would have elicited a bigger reaction from the public [66.] Possibly things such as small signs coming out from shoulders, etc [67.] It ended to be toned down or kept conceptual [68.] That's probably one design thing (problem) [69.] Because they didn't have the expertise, they couldn't carry out the design

Table 46. Units of relevant meaning from Participant 2: Question 9.

Units of relevant meaning	
Question 9.	[61.] It was just very hard with limited resources and limited time [62.] They only had about three weeks to do it and 1 day a week [64.] They wanted to take it to a grander scale [65.] To put more features that would have elicited a bigger reaction from the public [66.] Possibly things such as small signs coming out from shoulders, etc [67.] It ended to be toned down or kept conceptual [68.] That's probably one design thing (problem) [69.] Because they didn't have the expertise, they couldn't carry out the design

Question 10 produced 11 units of general meaning shown in table 47 and 8 units of relevant meaning shown in table 48.

Table 47. Units of general meaning from Participant 2: Question 10.

Questions	Answers	Units of general meaning
Question 10. If you could fix certain design aspects of that project, what or which aspect would it be?	[70]*Probably the switches being able to be automatic or somehow sensor activated if that makes sense.* [71]*They were all kind of manually...*[72]*you have to press each buttons for the purposes of experimenting and trying to get a reaction* [73]*but if it was kind of to be taken out in a real large scale project,* [74]*it would be good one switch could control everything, or if one switch had all the buttons* [75]*rather then, ok...left hand this finger, press this, right hand, your pinkie press that…* [76]*yeah just probably the accessibility for all the switches...*[77]*and I guess just kind of making the garment a little bit more individual as well,* [78]*trying to bring in that design element,* [79]*ideally we would love to have one for each age group, each gender,* [80]*but we just... because the time, we had to do the standard type black blazer.*	[70.] Probably the switches being able to be automatic or somehow sensor activated [71.] They were all manually controlled [72.] You have to press each buttons for the purposes of experimenting and trying to get a reaction [73.] If it was kind of to be taken out in a real large scale project [74.] It would be good one switch could control everything, or if one switch had all the buttons [75.] Rather then, for example left hand this finger, press this, right hand, your pinkie press that [76.] Probably the accessibility for all the switches [77.] Also she guessed, making the garment a little bit more individual [78.] By trying to bring in that design element [79.] Ideally they would love to have one for each age group and each gender [80.] Because of the time limitation, they had to do the standard type black blazer

Table 48. Units of relevant meaning from Participant 2: Question 10.

Units of relevant meaning	
Question 10.	70. Probably the switches being able to be automatic or somehow sensor activated 71. They were all manually controlled 72. You have to press each buttons for the purposes of experimenting and trying to get a reaction 74. It would be good one switch could control everything, or if one switch had all the buttons 76. Probably the accessibility for all the switches 77. Also she guessed, making the garment a little bit more individual 79. Ideally they would love to have one for each age group and each gender 80. Because of the time limitation, they had to do the standard type black blazer

In table 49 and table 50, show the units of general meaning and units of relevant meaning from question 11.

Table 49. Units of general meaning from Participant 2: Question 11.

Questions	Answers	Units of general meaning
Question 11. How do you describe the design process itself?	[81]*It was different to what we were used to,* [82]*it was very much... I was very much used to being starting with a very conceptual inspiration that was always visual* [83]*and for this it was a lot about technicalities and electronics and things like that...*[84]*so it was different, it couldn't....* [85]*we find it hard to kind of have all these knowledge* [86]*about visual garments and how they work stylistically and, you know, what things would be worn in what environments* [87]*and it kind of just had to be cast aside...*[88]*so I found that aspect of it frustrating to have all this knowledge in the area and not be able to use it* [89]*and being encouraged to not use it also...*[90]*so yeah that's probably what differed in the approach from normal.*	81. It was different to what they were used to 82. She was very much used to start with a very conceptual inspiration that was always visual 83. For this project, it was a lot about technicalities and electronics 84. It was different 85. They found it hard to have all these knowledge 86. Knowledge on visual garments and how they work stylistically and what things would be worn in certain environments 87. The knowledge just had to be cast aside 88. She found that aspect frustrating to have all this knowledge in the area and

	not be able to use it 89. And being encouraged to not use it 90. That's probably what differed in the approach from normal (designing)

Table 50. Units of relevant meaning from Participant 2: Question 11.

Units of relevant meaning	
Question 11.	82. She was very much used to start with a very conceptual inspiration that was always visual 83. For this project, it was a lot about technicalities and electronics 85. They found it hard to have all these knowledge 86. Knowledge on visual garments and how they work stylistically and what things would be worn in certain environments 87. The knowledge just had to be cast aside 88. She found that aspect frustrating to have all this knowledge in the area and not be able to use it 89. And being encouraged to not use it 90. That's probably what differed in the approach from normal (designing)

In the following two tables show units of general meaning followed by units of relevant meaning from question 12.

Table 51. Units of general meaning from Participant 2: Question 12 and 12a.

Questions	Answers	Units of general meaning
Question 12. Would there be a set of design guidelines for designers in designing such project, what would you think they would be like?	*91 I think given what I just said, 92 there should be some kind of visual guideline as well as just technical... umm… 93 I think it's important to remember that people respond to these things visually first and foremost, 94 so understanding of the body and how garments fit 95 and just social conventions around each garment 96 and what you choose to place technology in will always play a part in it... umm… 97 In terms of the technology side of things, 98 I think it's very important to kind of integrate it easily into whatever environment it's been put into*	91. Given what she said previously 92. There should be some kind of visual guideline as well as technical 93. She thinks it's important to remember that people respond to these things visually first and foremost 94. The understanding of the body and how garments fit 95. Social conventions around each garment 96. Also what you choose to

		place technology in will always play a part 97. In terms of the technology side of things 98. She thinks it's very important for it to be able to integrate easily into whatever environment it's been put into
Question 12a. Versatility, would you say?	99 *Yep*	99. Yep, versatility.

Table 52. Units of relevant meaning from Participant 2: Question 12 and 12a.

Units of relevant meaning		
Question 12.	92. 93. 94. 95. 96. 97. 98.	There should be some kind of visual guideline as well as technical She thinks it's important to remember that people respond to these things visually first and foremost The understanding of the body and how garments fit Social conventions around each garment Also what you choose to place technology in will always play a part In terms of the technology side of things She thinks it's very important for it to be able to integrate easily into whatever environment it's been put into
Question 12a.	99.	Yep, versatility.

In the second interview, 99 units of general meanings with a total of 77 units of relevant meanings were extracted. The units of relevant meaning were subsequently filtered through an eliminative process to distil non-redundant units of meaning relevant to the research questions using the clustering of themes that emerged from the interview.

Table 53. Clusters of non-redundant units of relevant meanings from the interview with participant 2.

Clusters of relevant meanings
Aesthetics - They were encouraged to not think of it as an aesthetic project - They didn't really think of the aesthetics - They didn't have the time or the expertise to think how aesthetic and technology be merged together
Technological emphasis - They were encouraged to embrace technology even though they didn't have the training - Because they didn't have the expertise, they couldn't carry out the design - For this project, it was a lot about technicalities and electronics - They were encouraged to embrace technology even though they didn't have the training - It was more how they incorporate the technology - She guessed the only way to form it was to think of ways to hide the technology
Usability - It was all battery operated and manually operated - Probably the switches being able to be automatic or somehow sensor activated - They were all manually controlled - You have to press each buttons for the purposes of experimenting and trying to get a reaction - It would be good one switch could control everything, or if one switch had all the buttons - Probably the accessibility for all the switches
People's reaction - The project was more about people's reactions in real life - It was more about reactions. - It was something that very much had to blend in with what people were wearing - To put more features that would have elicited a bigger reaction from the public - That's why they made the project more about people's reaction rather than technology itself.
Design process and difficulties - Her first ideas were projects that were not very feasible to make to somewhat her expertise - The process became more about toning it back and how it could be possible - Her definite first impressions were to keep it conceptual - She had no idea where to start - They all went into it a little bit blindly
Time constraints - It was just very hard with limited resources and limited time - They only had about three weeks to do it and 1 day a week - Because of the time limitation, they had to do the standard type black blazer - They didn't have the time or the expertise to think how aesthetic and technology be merged together.

Power Source - It was all battery operated and manually operated - Since everything was battery operated it was very heavy - They had the LED sign that was made out of 42 Christmas lights which needed about 6 AA that needed to be put into the back of the jacket plus the speakers
Weight - Since everything was battery operated it was very heavy - So it was very heavy to wear
Visual aspects - Visually, they didn't want it to be anything avant-garde - The visual side of things wasn't really designed at all - Knowledge on visual garments and how they work stylistically and what things would be worn in certain environments - There should be some kind of visual guideline as well as technical - She thinks it's important to remember that people respond to these things visually first and foremost

In table 53, there are 39 non-redundant units of relevant meaning clustered into 9 themes that emerged using a phenomenological reduction process. These themes included: aesthetics, technological emphasis, time constraints, power source, weight, and visual aspects. Through the process of clustering meanings into themes, a central theme emerged: the design process, its difficulties and design attributes. The next section discusses the relationship of these themes to the research questions.

6. 2. 2. Interview 2: relevant meanings in relation to the main research questions:

From the second interview, there emerged nine themes of relevant meanings and each is influential upon the others. These themes were then sifted using the research questions of this research, following:

1. How does the designer's understanding of design attributes affect the design process of Wearable Technology?

In the design process, several design attributes emerged in a somewhat organic manner and their overlaps with one another created greater understanding of the design problems. Aesthetic and visual aspects were discussed in the interview and emerged as quite important to the designer in consciously realizing the design attributes. A few aspects

were of external nature, such as time constraints and people's reactions to the wearer. These aspects also drove the approach to design attributes and realization of the design problem. Usability, the power source and weight of the Wearable Technology influenced one another, and appeared sequentially as encountered by the second participant (as a designer) during the process, rather than being anticipated and formulated in advance. This further reinforced designer's iterative way of thinking and solution-focused strategy.

2. How do different design purposes that have different types of functionality and usability requirements affect the design process in Wearable Technology?

The interview with the second participant highlighted that the functionality of Wearable Technology is not always steered by a specific design purpose but can also be driven by the designer's initial idea or inspirations. For example, the functional features of Wearable Technology according to the second participant were inspired by features of a car, which were then embedded into a wearable piece. The design purpose, which was to assist pedestrians moving in an urban space, does not necessarily include the brief of embedding car features. This was more of a thematic, inspirational or conceptual cohesive motive than an essential or function-contingent artefact. Usability as a design attribute of Wearable Technology emerged during the design process but was realized by the designer primarily via the implementation of other design attributes, such as their approach to weight and power source.

If compared to the first interview, there is a significant difference in the designers' understanding of usability. Even though the first and the second participant worked together on the same project addressing the same brief, the first participant viewed usability as secondary to aesthetics or partially shaped by aesthetic choices in the design process, whereas the second participant viewed it through a more technical lens, i.e. the consequence of such design criteria as selection of the device's power source, weight, and automated vs. manual operation of the system's control, etc.

3. How can an understanding of the interdisciplinary iterative design process of Wearable Technology provide a new conceptual understanding of the field?

Drawing on the interview with the second participant, different roles or job descriptions in a group of designers collaborating on a brief were apparent. The second participant gave the sense of emphasizing less the visual and aesthetic qualities of the design. However, as the group worked collaboratively, the first participant's role in designing the 'look' complements the second participant's considerations concerning the more technical design attributes such as power source and weight.

The multiple design attributes, that overlap one another, may require a collaborative work effort, so as to maintain the holistic design view that encompasses all design attributes while providing a more efficient design process of Wearable Technology. The collaborative work mode also reflects the multi-disciplinary nature of Wearable Technology.

6. 3. Participant 3

The third interview conducted on 30 September 2011 with participant 3 revealed how her group's Wearable Technology project followed a similar design brief to the previous participants, which was to design a device that assists walking or interacting within the city. However, she revealed that her group's design was derivative of a previous personal project of her own that explored the idea of fear and loneliness of being in the city. Thus, the design for the device was a neck device capable of detecting a user's heartbeat and sending the data to another user, making it an interconnected device requiring a minimum of two users in order to function. A point to be considered here is that the third participant received a similar brief to the previous two participants, but through the process, produced a different translation of the initial design brief.

The group consisted of four members including three fashion design students and one visual communication design student, hence the design project was expedited collaboratively. The difficulties of working within a group were mentioned and that some

group members disagreed at certain points, which contributed to the iterative nature of the design process. In addition, extensive background research for the project, conducted due to unfamiliarity with the technological elements required, was construed as contributing to the iterative design process. The group pursued a repetitive elimination process of the less feasible ideas, the consequence of time constraints.

Technological elements of the design were construed as challenging during the design process, largely due to a lack of previous training in this area. This was the consequence of her training as a fashion design student, which involved little to no exposure to technological expertise, other than those commonly found in fashion (e.g. textile technology). The effect of learning about unfamiliar techniques for designing was evident in the participant's reliance upon the Internet, as an initial tool for tackling a challenging aspect of the design. Tutors provided further assistance in understanding design considerations and their implications during the conceptual process.

Several design attributes emerged in a rather organic way during iterative stages of the design process. Size and dimensions overlapped with the selection of a suitable power source. The physical configurations of mechanical elements and device positioning emerged during the design process, as the participant's group attempted to produce a less bulky appearance of design for the user. Again, this is evidence that the group tried to avoid the 'borg' aesthetic commonly found in Wearable Technology (Rhodes & Mase 2005) by trying to maintain sleeker visual appearance.

The choice of materials emerged as a concern of the design for the third participant who, if given an opportunity to redesign, would have preferred for the entire device to be made from one type of material. The end design for the project consisted of two joined parts, half made from plastic and half made from wood. The concern with appearance may be the consequence of the designer's background training in fashion. Issues related to the choice of material concerned the group who wanted to ensure a solid enveloping material while maintaining its compact physical configuration encapsulating the technological elements.

Within the design process, the third participant mentioned that the process consisted mainly of narrowing down ideas and visiting previously discussed design issues repeatedly. Moreover, the group shifted their perspective towards design problem, from initially looking at certain parts of the body for affixing the technology, to how they could translate the design brief through the design. These considerations sit in parallel with the nature of design process itself which is solution-focused, instead of problem-focused, and the group decided to eliminate unfeasible ideas and perspectives to fulfil the design brief (Lawson 1980).

When asked what might constitute guidelines for designing Wearable Technology, the third participant mentioned that it needed to be practical. She elaborated 'practicality' by mentioning durability and waterproofing as requirements of Wearable Technology design and that the device must be constantly available (viewable, controllable, touchable) for the user while being worn.

In order to further mine findings gained from the interview, a series of phenomenological reduction filters are applied below in order to garner the emerging themes. These are outlined below.

6. 3. 1. Units of relevant meanings

In this section, units of general meanings extracted from the process of interviewing participant 3 are summarized along with the units of relevant meaning.

Table 54. Units of general meaning from Participant 3: Question 1 and 1a.

Questions	Answers	Units of general meaning
Question 1. Please describe your Wearable Technology project.	[1]*Yep, ok, it's basically a neck device,* [2]*that senses when the wearer is distressed and transmits a heartbeat of a friend, or a partner…*[3]*so it can't be individually done,* [4]*so the partner would also be wearing it and* [5]*it would work like that*	1. It's basically a neck device 2. It senses when the wearer is distressed and transmits a heartbeat of a friend, or a partner 3. It can't be individually done 4. The wearer's partner would also be wearing it 5. It would work like that

Question 1a. So, there are two wearers, so it's like a pairing?	[6]*Yeah, well there could be more;* [7]*it's basically an interconnected device.*	6. There could be more wearers 7. It's basically an interconnected device

Table 55. Units of relevant meaning from Participant 3: Question 1 and 1a.

Units of relevant meaning	
Question 1.	1. It's basically a neck device 2. It senses when the wearer is distressed and transmits a heartbeat of a friend, or a partner 3. It can't be individually done
Question 1a.	6. There could be more wearers 7. It's basically an interconnected device

Following are units of general meaning and units of relevant meaning from questions 2, 3 and 3a.

Table 56. Units of general meaning from Participant 3: Question 2, 3 and 3a.

Questions	Answers	Units of general meaning
Question 2. How many people were involved in the project?	[8]*Well basically in the group designing it, there were four.*	9. There were four members in the group
Question 3. Did they come from different fields of practices?	[9]*There were three from Fashion design including myself, and* [10]*one was from VisComm(*),* [11]*so it's an interdisciplinary subject.*	10. There were three from Fashion design including herself 11. One was from VisComm(*) 12. It's an interdisciplinary subject.
Question 3a. Cause, I thought it would be just between industrial and fashion?	[12]*No, it was open to everyone there,* [13]*a few VisComm(*) were in the class.* [14]*Mainly, it was fashion and industrial students, who chose the class.*	13. It was open to everyone there 14. A few VisComm(*) were in the class. 15. Mainly, it was fashion and industrial students

(*) VisComm: Visual Communication

Table 57. Units of relevant meaning from Participant 3: Question 2, 3 and 3a.

Units of relevant meaning	
Question 2.	8. There were four members in the group

Question 3.	[9.] There were three from Fashion design including herself [10.] One was from VisComm(*) [11.] It's an interdisciplinary subject.
Question 3a.	[12.] It was open to everyone there [15.] Mainly, it was fashion and industrial students

(*) VisComm: Visual Communication

During the interview, question 4 evolved to become conversational, which is shown in the following table eliciting units of general meaning acquired and followed by a table of units of relevant meaning.

Table 58. Units of general meaning from Participant 3: Question 4, 4a-4f.

Questions	Answers	Units of general meaning
Question 4. According to your background of practice, what are the challenges of the project?	[16]*Probably the technical elements.*	[16.] Probably the technical elements.
Question 4a. So that's including the machinery?	[17]*Yes,* [18]*so how to make it work and stuff like that,* [19]*although the internet was quite helpful, so…*	[17.] Yes, including the machinery [18.] How to make the machinery works [19.] The internet was quite helpful
Question 4b. The internet?	[20]*Yep.*	[20.] Yes
Question 4c. Oh so you did research and all that through there?	[21]*Yep.*	[21.] Yes, she did research via Internet
Question 4d. So with this device, how do you detect the person's mood?	[22]*Mood?* *(Participant unclear on previous question asked)*	[22.] Mood?
Question 4e. Yes, meaning, how do the device recognize that the person's stressed?	[23]*It's through a series of sensors,* [24]*so they're all fairly readily available,* [25]*mainly the heart-rate is the core,* [26]*but through detections at the neck, there's like, um, changes in the skin conductivity, and stuff like that.*	[23.] It's through a series of sensors [24.] They are all fairly readily available [25.] Mainly the heart-rate is the core emphasis of the project

		[26.] In addition, through detecting changes in the skin conductivity around the neck
Question 4f. Oh so it is a galvanic type, so it touches the skin?	[27]*Yeah, so there's a sensor that will touch the skin,* [28]*so it's all based on the heart rate mainly, though,* [29]*cause the project was based all around the heart.*	[27.] There's a sensor that will touch the skin [28.] It's all based mainly on the heart rate [29.] The project was based all around the heart

Table 59. Units of relevant meaning from Participant 3: Question 4, 4a-4f.

Units of relevant meaning	
Question 4.	[16.] Probably the technical elements.
Question 4a.	[18.] How to make the machinery works [19.] The internet was quite helpful
Question 4b.	(None)
Question 4c.	[21.] Yes, she did research via Internet
Question 4d.	(None)
Question 4e.	[23.] It's through a series of sensors [25.] Mainly the heart-rate is the core emphasis of the project [26.] In addition, through detecting changes in the skin conductivity around the neck
Question 4f.	[27.] There's a sensor that will touch the skin [29.] The project was based all around the heart

The next two tables display units of general meaning and units of relevant meanings arising from question 5.

Table 60. Units of general meaning from Participant 3: Question 5.

Questions	Answers	Units of general meaning
Question 5. With the difficulties that you've encountered with the technical elements, given with your background practice, would you say that you haven't had enough previous training for it?	[30]*Well, we really haven't had any in the technical element,* [31]*but then the reverse side was industrial students didn't know how to approach it* [32]*without coming up with ideas that were already present in the market, so…*	[30.] They haven't had any training about the technical element [31.] Industrial students didn't know how to approach it [32.] Previously present ideas on the market was used as an approach

Table 61. Units of relevant meaning from Participant 3: Question 5.

Units of relevant meaning	
Question 5.	30. They haven't had any training about the technical element 31. Industrial students didn't know how to approach it 32. Previously present ideas on the market was used as an approach

Units of general meaning and units of relevant meaning from question 6, 6a, 6b and 6c are displayed in the following two tables.

Table 62. Units of general meaning from Participant 3: Question 6, 6a-6c.

Questions	Answers	Units of general meaning
Question 6. OK. When you were first given the design brief, how did you approach it? How did you and you group mates approach it?	[33]*Um, well it's slightly based off on individual project we needed to do before,* [34]*so we based it on mine, mainly,* [35]*which is a hand, sort of, device* [36]*that shone a light in the direction of home when an individual is feeling distressed.*	33. The project was slightly based off on individual project they did beforehand 34. They mainly based it on hers 35. It is a hand device 36. It can shine a light in the direction of home when an individual is feeling distressed
Question 6a. OK. So the individual project was a hand piece?	[37]*Yep.*	37. Yes, it was a hand piece.
Question 6b. And did it use the same mechanism as the one done with the group?	[38]*Yeah, very similar in the detection in the moods and stuff like that.*	38. It is very similar in the detection of moods
Question 6c. But the feedback is different?	[39]*Yeah, one was based mainly around homesickness and connection to home and* [40]*the other one was based on connection to people, individuals.*	39. The first one was based mainly around homesickness and connection to home 40. The second one was based on connection to people and individuals

Table 63. Units of relevant meaning from Participant 3: Question 6, 6a-6c.

Units of relevant meaning		
Question 6.	33.	The project was slightly based off on individual project they did beforehand
Question 6a.	37.	Yes, it was a hand piece.
Question 6b.	38.	It is very similar in the detection of moods
Question 6c.	39.	The first one was based mainly around homesickness and connection to home
	40.	The second one was based on connection to people and individuals

In the following two tables, are the units of general meaning and units of relevant meaning from question 7 and 7a.

Table 64. Units of general meaning from Participant 3: Question 7 and 7a.

Questions	Answers	Units of general meaning	
Question 7. How would you describe your personal initial design related challenge?	[41]*Um, well initially it would be coming up with an original design idea,* [42]*technically, we had assistance from a helper in the class, and he was like a tutor's helper.... I'm not sure...a tutor aid…* [43]*Um, basically the tutor brought him in just cause he knew he can help us with the technical elements.* [44]*So we started with him and did further research.*	41.	Initially it would be coming up with an original design idea
		42.	They had technical assistance from an extra tutor in the class
		43.	The tutor brought him in because so he can help them with the technical elements
		44.	They started with tutor's assistance and did further research
Question 7a. So, basically would you say that the research part is a strong element of how you initially approach the design challenges?	[45]*Yeah, I'd say so,* [46]*cause as soon as you start looking up ways to detect things,* [47]*there's sort of online tutorials of similar projects* [48]*and then how to do them or whatever they did.*	45.	Yes, research is a strong part of the initial approach to design challenges
		46.	They start looking up ways to detect things
		47.	They found online tutorials of similar projects
		48.	Including how to do the similar projects.

Table 65. Units of relevant meaning from Participant 3: Question 7 and 7a.

Units of relevant meaning		
Question 7.	41.	Initially it would be coming up with an original design idea
	44.	They started with tutor's assistance and did further research
Question 7a.	45.	Yes, research is a strong part of the initial approach to design challenges
	46.	They start looking up ways to detect things
	47.	They found online tutorials of similar projects

Units of relevant meaning from questions 8, 8a and 8b are shown in table 66 followed by their units of relevant meanings in table 66.

Table 66. Units of general meaning from Participant 3: Question 8, 8a and 8b.

Questions	Answers	Units of general meaning
Question 8. In the process of designing it, of course you've encountered a lot of design attributes. It could be the size, the weight and then the look of it, or how it could be powered, those sorts of things. So what design attributes lead to the design considerations that you made during the process?	[49]*Probably all of them.* [50]*There wasn't as much of an issue, mainly size would be the big one,* [51]*because we needed it housed in a solid housing, I suppose, to soft housing.* [52]*With Wearable Technology, technology has come a long way,* [53]*so you can get quite slim and sort of discrete power sources and sort of power boards to go on clothing.*	49. Probably all of them 50. The size would be one of the main issues 51. They needed the technical elements housed in a solid housing 52. Technology has come a long way 53. Slim and discrete power sources and power boards to be embedded to clothing is attainable
Question 8a. So basically, it's more of the size of the entire device itself, not necessarily the size of the elements, would you say?	[54]*It would be the size of the elements* [55]*but we needed to stack the elements up um as opposed to spreading them out flat, in that respect.*	54. It would be the size of the elements 55. They needed to stack up the elements as opposed to spreading them flat

Question 8b. So making it as compact as possible?	[56]*Yeah that was probably a little bit difficult.*	[56.] Making it compact was difficult

Table 67. Units of relevant meaning from Participant 3: Question 8, 8a and 8b.

Units of relevant meaning	
Question 8.	[50.] The size would be one of the main issues [51.] They needed the technical elements housed in a solid housing [53.] Slim and discrete power sources and power boards to be embedded to clothing is attainable
Question 8a.	[54.] It would be the size of the elements [55.] They needed to stack up the elements as opposed to spreading them flat
Question 8b.	[56.] Making it compact was difficult

Table 68 and table 69 display units of general meaning and units of relevant meaning from questions 9 and 9a.

Table 68. Units of general meaning from Participant 3: Question 9 and 9a.

Questions	Answers	Units of general meaning
Question 9. Could you please tell me what are the difficulties of approaching the design brief?	[57]*As a group, probably, it's just having different design ideas.*	[57.] It is having different design ideas within a group
Question 9a. So making it work as a group?	[58]*Yeah, designing in a group is always a little bit difficult....* [59]*the brief was quite broad...* [60]*Um, it focuses more on the experience of the wearer and how they interacted with the city around them…* [61]*Um, so mainly it was focusing on the environment of the city and problems related to living in the city...* [62]*um, so we focused on the distress and this sort of fear it could cause* [63]*and ways to positively impact that.*	[58.] Designing in a group is always a little bit difficult [59.] The design brief was quite broad [60.] The project focuses more on the experience of the wearer and how they interacted with the city [61.] Mainly the project was focusing on the environment of the city and problems related to living in the city

	[62.] They focused on the distress and fear it could cause [63.] And ways to positively impact distress and fear of living in the city

Table 69. Units of relevant meaning from Participant 3: Question 9 and 9a.

Units of relevant meaning	
Question 9.	[57.] It is having different design ideas within a group
Question 9a.	[58.] Designing in a group is always a little bit difficult [59.] The design brief was quite broad

The following two tables display units of general meaning (table 70) and units of relevant meaning (table 71) from questions 10 and 10a.

Table 70. Units of relevant meaning from Participant 3: Question 10 and 10a.

Questions	Answers	Units of general meaning
Question 10. Within the design process itself what recurring design problems appeared?	[64]*Yeah, um because our base for things we could do with the technology we had was so broad* [65]*we had lots of things it could do in our minds and* [66]*just trying to organize them was a little bit messy,* [67]*so we got confused within ourselves.*	[64.] Their base knowledge on the technological capabilities was so broad [65.] They had learnt lots of the technological capabilities in their minds [66.] Trying to organize the ideas was a little bit messy [67.] They got confused within themselves
Question 10a. So within the research itself that gave you a lot of options and that gave you some sort of a base understanding of what the technology are capable to do? And then narrowing it down	[68]*It was, yeah.* [69]*I think in the end still, it was still a little bit vague* [70]*because we didn't really have enough time to develop it fully...*[71]*we sort of left a few options open....* [72]*as well as sending the signal of distress you had the option of just sending a signal.* [73]*So like, you would send a love heart to someone just as a reminder that you love them...*[74]*you could send your heart beat to someone and that sort of aspect as well and different ones like that.*	[68.] Narrowing down ideas was a recurring problem [69.] She thinks in the end it was still a little bit vague [70.] They didn't really have enough time to fully develop it [71.] They left a few options open [72.] Other than sending the signal of distress the wearer had the option of just sending a signal

to the one that's really necessary for the project, would you say that's a recurring problem?	73. 74.	The wearer would send a love heart to someone just as a reminder of love The wearer could send heart beat to someone, etc.

Table 71. Units of relevant meaning from Participant 3: Question 10 and 10a.

Units of relevant meaning		
Question 10.	64. 67.	Their base knowledge on the technological capabilities was so broad Trying to organize the ideas was a little bit messy
Question 10a.	68. 70.	Narrowing down ideas was a recurring problem They didn't really have enough time to fully develop it

The following tables display units of general meaning and units of relevant meaning from question 11, 11a-11e.

Table 72. Units of relevant meaning from Participant 3: Question 11, 11a-11e.

Questions	Answers	Units of general meaning
Question 11. OK. Now that the project's done, if you could fix a certain design aspect of the project what would it be?	[75]*Um, I would want it to work properly.*	75. She would want it to work properly.
Question 11a. Of course, but in a more concrete sense?	[76]*Probably the material.*	76. Probably the material
Question 11b. So the enveloping material?	[77]*Yeah, the material of what the thing is made of.*	77. The material of what the thing is made of
Question 11c. What did you use?	[78]*It was sort of a circular device worn around the neck but mainly the shoulders.* [79]*So the head of it, around the chest was made of a solid hard wood and then we carved that out* [80]*and then the neck piece was made out of heat sensitive plastic* [81]*and then we just join the two* [82]*and it was a bit messy to be honest* [83]*but because we*	78. It was a circular device worn around the neck but mainly the shoulders 79. The head of around the chest was made of carved out solid hard wood 80. The neck piece was made out of heat sensitive plastic

	haven't had much experience with hard materials and working with materiality in that way, [84]that was the best we could do at the time given. [85]It didn't look too bad in the end [86]but obviously I'd want the whole thing to be the same material or to still work a little bit better together.	81. They just join the two 82. It was a bit messy 83. They haven't had much experience with hard materials and materiality in that way 84. It was the best they could do at the time given. 85. It didn't look too bad in the end 86. She would want the whole part to be the same material
Question 11d. So this device is actually rigid, it's not flexible?	*[87]Well the plastic is slightly flexible, [88]it's a material that you can boil and mould like plasticine [89]and it sets hard: Plastimake. [90]It has become quite popular now, [90]but it gives a little bit of flexibility.*	87. The plastic is slightly flexible 88. It's a material that you can boil and mould like Plasticine 89. It sets hard: Plastimake 90. It has become quite popular now 91. It gives a little bit of flexibility
Question 11e. So does it adjust to the contour of a person's shoulder and neck?	*[91]We made it fairly basic. [92]Um, it could fit lots of people [93]because for the exhibition we had interactive video where everyone was putting it on and trying it out [94]and that worked quite well, [95]I think if you have one or two sizes in the sort of generic size, it would be ok. [96]Because we tried it on a few people and [97]it fits to like, really little girls and quite big men.*	92. They made it fairly basic. 93. It could fit lots of people 94. In the exhibition they had an interactive video where everyone was trying it on 95. It worked quite well 96. She thinks by having one or two generic size, it would be ok 97. They tried it on a few people 98. It fits to like, really little girls and quite big men.

Table 73. Units of relevant meaning from Participant 3: Question 11, 11a-11e.

Units of relevant meaning		
Question 11.	75.	She would want it to work properly
Question 11a.	76.	Probably the material
Question 11b.	77.	The material of what the thing is made of
Question 11c.	78.	It was a circular device worn around the neck but mainly the shoulders
	79.	The head of around the chest was made of carved out solid hard wood
	80.	The neck piece was made out of heat sensitive plastic

	81.	They just join the two
	82.	It was a bit messy
	83.	They haven't had much experience with hard materials and materiality in that way
	86.	She would want the whole part to be the same material
Question 11d.	87.	The plastic is slightly flexible
Question 11e.	92.	They made it fairly basic
	93.	It could fit lots of people
	96.	She thinks by having one or two generic size, it would be ok.
	98.	It fits to like, really little girls and quite big men.

Table 74 and 75 present units of general meaning along with units of relevant meaning from question 12, 12a and 12b.

Table 74. Units of general meaning from Participant 3: Question 12, 12a and 12b.

Questions	Answers	Units of general meaning
Question 12. How do you describe the design process in designing for the project?	[99]*It was quite long, I'd say.* [100]*When over the entirety of the time we had.... um we kept going over certain things as I've said before,* [101]*what it did...it was narrowing it down again and again.*	99. The design process was quite long 100. Overtime, they kept on going over certain things 101. The process was about narrowing it down repeatedly
Question 12a. So there's a lot of elimination process or elimination stages on the process itself?	[102]*Yeah, and then refining what we've got and then going back and doing it again* [103]*because certain people weren't happy.*	102. It was about refining things and then going over them repeatedly 103. Because certain people weren't happy
Question 12b. So with the initial design brief that you said, it was quite broad and you were given basically the option of looking at all of these possibilities of using the technology and now trying to narrow it down, that would be	[104]*Yeah, so initially we went with looking at certain areas of the body that we wanted the technology to go on as a way,* [105]*did not really work that well.* [106]*Um, and then we focused on areas that we previously looked into,* [107]*so areas of comfort or fear...things like that…*	104. Initially they went with looking at certain areas of the body they wanted the technology to go on 105. It did not really work that well 106. They focused on areas they previously looked into 107. They looked into areas of comfort or fear

practically, the main substantial part of the design process?		

Table 75. Units of relevant meaning from Participant 3: Question 12, 12a and 12b.

Units of relevant meaning	
Question 12.	99. The design process was quite long 100. Overtime, they kept on going over certain things 101. The process was about narrowing it down repeatedly
Question 12a.	102. It was about refining things and then going over them repeatedly
Question 12b.	104. Initially they went with looking at certain areas of the body they wanted the technology to go on 105. It did not really work that well 106. They focused on areas they previously looked into

Units of general meaning and units of relevant meanings from question 13 and 13a are shown in table 76 and table 77.

Table 76. Units of relevant meaning from Participant 3: Question 13 and 13a.

Questions	Answers	Units of general meaning
Question 13. Just thinking out loud, would there be a set of general guidelines in designing Wearable Technology, in what form would you say it should be?	*[107]Um, obviously practical.... [108]cause anything wearable has to be, sort of be a little bit durable. [109]Probably, waterproof as well. [110]A lot of things aren't sort of given that.*	107. Obviously a practical guideline 108. Because anything wearable has to be a little bit durable 109. Probably waterproof as well 110. A lot of wearable things aren't waterproof
Question 13a. So basically waterproofing, do you think it will	*[111]A little bit, [112]also you won't worry so much about what you're doing cause that's the difference between Wearable Technology and hand held technology.*	111. Waterproofing increase wearability 112. A user won't worry so much about what they're

increase the wearability of it?	[113]*You can always put your phone away,* [114]*whereas a wearable one stay on you and* [114]*you're able to forget about it and just think about when you have to.* [116]*So, I think I actually made mine waterproof just because the technology is for wearable things that already goes towards that.*	doing because that's the difference between Wearable Technology and hand held technology 113. A user can always put the phone away 114. Whereas a wearable device stay on 115. A user is able to forget about it and just think about the device when you have to 116. She actually made hers waterproof 117. Because the technology is to be worn

Table 77. Units of relevant meaning from Participant 3: Question 13 and 13a.

Units of relevant meaning	
Question 13.	107. Obviously a practical guideline 108. Because anything wearable has to be a little bit durable 109. Probably waterproof as well 110. A lot of wearable things aren't waterproof
Question 13a.	111. Waterproofing increase wearability 112. A user won't worry so much about what they're doing because that's the difference between Wearable Technology and hand held technology 113. A user can always put the phone away 114. Whereas a wearable device stay on 115. A user is able to forget about it and just think about the device when you have to 116. She actually made hers waterproof 117. Because the technology is to be worn

The interview with Participant 3 produced 117 units of general meaning along with 70 units of relevant meaning. The units of relevant meaning were then clustered to produce several themes of non-redundant units of meaning connected to the research questions. The themes acquired include: technological issues, background research, design process, lack of previous training, the enveloping

material, waterproofing and durability, size, power source, design characteristics of Wearable Technology and designing as a group (collaboration) (see table 78).

Table 78. Clusters of non-redundant units of relevant meaning from the interview with participant 3.

Clusters of relevant meanings
Technological Issues - Probably the technical elements. - How to make the machinery works - It's through a series of sensors - There's a sensor that will touch the skin
Background research - The internet was quite helpful - Yes, she did research via Internet - They started with tutor's assistance and did further research - Yes, research is a strong part of the initial approach to design challenges - They found online tutorials of similar projects
Design process - Initially it would be coming up with an original design idea - Trying to organize the ideas was a little bit messy - Narrowing down ideas was a recurring problem - Previously present ideas on the market was used as an approach - The design process was quite long - Overtime, they kept on going over certain things - The process was about narrowing it down repeatedly - It was about refining things and then going over them repeatedly
Lack of previous training - They haven't had any training about the technical element - Industrial students didn't know how to approach it
Enveloping material - They needed the technical elements housed in a solid housing - The material of what the thing is made of - Probably the material - They haven't had much experience with hard materials and materiality in that way - She would want the whole part to be the same material
Waterproofing and durability - Because anything wearable has to be a little bit durable - Waterproofing increase wearability - She actually made hers waterproof - Probably waterproof as well - A lot of wearable things aren't waterproof

Size - The size would be one of the main issues - Slim and discrete power sources and power boards to be embedded to clothing is attainable - Making it compact was difficult - It would be the size of the elements - They needed to stack up the elements as opposed to spreading them flat - It could fit lots of people - She thinks by having one or two generic size, it would be ok. - It fits to like, really little girls and quite big men.
Power source - Slim and discrete power sources and power boards to be embedded to clothing is attainable
Design characteristics of Wearable Technology - A user won't worry so much about what they're doing because that's the difference between Wearable Technology and hand held technology - Whereas a wearable device stay on - A user is able to forget about it and just think about the device when you have to - Because the technology is to be worn
Designing as a group - There were four members in the group - It is having different design ideas within a group - Designing in a group is always a little bit difficult

In table 77, there are 45 non-redundant units of relevant meanings, clustered into the 10 themes that were outlined mentioned previously. The central theme that emerged from the interview with participant 3: Wearable Technology characteristics and its design process, along with its design issues and problems.

6. 3. 2. Interview 3: relevant meanings in relation to the main research questions:

In the following reflection of the themes in relation to the research questions extrapolates the main knowledge generated by the interview with participant 3.

1. How does the designer's understanding of design attributes affect the design process of Wearable Technology?

From the interview with participant 3, comes the understanding that design attributes that appeared during the design process of Wearable Technology were more likely to be contextual to the specific design purposes. The design attributes appeared in a

varied and organic way due to a designer's individualistic approach to background research related to specific design project requirements. Several design attributes emerged as important during the design process *after* testing the Wearable Technology with users, such as its size and dimensions, durability and material. This indicates importance of prototyping in the design process, as it positions the designer as an observer, enabling evaluation and self-criticism of the design, which, in turn, improves the designer's understanding of the problem and requisite design attributes.

2. How do different design purposes that have different types of functionality and usability requirements affect the design process in Wearable Technology?

Drawing from the interview with participant 3, it became apparent that specific types of functionality and usability propelled the design process of Wearable Technology, by forcing designers to emphasize certain design attributes. This also motivates designers' prioritization of important design attributes in relation to the design project's functionality and usability requirements. Thus, the act of eliminating the less relevant design attributes in the project was interlocked with the designer's familiarity with usability and functionality requirements.

The project designed by participant 3's group aimed to utilize the 'fear' aspect of walking in the city as part of defining their design purpose, thus shaping entirely unique functionality and usability requirements, somewhat adapted by their own agenda. This was also evident throughout the interview, where participant 3's emphasis on design attributes included material, size and waterproofing or durability. The third participant's design project was less intimate and less sociable compared with the previous participants' projects, that required visible and audible feedback from the device in order to achieve the intended functionality and usability requirements.

3. How can an understanding of the interdisciplinary iterative design process of Wearable Technology provide a new conceptual understanding of the field?

The findings from interviewing participant 3 help us understand that there are difficulties to be anticipated when attempting to tackle an interdisciplinary design project in a collaborative environment. As mentioned previously, Wearable Technology requires concurrent design considerations from multiple different disciplines, which necessitates designers working collaboratively to input their expertise and knowledge.

The discovery of emergent design attributes revealed during the process (not anticipated from the outset) was reported in each study. In the next chapter, the themes extracted from the three case studies are discussed in relation to the proposed framework of design attributes of Wearable Technology proposed by the research as a vehicle for conceptualizing Wearable Technology design.

CHAPTER 7
DISCUSSION ARISING FROM RESEARCH FINDINGS

This section presents an overview that draws together the research in its entirety (including its approach and findings) to provide a summative conclusion. These findings are intended to be perceived as emerging ideas, rather than concrete theories and shall open pathways for possible future research endeavours.

In the first part of the thesis, a fresh attempt to define the meaning and understanding of Wearable Technology was undertaken by reviewing the existing bodies of work across different fields along with their concomitant literature in order to present a fuller, interdisciplinary understanding of the research subject. Wearable technologies have defied conventional boundaries and have been partially addressed from different angles, lacking an integrative interdisciplinary view. Intrinsic to this interdisciplinary character, Wearable Technology perforates multiple fields, adopting different emphases in each and different features from these influences, as well as the research approaches inherent in different fields (for example in fine arts, computing, pop culture, engineering, design, fashion, and cybernetics discourse). The interdisciplinary or genre-transcendent character of Wearable Technology thus encapsulates aspects of identity creation, functionality and pragmatism, as well as individualisation, expression and interface.

In the beginning, this presented a challenge as no singular definitive explanation, which traverses all these fields, was to be found. However, therein, was a motivating impetus for the research. It quickly became apparent that each field has its own contextual ideas (or theoretical frameworks) for projecting its practice, while maintaining some shared characteristics, which can be conflated as **technology as part of body, worn object or artefact**. However, this description can be problematic if the term 'technology' is taken in a literal way.

In fashion, technology can be loosely identified with any mechanism involved with the production of the artefact, thus only manifested as witness to the technology and it does not contribute to enhancing a user's ability, other than advanced garment technology

that is reactive to a user's situational condition (e.g. Sportswear). Moreover, technology as an ornamental element is commonly found through examples of Wearable Technology in fashion, functioning as embellishment. In fine arts, technology can also be translated as any mechanism included as part of an object's ability in heightening its function as an artistic platform in a performative manner. The mechanism in fine arts is not always electronic and includes any system whether digital or analogue. Whereas people often assume technology implies digital technology and recent technology, that is not the correct ontology, which in vernacular parlance usually pertains to the application of scientific knowledge for practical purposes, i.e. it has chiefly to do with purposeful knowledge application and assistance or enhancement rather than to do with the mechanism itself. In contrast, referring to the two fields mentioned above, Wearable Technology is defined through its ability as an expressive medium, while in computing its emphasis is very much forced upon extending human capabilities by allowing further mobility through advanced wearable technological hardware solutions. This emphasis in wearable computing results in a character that is negligent to the term 'wearable' itself, thus lacking the appeal found in fashion where 'wearing' carries the emphasis.

Through the exploration of pop culture and cybernetics discourse, a deeper theoretical foundation can be gleaned as the confluence between human and technology provide a cultural background for understanding the physical manifestation of Wearable Technology. It is apparent that, through its widespread appeal, pop culture has pushed Wearable Technology forward in the public eye by displaying its technological function as an extension of human ability and its prosthetic quality. Other than in pop culture, the notion of cyborg beings is also found in cybernetics discourse, often utilised in analogies for describing cultural discussions and ideas.

Wearable Technology is embodied by multiple fields with a variety of emphasis in each field, thus requiring the definition of margins that allow a streamlined and focused research inquiry. This research constrains its focus to include only Wearable Technology that embodies electronic components and has the ability of extending user's ability through

its function. The research further focused on explicating design attributes, with the potential to assist, affect and influence the design process of Wearable Technology. A series of design attributes were developed through a process of selective condensing and converging existing theories, characteristics and design guidelines of Wearable Technology in fashion and computing.

These design attributes were subsequently applied within the interview structure, with participants who were experienced in designing Wearable Technology. The resulting interviews produced several research findings that provide insights about the Wearable Technology design process and the strategies employed by designers.

Table 79. Clusters of relevant meanings from interview 1, 2 and 3.

Clusters of relevant meanings		
Interview 1	**Interview 2**	**Interview 3**
• Aesthetics	• Aesthetics	• Technological issues
• Lack of knowledge in electronic components	• Technological emphasis	• Background research
• Usability	• Usability	• Design process
• Device positioning	• People's reaction	• Lack of previous training
• Background research	• Design process and difficulties	• Enveloping material
• Design process	• Time constraints	• Waterproofing and durability
• Time constraints	• Power source	• Size
	• Weight	• Power source
• People's reactions		• Design characteristics of Wearable Technology
	• Visual aspects	• Designing as a group

In the previous chapter, there were 19 clusters of relevant meanings that emerged from interviews with 3 participants. The analysis of these 3 interviews pointed towards central themes that can help understand the designer's experience of designing

Wearable Technology. In this chapter, these clusters are grouped according to their overlaps and examined to elaborate research findings. The themes draw from and reflect the practice of user-oriented design scenarios and are used to interrogate the main research concerns in this thesis.

Seen in table 79, clusters of relevant meaning are listed according to each interview, which highlights their similarities. Other than displaying their overlaps, these similarities are used as a foundation for grouping the themes for discussions. These groupings consist of:

- Aesthetics, visual aspects and people's reaction.
- Design process, background research and time constraints
- Technological issues and/or emphasis, lack of background or previous training and designing as a group
- Design characteristics of Wearable Technology and emerging design attributes of Wearable Technology: Usability, device position, power source, weight, enveloping material, waterproofing/durability and size.

7. 1. Aesthetics, visual aspects and people's reaction

Interviews with three different participants described ways in which aesthetics became a substantial design consideration during the design process. The first participant's main role in her group was to design the aesthetic, 'look' and feel for the Wearable Technology device, which was clearly emphasised her interest during the interview. The second participant described her experience during the design process as frustrating because she and her group were encouraged not to emphasize aesthetic quality of the project, rather to favour functionality, which ran contrary to their usual design paradigm. The third participant, touched upon her view of aesthetics in Wearable Technology by mentioning the choice of power source and material that were influential determining the device's size, and thus affected the aesthetic of the resulting Wearable Technology device.

The issue of aesthetics is discussed in detail earlier in the thesis (Section 2.6) leading to an understanding that it is based upon personal taste and has no empirical grounding,

i.e. it is highly subjective. It is necessary for this research to include aesthetics in its discussion, as throughout the literature review and interviews, the word aesthetics repeatedly surfaced both amongst earlier research and amongst the interviewed designers. Researchers sometimes shy away from highly subjective and un-measurable qualities such as aesthetic values, however their importance so dominates the discussion and the literature, that in fashion particularly, and in wearable art, it is often the driving motivation, and possibly this emphasis is what distinguishes Wearable Technology design from the wearable computing paradigm, which centres on functionality, interaction and interface. Is it then possible to propose a series of design attributes as a strategy for designers approaching Wearable Technology design? This research has reinforced the solidity of the relationship between design attributes and aesthetic design.

A finding emerged throughout the research is that aesthetics in Wearable Technology relate to the physical appearance of Wearable Technology which is strongly contingent on a designer's subjective judgement ('taste'). It is a challenge that requires designers to be honest and truly remains faithful to the specific purpose of the design's functionality. The physical appearance design is also often found to be 'unusual' from a user's perspective in the context of their quotidian surroundings, thus suggesting that, in order to achieve acceptable physical appearance design, Wearable Technology needs to seamlessly integrate physical design, determined less by personal (subjective tastes) judgment of the user, i.e. perhaps advocating that a model of universality and utility over expressiveness and individuality may prove easier to assimilate.

The physical appearance of Wearable Technology is characterised by the altered shapes of the human body that appear as a by-product of wearing the technology. Thus, it is heavily influenced by the selection of enveloping material, type of electronic elements in the system, and the positioning of device. The body-worn nature of Wearable Technology gives rise to a unique situation in which multiple designers of different fields need to work collaboratively in order to achieve a fully cognisant design. This was evident in the fact that

not all designers were familiar with electronic components required for making Wearable Technology and not all designers were familiar with designing for the human body.

The frustration over not being able to approach the design process aesthetically, the emphasis on designing aesthetics and the visibility of the power source and size as influences on aesthetics can all be related to the participants' background training as fashion design students. As part of this visual practice, the design process in fashion often commences with sketching, as mentioned by the first participant during the interview. This act of sketching is an important method known to translate abstract ideas into concrete form, which has existed since long before the Renaissance era (Cross 1998). The method of sketching ideas assists designers in the process of self-criticism of the design, thus facilitating the eliminative process of redundant ideas.

Several researchers, e.g. Rhodes and Mase (2005), have expressed the aesthetics concerns of Wearable Technology and through their discussion of the often-found 'borg' aesthetics of existing Wearable Technology works. Moreover, many Wearable Technology devices emphasize technological capabilities, while marginalizing the aesthetics of the device as secondary in importance. This raises the question: What sort of aesthetics is suitable for the design of Wearable Technology?

Interestingly, one of the clusters of relevant meaning that emerged from one of the interviews, points to a similar connection. The user, or in this case, the wearer, will experience reactions from the public or his/her surroundings if the design purpose of the device requires attention from non-users. One of the design purposes of the first and second participant's project is to transform pedestrians by giving them car-like qualities, such as the horn sound (audio) and turning lights (visual). Thus, attention from a user's surrounding environment is unavoidable and necessary, even desirable and contingent. However, the third participant's Wearable Technology design purpose is based upon more emotional qualities expressed between users, and does not necessarily require feedback or attention from a user's surroundings. Therefore, design purpose dictates aesthetic

requirements of Wearable Technology as it determines the necessary reactions or responses from a user's surroundings.

The importance of the visual design of Wearable Technology is closely interrelated with the aesthetics, as it is part of the design process involving mainly the designers. The process of aesthetic judgements occurs only when the design prototype is tested by a user in real environments. Therefore, the visual appearance, or 'look', of Wearable Technology is a platform that the designers steward. The process itself will include sketching as it provides an approach for translating abstractive ideas into visual or 'concrete' forms (commonly found throughout all design-related fields).

Drawing on the interviews, the substantial influence of a fashion design approach in designing Wearable Technology is borne out through their concern with the visual, as these designers are accustomed to designing for the human body. They understand that unless the design purpose requires attention grabbing, the design should not be visually intrusive, out of the ordinary or avant-garde. It is also important to clarify that visual design can be translated broadly as the 'overall look' of the Wearable Technology device along with its visual feedbacks, which is a consequence of its design purpose.

7. 2. Design process, background research and time constraints

The importance of background research in the design process of Wearable Technology is also essential in ensuring design problems are clearly defined. This part of design process also contributes to the way in which designers determine purposeful design functionality that, in turn, influences other design attributes. A series of mind-mapping activities was also mentioned as part of the design process of Wearable Technology, thus making it clear that designers redefine and reshape their own design problems.

The design process experienced by three different participants all referred to the iterative nature of design process. The stages including sketching, mind-mapping, brainstorming and revisiting several design issues were as mentioned part of the design process. A mentioned previously, the method of sketching was utilized to help transforming

ideas into visual forms, while mind-mapping was seen as a means of ensuring holistic design problems, design considerations and streamlining ideas.

The narrowing down of ideas was experienced as part of the design process, as the designers attempted to find feasible solutions to the design problems. These problems are interrelated, which required them to mind-map in order to eliminate non-relevant and unfeasible design solutions. The time frame of the projects constrained and propelled the participants in managing their solution-focused design strategy, which reflects the nature of the general design process itself (Cross 2006).

The introduction of design attributes for Wearable Technology earlier in the thesis, is proposed precisely to assist designers when mind-mapping design problems for a Wearable Technology project. Reviewed with the insights of interview analysis and the clustered relevant meanings that emerged from them, foregrounded the situation that when a designer begins a design process with no prior training or experience in designing similar projects, timeframe has the tendency to become a constraint that can compromise effective design solutions.

7. 3. Technological issues or lack of previous training and designing as a group

The technological issues encountered by the participants during the design process were seen as problematic as they had little to no previous experience in designs that merge fashion and technology. The interviewee's background training in fashion design may have exposed them to textile technology, which is different to Wearable Technology as it is perceived in this research. The infusion of electronic elements as part of a garment's functionality becomes the emphasis in Wearable Technology, which adds a new layer to the design process.

In fashion, the design problems may include the choice of materials, climate, gender and social conventions. The role of fashion design in understanding the human body as a design space is pushed further when the worn garments does not only function as a covering for the body, but it also has technological functions. When technological function

is added in becoming Wearable Technology, the designers need to comprehensively understand not only the hardware specifications but also the software, which determines its functionality and usability. Interestingly, even though the three participants' groups consisted of students from various areas of studies (fashion design, industrial design and visual communication students), difficulties infusing technology in their designs were encountered nonetheless. These problems were mainly caused by their minimal exposure to available technology, an unfamiliarity with electronic capable of delivering the design purpose defined in the initial design brief.

This supports experts from other fields working together with fashion designers to achieve successful designs. This indicates that, in order to achieve successful Wearable Technology that adequately considers the visual, the user and the technology work collaboratively, integrating technological experts and designers.

7. 4. Design characteristics of Wearable Technology and emerging design attributes of Wearable Technology

Observed in all three interviews, it was apparent that the fashion design background affected the way in which participants perceive Wearable Technology. The participants understood that technological function was not an addition to the design but was an integral part of it. This consciousness led them to take into account the technological capabilities along with technical specifications in their design considerations during the process. This was evident in the design attributes that only emerged during the process. In the interviews these included: Usability, device position, power source, weight, enveloping material, waterproofing/durability and size.

The similarities found between the two are highlighted inside the box on the table above, showing not only that the participants were conscious of these design attributes, but also that they included them in their conceptualization of the design problem. The attributes that were not found in the interviews were still mentioned but in a non-distinct manner. For example, the design project for participants 1 and 2 was a garment capable of

assisting user navigation in high-density pedestrian space. The design was executed by embedding features found in a car into a blazer-type garment, thus enabling the act of signalling other pedestrians. The design purpose does not necessarily require wireless connectivity. Heat and washability does not yet seem to be of high enough relevance to be ranked in the design problems, since the project was finished in a prototypical stage. However, utilizing detachable electronic parts could rather easily solve the washability design attribute, while heat and sensation would require further testing of the prototype.

Table 80. Comparison between design attributes of Wearable Technology proposed in this research and design attributes of Wearable Technology raised by the participants during interviews.

DESIGN ATTRIBUTES OF WEARABLE TECHNOLOGY	
PROPOSED	**INTERVIEW RESULTS**
Functionality	
Usability	Usability
Device positioning	Device positioning
Power source	Power source
Weight	Weight
Enveloping material	Enveloping material
Durability	Durability
Size	Size
Heat	
Washability	
Sensation	
Connectivity	

The design project of participant 3 sets a different design agenda, including the exchanging of private data (e.g. the use of a heart rate sensor) between users, thus shifting emphasis to different design attributes. Participant 3's Wearable Technology device required wireless connectivity in order to function and also took into account the sort of feedback sensations the user would receive from the device.

The dominance of usability as one of the design attributes of Wearable Technology was evident in interview results, emerging as the central focus for designers in that it is interlinked with all other design attributes, or could be thought of as an 'umbrella' attribute that influences all others, upon which all other attributes are contingent. Thus, functionality operates above all other design attributes as the governing idea modifying other design attributes, and it must constantly confer with the specific design purpose. Aligned with the designers' loyalty to the specific design purpose, and its contingent functionality, it is inevitable that Wearable Technology design requires absolute context awareness on the part of the designer.

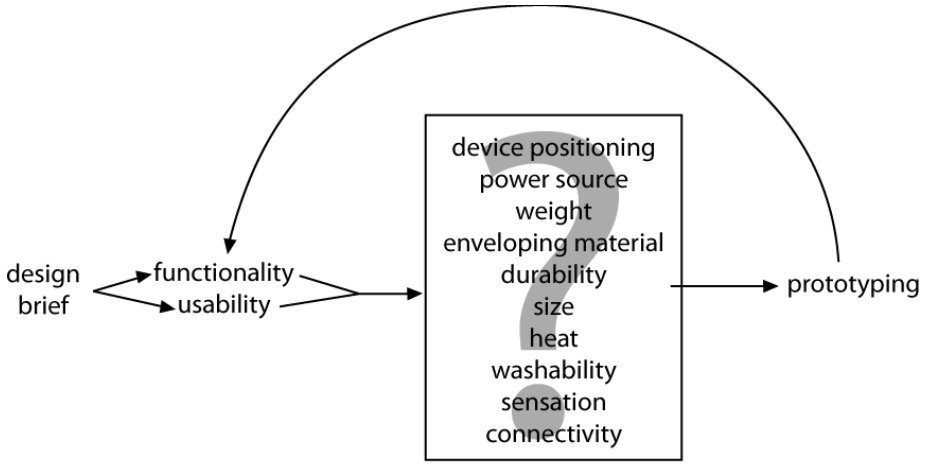

Figure 18. Iterative use of design attributes in Wearable Technology design.

Understanding how and when these design attributes can be helpfully applied is clarified by understanding the design process of Wearable Technology, as it reveals the natural if somewhat unstructured discovery of these attributes by designers incrementally as the design process unfolds. Functionality and usability as design attributes have been shown to be the dominating considerations for designers in determining which other design attributes are necessary to prioritize. In retrospect, the attributes have also become a set of

evaluation tools that may be utilized by designers to refine and organize other design attributes during the process.

As seen in the sequential flowchart diagram (Figure 18), commencing with receiving the design brief, designers subsequently define what kinds of functionality the design needs, along with which usability attributes are necessary. Then, extrapolating from functionality and usability, the designer can determine which other design attributes are relevant to the design. At this stage, designers are assisted by the process of mind-mapping potential design problems, and eliminating redundant or non-expedient solutions, often according to pragmatic constraints. The designer progress to prototyping the design while constantly referring to the previous functionality and usability requirements as evaluative tools to further redefine previously determined design attributes.

The findings of this research have been beneficial in contributing to our understanding of the design process of Wearable Technology:

- Design purpose defines the context of Wearable Technology;
- Design purpose dictates the functionality and usability of Wearable Technology;
- Functionality and usability are the base foundation for designers in prioritizing relevant design attributes of Wearable Technology;
- Designing Wearable Technology is essentially designing technology to be worn on the human body; meaning that a fashion design approach alone is not sufficient, as it requires designing the technology;
- Within a design process, timeframe can become a constraint, thus limiting design ideas and potentially compromising design solutions;
- Aesthetics in Wearable Technology are contextual and can only be observed and tested through the process of prototyping;
- Designing the visual appearance of Wearable Technology requires the designer's awareness of the context and purpose of the design.

In conducting the research towards this thesis, the researcher acknowledges a problem that emerged was the difficulty in finding suitable participants for the case studies, i.e. designers who have experienced designing Wearable Technology (according to the definition in this research). This limited the recruitment by excluding participants with more varied background training, who would have been beneficial to our understanding of the implications of background education on the design process of Wearable Technology.

The ramifications of aesthetic subjectivity in perceiving Wearable Technology also opened the way for a future research agenda inquiring how it affects the design process that extends way beyond the scope of this thesis. The elasticity of what aesthetics can be and can mean across different disciplines is acknowledged but intentionally not tackled here. Quite apart from the discipline of aesthetics in philosophy, it is clear that aesthetics are shaped by individual, cultural and learned experience and simultaneously are constantly cited as highly important by the designers themselves in this study.

The scope of this research is intentionally constrained within a design perspective to ensure a focused approach. It is a response to the dearth of genuinely interdisciplinary design strategy for this relatively young field of designing wearable technologies that has the difficult task of assimilating cultural, technical and solution-focused thinking encompassing a wide arc of knowledge. However, the process of undertaking this research and the wide scope of design practice evident in the interdisciplinary outward-looking literature survey also symbolically mirror the nature of Wearable Technology itself, which is multidisciplinary and collaborative.

CHAPTER 8

CONCLUSION

This chapter presents the research conclusion, which is divided into several sections. The first section discusses significant contributions of this research followed by a section discussing future research possibilities and acknowledges challenges encountered during the research.

8. 1. Significant Contributions of this Research

Major outcomes from this research will benefit emerging and growing field of Wearable Technology, including understanding:

8. 1. 1. Wearable Technology as a Multi Disciplinary Field

The exploration of related literature provided an overall understanding of the intersection Wearable Technology across several different fields: computing, art, fashion, cybernetics discourse and pop culture. Its multi disciplinary existence often overlaps and one field affects another, which presents a complex situation. Designing Wearable Technology automatically invites absolute understanding that the object to be designed is to be worn on the body, and thus requires a multi-disciplined approach in design. Moreover, its multi-disciplined nature is evident in the design activity, which involves collaborative design (involving designers and/or experts from different fields). This was borne out in the results of semi-structured interviews conducted for this research, which showed that a designer's lack of knowledge in certain areas necessitated interaction with other designers (in the form of assistance and/or designing together as a team).

8. 1. 2. Wearable Technology Design Attributes

A set of Wearable Technology design attributes were introduced and discussed in Chapter 3 consisting of size/dimensions, washability, durability, enveloping/fabrication,

social connectivity, sensation, usability, functionality, device position, power source, heat and weight. These design attributes overlap each other and are proposed as a form of assistance or strategy for designers in conceptualizing their design. These design features were developed in response to the reviewed literature on Wearable Technology design. Through the interview analysis, it was found that these design attributes can be beneficial to increasing the efficiency of a designer's mind-mapping stage in the design process.

Several observations arising from the design attributes include:

- Functionality and usability often affects designers prioritizing of the relevance of other design attributes
- The dominance of each design attribute is also contextual to its design purpose.
- These design attributes are a set of conceptualization strategies for designers formulating possible design problems.

These characteristics further demonstrate that Wearable Technology design attributes are highly flexible in use in the design process and facilitate designers tackling multiple design considerations simultaneously.

8. 1. 3. Wearable Technology Design Process

Understanding the Wearable Technology design process is developed through the semi-structured interviews with designers, with experience designing wearable technology. Through this research it is understood that the Wearable Technology design process is iterative and collaborative, due to the multi-disciplinary nature of Wearable Technology. Functionality and usability were seen as motivations driving the progression of the design process as they were dictated by its specific design purpose. Thus, these two design attributes emerge as evaluative criteria during the process.

Project time constraints have the potential to force designers to compromise their design decisions. The proposed Wearable Technology design attributes proved assistive as a set of conceptualization strategy and for working with experts of different (but related) fields. Thus, the outcomes of this research contribute to a more efficient design process.

In terms of understanding the design of Wearable Technology itself, it has become clear that it is absolutely essential for the designers to be critically aware of human body as the surface on which the technology is worn. Therefore, the designer's understanding of the human body, its contours, limitations, ability and overall characteristics are crucial to achieving a successful design. The design attributes included in this research provide a first step for designers in thinking more comprehensively about the body and design function in the mind mapping process.

8. 2. Future Research Possibilities

The understandings presented in the previous chapter included several key points that further emphasize the multi-disciplinary design process of wearable technology. This clearly corroborates the initial research hypothesis defining the subject scope of the research over-arching multidisciplinary fields.

As mentioned in Chapter 2, the definition of Wearable Technology in this research is a wearable device, which has the ability to sense a user situated in their context for its functional and expressive qualities, potentiating many challenges. This research has explored the designer's perspective designing Wearable Technology in order to better understand its multidisciplinary complexity. However, there are many questions that would be interesting to explore in future research, such as:

- How does designing Wearable Technology as a team (collaborative) affect the final design product?
- To what extent can Wearable Technology design attributes increase efficiency in a design process?
- How perceptible are the Aesthetics of Wearable Technology from the perspective of the user/wearer?

These questions can be answered through further research in the field of design thinking in Wearable Technology, by applying the design attributes in a collaborative design process involving more than just the Wearable Technology designer. An ideal proposition

may include a Wearable Technology designer, a technology expert (hardware or/and software) and a fashion designer. Other possible future research may include further evaluation upon Wearable Technology prototypes by involving new users that have never been exposed to the technology.

Furthermore, potential applications of Wearable Technology in a broad range of fields suggest a promising area of future development. Fields such as health and science will benefit and experienced advantages from Wearable Technology. It transforms the way we live our lives today (for example a simple kinetic watch). The growth of digital technology and its miniaturization opens new pathways for Wearable Technology to be assimilated more ubiquitously in the future.

Holistically, this research has contributes to future research enquiry as it reframes and repositions the Wearable Technology as a design field. This research has magnified our understanding of designing Wearable Technology and its design process as well as possible design attributes from the designer's perspective. Here, a new approach to designing Wearable Technology has been proposed and discussed in an attempt to recognize those design attributes that are of highest priority and ways in which they interactively overlap.

More specifically, the accomplishments of this thesis are:

- An analysis of Wearable Technology and its infusion in the fields of fashion, computing, art, pop culture and cybernetics discourse.
- The newly - defined design space of Wearable Technology with its characteristic axes elaborated, thus inviting new enquiry of research.
- The enumeration of design attributes supported by semi-structured interviews.
- The development and investigation of the design attributes that are most likely to be prominent challenge(s) within the design process.

It is apparent that these questions still afford further investigations. However, these research findings should be construed as a significant endeavour towards designing better

Wearable Technology. Initially, the multidisciplinary existence of Wearable Technology provided evidence of how it has managed to evolve and progress, however the field itself is not well researched in terms of design thinking, including design processes and design attributes. Therefore, my wish is for this research is to be thought of as a catalyst, which contributes to continuing progress in the field of design thinking research of Wearable Technology.

APPENDICES

APPENDIX A: RESEARCH PARTICIPANTS INTERVIEW TRANSCRIPTS

The following are transcribed interview transcripts from the research participants (interviewee answers are in italics).

PARTICIPANT 1 (interview date: 27/11/2102)

No.	Questions
1.	Please describe your wearable technology project. *OK…so the project that we did, which is a bit of a while ago now, we had to design something that would assist with walking in the city…the final design that me and my group came up with was a jacket that had indicators on it and also had lights showing messages and we wanted to document kind of how this would affect walking through a congestion in the city, essentially using the blinkers, people would know and move out of your way or look at the sign, we had like, a red light saying stopping at the back or if you press the button that says stopping people would know through that and they would be able to navigate easier around you.* So you practically become a walking traffic light? *Yes, and we also…. a lot of our ideas behind it was thinking about like how on the road there were so many rules and how pedestrians, it's kind of like free for all, do what you want, and there are no actual set rules and we were looking at how George street used to have pedestrian lanes, they have, like where to walk…down the right or left and how that's kind of disappeared and it's all just a jumble now and there's no, like etiquette* So basically it's almost like trying to bring the etiquette forward through the design? *Yes.*
2.	How many people were involved in the project?
	Um…. in our group there were three of us that specifically worked on the project
3.	Did they come from different fields of practices?
	There were 2 fashion students and 1 industrial design students

4.	According to your background of practice, what are the challenges of the project?
	I guess, since we were kind of taught to design for the body and like aesthetics and stuff as well…I think were the challenges, especially…. like, cause we don't really know much about how to…in the terms of how to actually making it, we don't really know much about how to put together, like the electrical side of it and the lights and how that would work in a garment and putting the technology into it. So it's more of the idea of embedding the technology that was quite a challenge because you say coming from a fashion background when everything pretty much don't have the electronic element in a way? *Yes, but I guess they're trying to encourage that a little bit more now, but we never really cover that in our lessons. So, we didn't really know what kind of products or things that we could use to put into it so it was kind of hard to design with…. we kind of knew what we wanted but we don't know what was available to use.* So, given the fact that you haven't been trained that way, do you reckon if you had known more, it would be much easier? *Yes. If we had known more of the electrical side of it, it would've really helped us and it would help us create a better design probably in the end…because we kind of had to make it a little bit simpler for us to actually produce the design but for the actual project we needed to have a prototype but it didn't have to be the working product.*
5.	Please describe how you approached the design brief.
	We did have some assistance from different tutors who ware more experienced and we had a few lessons showing us different things that we could use but because everyone in the class were doing such different things, it was kind of, like, we didn't have much time and everyone kind of wanted a one on one time but, is that what you were asking for or? Yes, but I 'm really interested in looking into how you approach the design brief… *First of all of course we did the research and we came up with the*

	idea from looking at videos and finding what the main problems were and….so we went about it that way first and I myself did a lot of designing like fashion model which is the way I've been taught of and a lot of my ideas came out that way when I would sketch down how I want it to look first and then work out how it would work afterward. So would you say, in terms of your background training, which is fashion design, how it looks is what concerns you the most when you were approaching the design brief? *Yes…we had like the background idea of how we want it to do (its task) but being taught that way, aesthetics is quite important when designing it and that was…. in my group we had different jobs and my job was to design the aesthetic of it and then the industrial girl did a lot more work with like putting it together and yeah, a lot of it was sketching and that's the way I work.*
6.	How do you describe your personal initial design-related challenges on the project?
	We had to think of who would actually wear the design and who struggled the most with that…. who are the kind of people that need to be somewhere and we had like shopper and business people and uni students that wanted to walk fast, so we wanted something that kind of versatile, and because we didn't have much time, we needed to have a prototype that we could just create and we probably would've liked to have created something little bit more 'designed' but we ended up using a kind of, not like a blazer but a kind of, a premade jacket and we put the electrical lights into it. So, basically, when you were thinking of it the design attributes, one of them being the user him self and how they will wear it? *Yes.*
7.	What design attributes lead to design considerations for the project?
	We had to change our design a little bit because of the constraints of these things, one of the main factors was how people would react to it and how we would be able to document it and also at the end, it has a lot to do with how the user would be able to activate the signals and the usage of lights.

	Ah, the trigger? *Yes, so we had to …use…. a lot of the design was based around that like, how we would get the switches and how they would be able to do that without knowing to much about technology and how we would be able to…get those lit down to somewhere that the person could activate it, so that kind of changed our design a little bit.*
8.	What are the difficulties of approaching the design brief of the project?
	As I've said before, it was kind of….mainly figuring out how all the electrical parts are going to work…and also knowing what I could use in the design, cause I kind of….we kind of had an idea of what we wanted but we didn't know if it was possible for us to pull it off.
9.	Within the design process, what recurring design problems appeared?
	Maybe when we went out to like demonstrate it, we didn't expect people's reaction to be what they were so that was kind of, came up and …. So, is it recurring? *Yes, it did happen when we were testing but yeah, we didn't have enough time to like… we changed a little bit of how we walk and the places we went to but it wasn't kind of like a…. recurring problem but an interesting find.* How would you describe people's reactions to that, in general? *A lot of them general surprised and they thought it was funny and I guess this was to be expected because it's something that hasn't been seen before and it would probably be different with a lot of people using it and it becomes more mainstream or like, acceptable but I guess with this kind of thing you can't really expect this to happen.*
10.	If you could fix (a) certain design aspect(s) of the project, what or which aspect would it (they) be?
	I think we've talked about this, saying we would like to create more of them and kind of set them out in different places and we also would've like to design a few different…. in the end we'd like to have

	a few more different signals on the jacket but we would like to have a few more different saying, cause we only had 'stopping' at the end, we would've like to have like a few different directional sayings on the jacket and maybe something on the front and maybe tried different things and see how that would've worked.
11.	How do you describe the design process in designing for the project?
	It was quite an enjoyable process but we end up…we had a lot of time to brainstorm and brought up proposals and do a lot of research so, I think that was good that we had quite an amount of time to do background research which we really needed to do because we all went out to do different things there were also different perspectives and it's also a good thing. All the visuals, like the videos and people on the street and photos and documenting were really helpful…We also did a lot of mind mapping which kind of led us to our final idea, like writing down all the key points that were the problems that people had encountered whilst walking and like things that could be improved and what we wanted to see happen.. This will seem like I'm repeating the question but then again it is quiet important, what are the main design concerns when you were designing it in the process? *Um…I'm just trying to…. cause it's been a while…um…do you mean the concerns of like…. when, like?* OK, so it could either be, like you have the initial sketch of the idea and the other part of the group will be thinking of how to embed all the electronics nicely and the of course you will have design concern, ok how are we going to do that? Is it the size that matters or maybe you were thinking would it weight too much on the jacket? Or what about the dimensions? On/off? *Yeah when we put it together we had quite a few concerns like, taking the sketch into a reality and we were concerned about what kind of jacket that we're going to put it into, as I've said before we wanted something that was…wouldn't stand too much out from the crowd and something that would be ….can be used everyday. Essentially that was where our design was heading, but we found it really quite difficult to find an item of clothing or like a designer item that would work for everyone so that was one of our main*

	problems… also implementing them into the shoulders, we needed them to be seen and we had the concern of putting it in the back or the shoulders where would be the most visible…same with the lights we needed to have a material that would support them but we also needed them to be seen also…. that was a bit of the concern as well and how that jacket would support the battery packs and things like that and the weight and how that would work with the fabric So, meaning the weight of the electronics and how the weight of the garments and how it would support that? *Yes*
12.	If you could fix (a) certain design aspect(s) of the project, what or which aspect would it (they) be?
	I would personally change the actual jacket that we used because it probably wasn't the best design for what we were trying to go for…if we like had more time, it would've been nice to actually create an original design that would kind of suit all different types of people that would need this product, I guess.. So changing the jacket to something that would appeal broader… *Yeah, more appealing …*
13.	Would there be a set of general guidelines in designing wearable technology, in what form of would you describe them to be?
	I'm not sure if we had a specific guideline that we needed to sit down to, it was a pretty creative environment that we were in and because it wasn't something that we had to produce…it was more of a kind of conceptual and looking at how people would react, we weren't sent with that many guidelines but we did have to do something that would change the way people were walking or how they would interact with the environment. Through the design… *So it needed to integrate the people with the environment, I guess that was something that was one of the main points…I don't know if I'm going a bit off topic here…but…* That's alright….um thank you very much that was really helpful and

	thank you very much! *That's ok*

PARTICIPANT 2 (interview date: 29/11/2012)

No.	Questions
1.	Please describe your wearable technology project. *It was in response to how peak hour pedestrian traffic can get a bit chaotic and everybody kind of does their own thing, so in response to that we kind of took a humorous approach and took features that would be associated with a car and see what would happen if they suddenly got kind of injected in a pedestrian environment… umm… so the project itself is a jacket with blinkers attached into transparent shoulder pads so the wearer could activate the right or left shoulder to blink according to which direction they wanted to go and we also had speakers sewn into the jacket so there were just noise every time the blinker would activate.. Umm...a very loud blinker noise would come on and we also kind of threw in some other sounds such as screeching brakes... umm... a horn tooting... so in addition to the product itself, the project was more about people's reactions, like in real life rather than how the jacket would work itself* So it's almost like you become a car? *Yes* Oh that's amazing
2.	How many people were involved in the project?
	There were three in our group
3.	Did they come from different fields of practices?
	Two were fashion design including myself and 1 was industrial design.
4.	According to your background of practice, what are the challenges of the project?
	Definitely the technology side of things we kept it quite lo fi. We

	found it was even a challenge for the industrial girl as well to kind of get our head around this. That's why we kind of make the project more about people's reaction rather than technology itself. It was all battery operated and manually operated as well so yeah that was definitely the challenge So, continuing with the previous question, the fashion design background, it was hard to embed the technology into the garment. Would you say that if you have gotten some sort of training like in a previous subject, do you think that would help you? *Yes definitely for that particular subject*
5.	Um. Of course when you were given the design brief, you have a certain approach as a fashion design student. Pleas try to describe to me how you approach that initial design brief for this subject
	From a fashion design perspective? Yes, according to your background *We were kind of encouraged to not think of it as an aesthetic project we were all very much encouraged to embrace technology even though we kind of didn't have the training more as a... I guess the tutors kind of had the vision that you'll never really get the chance to do this again with technology so they were kind of pushing from that angle so we all kind of went into it a little bit blindly. When we tried to kind of make the aesthetic, we were encouraged to not think too much about that but I guess the only way it would've informed it was to kind of think of ways we could hide the technology. I also forgot the feature that we included in LED lights we also made the sign follow me at the back. That was in response to how people…. things like if there's a lot of people waiting on the side of the road to cross, one would only cross if other people start to do it, even that the lights don't go on so that was just kind of a play on that. Um, the fashion design helped in, you know, thinking about materials that would cover the sign when it wasn't lit but will still shine through when it was, um... just knowledge about the garment so where the different switches could go, but aesthetically didn't really… We didn't really have scoped to kind of allow it... it wasn't...it was more about reactions. We didn't have the time or the expertise to kind of think*

	how aesthetic and technology can kind of be merged together.
6.	Moving on, how do you describe...so we spoke about how your background training affected the way you approached the design brief and how it's slightly different and you're encouraged to embrace the technology itself. What about you personally, as a fashion designer when you were given that design brief, what was the first thing that came to your mind?
	In terms of the project? Or in terms of how I would... *I found definitely very daunting… umm... I kind of... My first ideas were kind of projects that were not very feasible to make to somewhat my expertise... Umm... And then the process became more about toning it back and how it could be possible.... but yeah, that's probably what I first thought. It was... cause we had the choice to either keep it as something conceptual or make it real.. Umm... and definitely my first impressions were to keep it conceptual because I just had no idea where to start; my ideas were really big...*
7.	Of course in the design process there are certain design attributes that came up when you were trying to design the jacket or when you were trying to design the visual feedback...what were the design attributes that emerged during the process which became part of the considerations that made, design wise?
	We definitely considered to keep it very normal, if that make sense. so visually we didn't want it to be anything avant-garde, it was something that very much had to blend in with what people were wearing, so instead of designing something from scratch, we used a blazer and then we altered it from there, so it wasn't really...the visual side of things wasn't really designed at all. it was more how we incorporate the technology . That was the only designed part. Oh ok. So the embodiment of technology into the garment, that's the main consideration? *Yes*

8.	Is there any difficulty when you were trying to embed that technology? What would be the concrete example you encountered when you were trying to embed technology into the garment itself?
	Definitely a power source and cause everything was battery operated it was very heavy and we had the led sign that was made out of 42 Christmas lights which needed about 6 AA that needed to be put into the back of the jacket plus the speakers so it was very heavy to wear and that was probably something that would have never made it usable in real life situation.
9.	Within the process itself, were there any design problems that kept on recurring? For example: ok we decided we're going to use Christmas lights, we tested it, there were certain problems and you changed it again, or as you've said before the ideas were big, and you started moving backwards and you try to turn it down. Were there recurring design problems that you encountered during the process itself?
	Probably, how big we could take it was the biggest problem… Umm… Yeah, it was just very hard with kind of, limited resources and limited time; I think we only had about three weeks to do this and 1 day a week… I mean we had our whole semester but in terms of actually making it when it got down to it, that's how much was allowed for the physical making of the jacket… Umm. Yeah like we did want to take it to a grander scale and put more features that would have elicited a bigger reaction from the public, possibly things like, you know, small signs coming out from shoulders or something like that, but it just ended to be toned down or kept conceptual. So, yeah that's probably one design thing, cause we didn't have the expertise we couldn't carry out the design.
10.	If you could fix certain design aspects of that project, what or which aspect would it be?
	Probably the switches being able to be automatic or somehow sensor activated if that makes sense. They were all kind of manually...you have to press each buttons for the purposes of experimenting and trying to get a reaction but if it was kind of to be taken out in a real large scale project, it would be good one switch could control everything, or if one switch had all the buttons rather

	then, ok...left hand this finger, press this, right hand, your pinkie press that… yeah just probably the accessibility for all the switches...and I guess just kind of making the garment a little bit more individual as well, trying to bring in that design element, ideally we would love to have one for each age group, each gender, but we just... because the time, we had to do the standard type black blazer.
11.	How do you describe the design process itself?
	With technology? Yes *It was different to what we were used to, it was very much... I was very much used to being starting with a very conceptual inspiration that was always visual and for this it was a lot about technicalities and electronics and things like that...so it was different, it couldn't.... we find it hard to kind of have all these knowledge about visual garments and how they work stylistically and, you know, what things would be worn in what environments and it kind of just had to be cast aside...so I found that aspect of it frustrating to have all this knowledge in the area and not be able to use it and being encouraged to use it also...so yeah that's probably what differed in the approach from normal.*
12.	Would there be a set of design guidelines for designers in designing such project, what would you think they would be like?
	I think given what I just said, there should be some kind of visual guideline as well as just technical... umm… I think it's important to remember that people respond to these things visually first and foremost, so understanding of the body and how garments fit and just social conventions around each garment and what you choose to place technology in will always play a part in it... umm… In terms of the technology side of things, I think it's very important to kind of integrate it easily into whatever environment it's been put into Versatility, would you say? *Yep*

	Anything else? *Just in general, or specific to technology?* Um, just in general, even if you're coming from a fashion design background and then given this project and then, of course as you mentioned before, you were encouraged to embrace technology but then again, there were minimum guideline out there that provides you a hierarchy on how to do it, and things to consider, and as you've said before you had to go into it blindly, and if you're just thinking out loud what sort of guidelines, do you think should be there? *Not really...that's the main thing.* *Great so that's it, thank you very much for your time*

PARTICIPANT 3 (interview date: 30/11/13)

No.	Questions
1.	Please describe your wearable technology project.
	Yep, ok, it's basically a neck device, that senses when the wearer is distressed and transmits a heartbeat of a friend, or a partner…so it can't be individually done, so the partner would also be wearing it and it would work like that So, there are two wearers, so it's like a pairing? *Yeah, well there could be more, it's basically an interconnected device.* Oh right, OK.
2.	How many people were involved in the project?
	Well basically in the group designing it, there were four.
3.	Did they come from different fields of practices?

	There were three from Fashion design including myself, and one was from VisComm So it's an interdisciplinary subject Cause, I thought it'll be just between industrial and fashion No, it was open to everyone there, a few VisComm were in the class. Mainly, it was fashion and industrial (students), who chose the class. *Yep*
4.	According to your background of practice, what are the challenges of the project?
	Probably the technical elements. So that's including the machinery? *Yes, so how to make it work and stuff like that, although the internet was quite helpful, so…* The internet? *Yep.* Oh so you did research and all that through there? *Yep.* So with this device, how did you detect the person's mood? *Mood?* Yes, meaning, how do the device recognize that the person's stressed? *It's through a series of sensors, so they're all fairly readily available, mainly the heart-rate is the core, but through detections at the neck, there's like, um, changes in the skin conductivity, and stuff like that.* Oh so it is a galvanic type, so it touches the skin? *Yeah, so there's a sensor that will touch the skin, so it's all based on*

	the heart-rate mainly, though, cause the project was based all around the heart monitor.
5.	With the difficulties that you've encountered with the technical elements, given with your background practice, would you say that you haven't had enough previous training for it?
	Well, we really haven't had any in the technical element, but then the reverse side was industrial students didn't know how to approach it without coming up with ideas that were already present in the market, so…
6.	OK. When you were first given the design brief, how did you approach it? How did you and you group mates approach it?
	Um, well it's slightly based off on individual project we needed to do before, so we based it on mine, mainly, which is a hand, sort of, device that shone a light in the direction of home when an individual is feeling distressed. OK. So the individual project was a hand piece? *Yep.* And did it use the same mechanism as the one done with the group? *Yeah, very similar in the detection in the moods and stuff like that.* But the feedback is different? *Yeah, one was based mainly around homesickness and connection to home and the other one was based on connection to people, individuals.*
7.	How would you describe your personal initial design related challenge?
	Um, well initially it would be coming up with an original design idea, technically, we had assistance from a helper in the class, and he was like a tutor's helper.... I'm not sure...a tutor aid… Um, basically the tutor brought him in just cause he knew he can help us with the technical elements. So we started with him and did further research. So, basically would you say that the research part is a strong element of how you initially approach the design challenges? *Yeah, I'd say so, cause as soon as you start looking up ways to detect things, there's sort of online tutorials of similar projects and then how to do them or whatever they did*.

8.	In the process of designing it, of course you've encountered a lot of design attributes. It could be the size, the weight and then the look of it, or how it could be powered, those sorts of things. So what design attributes lead to the design considerations that you made during the process?
	Probably all of them. There wasn't as much of an issue, mainly size would be the big one, because we needed it housed in a solid housing, I suppose, to soft housing. With Wearable Technology, technology has come a long way, so you can get quite slim and sort of discrete power sources and sort of power boards to go on clothing. So basically, it's more of the size of the entire device itself, not necessarily the size of the elements, would you say? It would be the size of the elements but we needed to stack the elements up um as opposed to spreading them out flat, in that respect.
9.	Could you please tell me what are the difficulties of approaching the design brief?
	As a group, probably, it's just having different design ideas. So making it work as a group? *Yeah, designing in a group is always a little bit difficult.... the brief was quite broad... Um, it focuses more on the experience of the wearer and how they interacted with the city around them… Um, so mainly it was focusing on the environment of the city and problems related to living in the city... um, so we focused on the distress and this sort of fear it could cause and ways to positively impact that.*
10.	Within the design process itself what recurring design problems appeared?
	Yeah, um because our base for things we could do with the technology we had was so broad we had lots of things it could do in our minds and just trying to organize them was a little bit messy, so we got confused within ourselves. So within the research itself that gave you a lot of options and that gave you some sort of a base understanding of what the technology are capable to do? And then narrowing it down to the one that's really necessary for the project, would you say that's a recurring problem?

	It was, yeah. I think in the end still, it was still a little bit vague because we didn't really have enough time to develop it fully...we sort of left a few options open.... as well as sending the signal of distress you had the option of just sending a signal. So like, you would send a love heart to someone just as a reminder that you love them...you could send your heart beat to someone and that sort of aspect as well and different ones like that.
11.	OK. Now that the project's done, if you could fix a certain design aspect of the project what would it be?
	Um, I would want it to work properly. Of course, but in a more concrete sense? *Probably the material.* So the enveloping material? *Yeah, the material of what the thing is made of.* What did you use? *It was sort of a circular device worn around the neck but mainly the shoulders. So the head of it, around the chest was made of a solid hard wood and then we carved that out and then the neck piece was made out of heat sensitive plastic and then we just join the two and it was a bit messy to be honest but because we haven't had much experience with hard materials and working with materiality in that way, that was the best we could do at the time given. It didn't look too bad in the end but obviously I'd want the whole thing to be the same material or to still work a little bit better together.* So this device is actually rigid, it's not flexible? *Well the plastic is slightly flexible, it's a material that you can boil and mould like plasticine and it sets hard: Plastimake. It has become quite popular now, but it gives a little bit of flexibility.* So does it adjust to the contour of a person's shoulder and neck? *We made it fairly basic. Um, it could fit lots of people because for the exhibition we had interactive video where everyone was putting it on and trying it out and that worked quite well, I think if you have one or two sizes in the sort of generic size, it would be ok. Because we tried it on a few people and it fits to like, really little girls and quite big men.*
12.	How do you describe the design process in designing for the

	project?
	It was quite long, I'd say. When over the entirety of the time we had.... um we kept going over certain things as I've said before, what it did...it was narrowing it down again and again. So there's a lot of elimination process or elimination stages on the process itself? *Yeah, and then refining what we've got and then going back and doing it again because certain people weren't happy.* So with the initial design brief that you said, it was quite broad and you were given basically the option of looking at all of these possibilities of using the technology and now trying to narrow it down, that would be practically, the main substantial part of the design process? *Yeah, so initially we went with looking at certain areas of the body that we wanted the technology to go on as a way, did not really work that well. Um, and then we focused on areas that we previously looked into, so areas of comfort or fear...things like that…*
13.	Just thinking out loud, would there be a set of general guidelines in designing Wearable Technology, in what form would you say it should be?
	Um, obviously practical.... cause anything wearable has to be, sort of be a little bit durable. Probably, waterproof as well. A lot of things aren't sort of given that. So basically waterproofing, do you think it will increase the wearability of it? *A little bit, also you won't worry so much about what you're doing cause that's the difference between Wearable Technology and hand held technology. You can always put your phone away, whereas a wearable one stay on you and you're able to forget about it and just think about when you have to. So, I think I actually made mine waterproof just because the technology is for wearable things that already goes towards that.*

APPENDIX B: DIAGRAM SHOWING INTERRELATIONSHIPS AND OVERLAPS WITHIN DESIGN ATTRIBUTES OF WEARABLE TECHNOLOGY

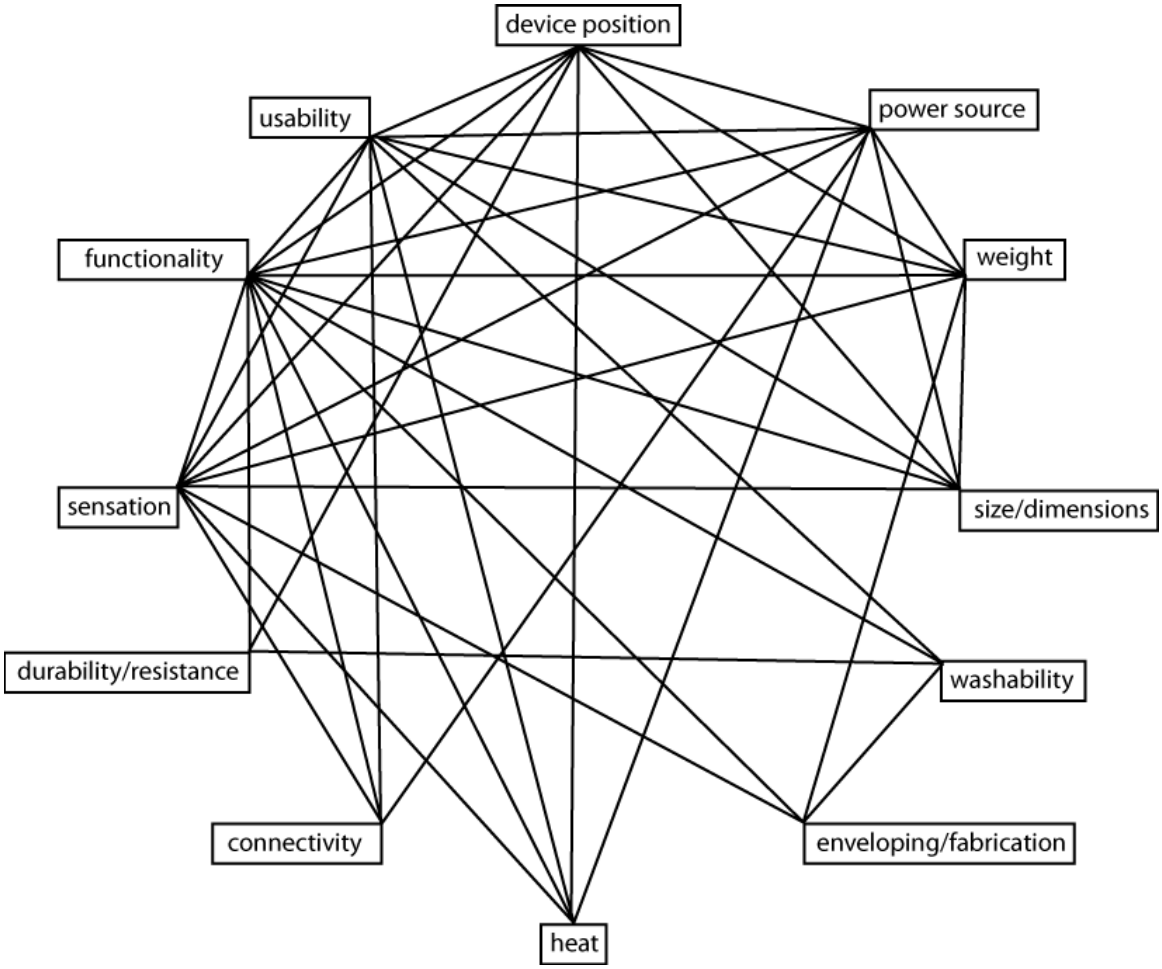

Diagram showing interrelationships and overlaps within design attributes of wearable technology

APPENDIX C: GLOSSARY

The following are terms encountered in this thesis.

Aesthetics Appreciation of beauty, related to subjectivity and/or general consensus of opinions.

Background training An individual's educational/professional training

Connectivity Ability to connect to a certain network.

Device positioning Location upon where the Wearable Technology device is located on a user's wearer's body.

Design
a. The creation of value for people (Meijkamp 2000).
b. The creation of objects, information, environments, services, etc. that afford the opportunity for people to create value in their use (Lancaster 1991).

Design process Stages or procedures of designing an object or artefact.

Durability/Resistance Longevity of use of Wearable Technology device and/or capability of Wearable Technology device to withstand certain environment conditions (eg. Weather-proof, durable fabrics, etc).

Emerging, emergent Becoming apparent/arising.

Enveloping/fabrication Encasing material of electronical elements of a Wearable Technology device.

Functionality A functional quality of a device that allows it to deliver results demanded by a user while wearing or using a device.

Heat Temperature released from elements of Wearable Technology device.

Interrelationships The way two or more things are related to other(s).

Iterative	Involving repetition
Multidisciplinary	Involving multiple disciplines of studies/fields
Non-redundant units of relevant meaning	Selected units of relevant meaning that are non-redundant to the research inquiry during phenomenological process.
Power source	Wearable Technology device source of power (eg. Batteries, solar panels, etc.)
Project time	Timeframe/ period scope of a project from start to finish.
Sensation	A form of feedback resulting from using/wearing Wearable Technology device
Size/dimensions	Overall dimensions of Wearable Technology device.
Smart Wearable Technology	A wearable device with the ability in sensing a user contextually in its functional and expressive qualities (Nugroho 2013).
Units of general meaning	Units of meaning elicited from raw data during phenomenological process
Units of relevant meaning	Units of meaning derived from units of general meaning that are relevant to research inquiry during phenomenological process.
Usability	A quality that allows a user to navigate his/her way in using the device, which influences the user's engagement and impression of interactivity and responsiveness of the device.
User	A person who uses or wear and operates Wearable Technology device.
Washability	Washable quality of an object or its enveloping material (in this research: Wearable Technology device).
Weight	Force of Wearable Technology device due to gravity

APPENDIX D: CONFERENCE PAPERS

-Hawaii International Conference in Arts and Humanities (HICAH)-2009

Wireless Gamelan: A Gestural Interactive Music Performance Environment

Mr. Jeremiah Nugroho
University of Sydney
Wilkinson Bldg G04 2006 Australia
jnug0221@mail.usyd.edu.au

Professor Kirsty Beilharz
University of Technology Sydney
P.O. Box 123 Broadway 2007 Australia
kirsty.beilharz@uts.edu.au

Abstract. This paper presents a new approach for implementing RFID technology. Specifically, it provides a new kind of musical instrument or live music performance environment. Contextualised in performative interactive art installation, we discuss the technical and musical implementation of our gestural Virtual Gamelan as a vehicle for investigating embodied RFID technology, exploring user responses to the interface and the technology, issues of body culture, embodiment and Cyborgism.

General Terms
Human-Computer Interaction

Keywords
RFID, Gamelan, Interaction Design, Auditory Aesthetics, Gestural Interaction, Spatial interfaces.

1. INTRODUCTION

The idea of an intangible (non-tactile, gestural, spatial) musical instrument to produce sound is an expansion of the conventional framework for human music creation and instrumental performance. A basic premise for this project is attempting to challenge the notion of post-humanism in which, according to N. Katherine Hayles, there are no essential differences or absolute demarcations between bodily existence and computer simulations, cybernetic mechanism and biological organism, robot teleology and human goals (Hayles 1999, pp. 2-3). In the Wireless Gamelan project, the designers embody cybernetic mechanism in the biological mechanism, thereby taking a literal interpretation of Hayles' notion of post-humanism. The cybernetic mechanism included in this project is the RFID technology (Radio Frequency Identification) while the biological organism is the human body.

The Oxford American Dictionary's definition of machine is "an apparatus using or applying mechanical power and having several parts, each with a definitive function and together performing a particular task (Elizabeth J. Jewell and Frank R. Abate, 2001)." In order for RFID technology to function, it always consists of several different parts including RFID tags, the RFID reader (or scanner) and some form of system that enables its successful function, e.g. a networked database or a networked music driving system. These parts are intended to be regarded as the machine in this project as the composite parts together provide the ability to perform a task. In this

way, the production of sound by embodying some parts of the machine (in the human body) in this project may be seen as an exploration of post-humanism.

1.1. Project Aim

As humans, we tend to react to new inventions in life. The awe, excitement or even fear of something new, in this case - new technologies, are unavoidable emotional responses. The aim of this project is to investigate the possibilities of how fear and paranoia about embedded technology can evolve and prompt negative views or influence the audience's interpretation of the music delivered via this technology. Therefore we test the possibility of this hypothesis by using an interactive art project, the Wireless Gamelan, and include the analysis of the social reaction provoked by the project.

2. CULTURE OF THE BODY, EMBODIMENT AND INDIVIDUALISATION

The body and the self consist of perceived boundaries, the culture (and politicising) of the body, our perception of it, through it and the body as a medium for expression and individuality. Individualisation can indicate belonging or alterity and the body can be used to evoke independence or to elicit separation.

Perception of self, or defining self, concerns mapping and drawing body-limits. On the one hand, we are examining the difference between embedded, implanted technologies and external motion actuators like sensors, camera-tracking or touch-pads and common musical instruments because Cyborg controllers have crossed a threshold when the chips entered the body (skin). On the other hand, an equally modern view perceives our "self" as extending much further and engulfing a richer anatomy of networks than merely arteries and veins surfaced by skin. William J. Mitchell's interpretation of Cyborgism that encompasses the networks with which we interact moves boundaries and permissions much further from our core or, at least, questions our boundary constructs and our location of being (2003).

The Cyborg performer is not an autonomous music-maker in the sense that a passive transmitter, not an entire machine, is encased in his/her body. The performer is reliant on contact with the RF wireless network and external music drivers in order for his body to be the instrument of performance

3. EMBODIED INTERFACE

The fact that the RF technology is able to work as wireless sensors for various tasks, allows us to explore a new way of human-computer interaction, in this case, human as a performer and computer as a musical instrument.

For the performer, traditional musical instruments provide a robust resistance to the sense of touch, a physical interface and even sometimes haptic (responsive) feedback to the user: the resistance of the tautening string and its release by plucking, the texture of percussion instruments, and so on. Electronic interfaces utilising touch, tangible controller pads, sliders, mixers, dials, knobs, tactile interfaces and electronic keyboards with weighted keys, all provide the kind of conventional haptic feedback we are accustomed to for sculpting performance and the sensibility that is honed with practice and repetition, familiarity and skill. The invisible sensor inside the body with a wireless or gesture-only method of "conducting" and controlling the audio output is already dramatically different. The performer must react to sound rather than touch, yet acuity, accuracy and refinement of gesture are key. The body is anticipating and choreographing while the ears are listening (perhaps eyes also looking).

Proprioception is the relationship between our mind and motor control arising from sense of space and spatial orientation around the body, the sense of the relative position of neighbouring body parts.

To revisit Hayles' view of post-humanism, there is the existence of an imaginative discourse sphere, in which another sphere exists, which is the Cyborg discourse. Thus, one can say that a Cyborg is a form of post humanism. The word Cyborg derives from the word cyber and organism. In this project, we decided to experience the definition of Cyborg in a literal sense. For the performer to become a Cyborg means to have the machine parts in his body included as a part of the system. Since RFID tags can only work with the existence of the reader and a previously calibrated system, it is a part of a machine system. Thus, we believe that by having RF tags underneath the skin, the body becomes integrated and protruded or extended and augmented by the machine. In this project, the role of the performer is almost like a catalyst where, without the performer, the system and the reader can not work alone. The fact that each RF tags has a unique identification code adds an interesting layer in order for this musical instrument to create and produce sounds. The personalization of the musical instrument becomes absolute, since only a performer with "matching" RF tags are able to generate the system to play music. Having tags implanted underneath the skin, the personalization becomes permanently embedded in the performer, which positions the performer as an absolute part in the system.

4. PROJECT IMPLEMENTATION

4.1. Musical Idea

The Max/MSP interface music patch is not simply an "action/reaction" model in which singular gestures trigger single auditory events, rather to produce a musical degree of complexity and richness, gesture actuated by the different tags triggered loop cycles for gamelan gongs of distinctive frequencies and spatial location (Figure 1).

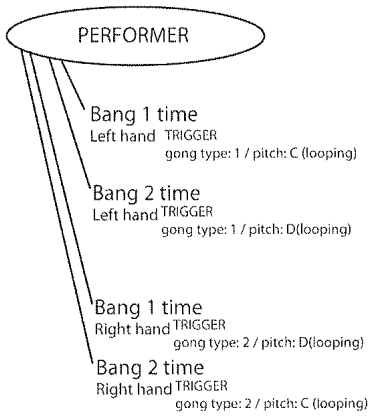

Figure 1. Event hierarchy diagram

The idea for the modality derives from a scale that is used in Traditional Indonesian Gamelan (a musical ensemble typically featuring a variety of instruments (Figure 2) such as metallophones, xylophones, drums, and gongs) music. Originally there were two main scales used in Gamelan performance. These are *Slendro* and *Pelog*. The scale used in the interactive art installation is *Pelog*, a seven-note scale used in Balinese Gamelan music.

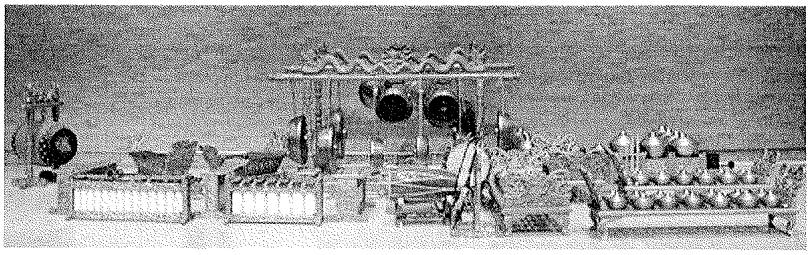

Figure 2. A Gamelan Orchestra
Photo by R. Zeckoski (http://www.flickr.com/photos/rzeckoski/516515135/)

The *Pelog* scale consists of seven different pitches, however, in practice, all seven notes are rarely heard together in one single composition. This is because of the instrument limitation of producing all seven pitches. The intervals of the *Pelog* scale are also hard to characterize, since the tuning for each gamelan is different to the other, characterized by the timbral spectra or overtone series of the instruments. However, one rough approximation of the seven pitches is a subset of 9-tone equal temperament.

The Pelog scale in Balinese Music has three different modes, *selisir*, *tembung* , and *sunaren*. The modes all start on the note named *ding*, and then continue going up the scale to *dong*, *deng*, *dung* and *dang* (Table 1). However, the same pitch will have a different name in a different mode.

The analogy for using the Gamelan music scale in the system lies on the origin of the word "gamelan" itself. It comes from the Javanese word "gamel", which means to strike or hammer, and the suffix "an" (Wiki "Gamelan Definition"). The way the instrument works to produce sound is by the player striking or hammering the instrument. In the installation system, the sounds are triggered by the strike or the bangs from the RFID tags when the reader reads the unique coded embedded in each tag. The wireless virtuality of the system refers to the scenario in which no physical gamelan instruments were present but rather were simulated using spectral modelling of the resonance of real instruments, spatially distributing the rendering across a quadraphonic speaker system to create an immersive and spatial audio experience.

Table 1. Balinese Modes of *Pelog* scale (Wiki "Gamelan Tuning 2008)

Balinese Modes			
Tone	**Selisir**	**Tembung**	**Sunaren**
1	Ding	Dung	-
2	Dong	Dang	Dung
3	Deng	-	Dang
4	-	Ding	-
5	Dung	Dong	Ding
6	Dang	Deng	Dong
7	-	-	Deng

4.2. Triggering System

This triggering system is implemented using a hierarchical system in the Max/MSP real-time programming software environment. While the original, physical gamelan is played by hitting the gongs or the panels with the hammer, this project is 'played' by triggering sound samples using RFID tags and consequent hand and arm gestures. In the Max/MSP software, a trigger is translated into a button-like signal, a message or 'bang'. Whenever the RFID reader reads a

unique set of identification code from an RFID tag, it will trigger a bang if it matches the system. This procedure of 'banging' in the system creates a resemblance with the 'banging' of gongs and iron panels in playing the real gamelan.

In order to increase the pitch of a certain type of gong associated with an RFID tag attached to a specific body-part, the performer must allow the reader to read the tag multiple times to determine the desired intervals. For instance, in order to increase the pitch from C to E, a tag must be read twice (according to the intervals).

4.3. Performance Scenario

First, the performer whose hand(s) has been implanted with RFID tags, moves inside the designated area of the installation. The performer commences by positioning his or her hand(s) near the readers (Figure 3). As the reader tracks the code inside the RFID tag, it will trigger sound samples. The sound samples are presented through a spatial audio system to create an ambient and visceral experience. As the music evolves, the performer starts to chant an Indonesian traditional song named "Janger".

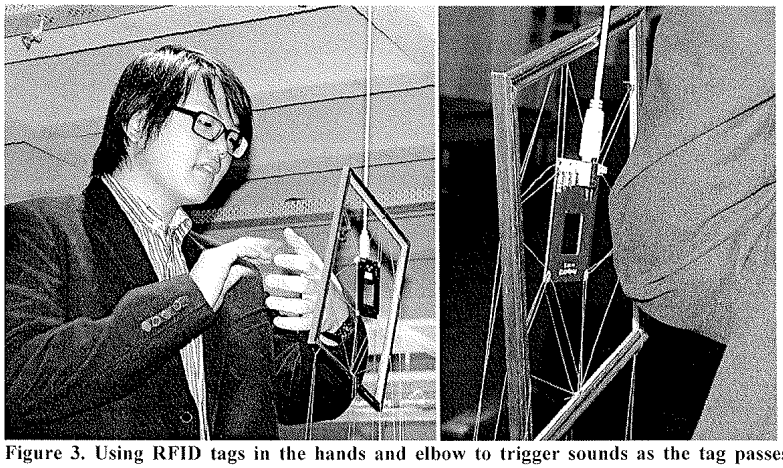

Figure 3. Using RFID tags in the hands and elbow to trigger sounds as the tag passes in proximity of the reader (scanner). Photo by Kirsty Beilharz.

The premier performance and pilot evaluation was held at the Hearth in the Faculty of Architecture, Design and Planning Wilkinson building on Wednesday, 9 July 2008. For the pilot performance, the performer did not implant the sub-dermal chips, but "tricked" the audience by hiding the RFID tags underneath adhesive bandages. This was done to provoke authentic reactions to the performance from the audience, in response to the performer's body manipulation.

4.3. Audience Response

In order to receive feedback, the audience was given subjective questionnaires after the performance. The objectives of the questionnaire are as following:

- To gain deeper insight on how human with embodied technology will be 'othered'.
- To gain opinion on how far accepted is the idea of seamless integration between human and machine.
- To see how the public may approach the implementation of the embodied RFID technology to their everyday life.

During the performance, we managed to get feedback from 22 audience members that filled in the questionnaires. When asked if the chip implant technology is disturbing or not, most of them think that it is disturbing and unacceptable. For the performance, we included several pictures, which explains the surgical procedure in implanting the RFID tags. These pictures managed to create a form of discomfort among the audience members, which resulted a number of audiences to fear the technology implementation. The fact that these RFID tags are included in the performance as if they have been surgically implanted, it articulates the notion of man-machine hybrid beings that allows the performer to be fully immersed and integrated with technology in a very literal sense (surgically implanted). However, if one is to look deeper, the performer also interpolates the notion of socially networked beings, since by pretending to have RFID tags implanted allows him to be connected directly to the technology and control the sound samples as well. We would like to argue here by the fact that the audience members thought that these RFID tags were implanted prior to the performance, invokes the feeling of disturbance and discomfort from the audience members.

Only 7 out of 22 audience members think that it is not disturbing to have chips implanted underneath one's skin. In instance, one of them mentioned the use of pacemakers and bionic ears, which have become accepted in the world today. Another audience member commented that the media played a big part in creating the public's paranoia towards the technology of man-machine hybrid beings. One of the audience members commented that it is not unacceptable if the technology of chip implants is to be used towards good causes for the community. The public's paranoia of having machine parts implanted inside one's body is also mentioned in one of the opinions, saying that the "Big Brother" sense plays a big part in building this paranoia. Here we can see that the majority of the audience members think that it is disturbing to have chips or machine parts implanted underneath one's skin.

When asked if they will look at people with chip implants differently, only 5 people agree, while 11 people disagree, and the rest could not decide what their answers were. By looking at the number of the respondents that disagree, we would argue that there is a possibility that these audience members do not have issues with man-machine hybrid beings. However, we would also argue that the underlying reason for this is because there is a rarity of people with chip implants or any kinds of implants in life these days. People with chip implants or any other kind of embodied technology are still a minority in the community. For that reason, these audience members hardly ever encounter this minority group.

We suspect these audience members have various underlying reasons to state that they will not look at people with chip implants differently. Since the performance / installation only includes implantable RFID tags which are small in dimension, it creates an altered perspective for the audience. What they saw during the performance was a human with almost invisible machine parts integrated to his body, which is why the majority of the audience members say in the questionnaire that they will not view someone with chip implants differently or perhaps their determination not to appear discriminatory. However, what if the machine parts were protruding outside from the skin and expose the connection between human flesh and machine parts? We believe that the visual and physical appearance of embodying technology, due to its perceived invasiveness, plays a prominent part in this case.

Throughout this exploration, we found various reasons that lend inflection to the practice of implanting RFID tags or embodying technology in general:

- The issue of surveillance or control over individuals by more powerful groups.
- The issue of (possible) extended or eternal life.
- The issue of (possible) alien appearances.
- The issue of medical procedures involved.

The most logical explanation for the first issue can be derived from the production and legalization stage of these machines. Serial numbers, I. P. Addresses, identification numbers on RFID tags have always been on-going issues in personal information systems. These identification systems are always included within the Cyborg issues. Therefore, for someone to be a Cyborg, his or her personal information (for example: location, personal financial records, etc.) can always be recorded and acknowledged by the more powerful groups or organizations, such as

the government and private companies or even other individuals. This paranoid or perhaps legitimate concern is perpetuated by publications such as *Spychips* that provokes the notion that RFID tags will inevitably and primarily be used for surveillance at worst and market research or pushing products at best, i.e. for manipulative processes and invasion of privacy.

The second issue can be explained by examples such as medical patients with pacemakers, cochlear implants, and disabled people with artificial implants. If a hearing impaired person's ability to hear can be amplified by having cochlear implants, then there is always a possibility for normal people to have similar implants in order to enhance his or her hearing ability.

The issue of alien appearances is connected with nanotechnology and technological fetishism. This particular issue will mostly arise in Othering (alterity) (Baumann and Gingrich 2004), prejudicing and discriminating against Cyborgs with the notion of man-machine hybrid beings. In the future, the idea of nanotechnology and seamlessly integrating machine parts underneath the skin is not something that is impossible to achieve. However, technological fetishism always includes technological voyeurism and technological exhibitionism, which could be regarded as the primary reason behind the alien appearances.

The fourth reason, which is the issue of medical procedure involved, is based on the experience of Wireless Gamelan project. In the performance, the audience members were persuaded to believe real implantation of the RFID tags as the result of false images displayed on the performance sheets. These images have provoked discomfort among the audience members, which caused the audience to view the RFID implantation technology as unacceptable and disturbing. This articulates the public's fear of the implantation technology, which is a part of the cyborg technology.

5. CONCLUSION

This project creates a parallel between the embodied technology and the culture of the body. By embodying a part of the technology inside the body, humans are becoming machines or Cyborgs. However, in this case, the paranoia of human extinction and being taken over by machines is irrelevant or negated by the purpose of performative music-making and the necessity of man and machine as composite parts in a *system*. The dependency for machine to operate relies entirely to human. However, the public fear and paranoia for embodied technology still plays an influential part in the acceptance of this technology. This paper has outlined the technological and musical project for performance that requires embodiment for its rendering. The performance provided the opportunity to gauge audience reaction to social and cultural issues of embodiment and technology pervasion, summarized in the second part of the paper. As technology plays an increasingly important and pervasive role in our lives, it is necessary to investigate and develop our understanding of the social ramifications and influence of context.

ACKNOWLEDGEMENTS

Special thanks to Sam Ferguson, research assistant and programmer on this project. This research is supported by an Australian Research Council Discovery Project Grant DP0773107 investigating "Gestural Interaction with Aesthetic Sonification": Chief Investigator, Professor Kirsty Beilharz.

REFERENCES

Albrecht, K. and McIntyre, L. 2006 *Spychips*, Penguin Books, London.

Baumann, G. and Gingrich, A. 2004 *Grammars of Identity / Alterity: A structural Approach,* Oxford: Berghahn Books, New York, pp. x, 5, 7, 142

Elizabeth J. Jewell and Frank R. Abate (editors). 2001 The Oxford American Dictionary, Oxford University Press, UK.

Hayles, N. K. 1999, *How We Became Posthuman: Virtual Bodies In Cybernetics, Literature, and Informatics*, The University of Chicago Press, London.

Mitchell, W. J. 2003, *Me++: the Cyborg Self and the Networked City*, MIT Press, Massachusetts.

Wiki "gamelan" http://en.wikipedia.org/wiki/Gamelan accessed 10 July 2008

-New Interfaces of Musical Expressions (NIME)-2009

Understanding and Evaluating User Centred Design in Wearable Expressions

Jeremiah Nugroho
University of Technology Sydney
702-730 Harris Street,
Ultimo, NSW 2007

Jeremiah.Nugroho@students.uts.edu.au

Kirsty Beilharz
University of Technology Sydney
Sense-Aware Lab
P.O. Box 123 Broadway NSW 2007
+61 2 9514 2292

Kirsty.Beilharz@uts.edu.au

ABSTRACT
In this paper, we describe the shaping factors, which simplify and help us understand the multi-dimensional aspects of designing Wearable Expressions. These descriptive shaping factors contribute to both the design and user-experience evaluation of Wearable Expressions.

Keywords
Wearable expressions, body, user-centered design.

1. INTRODUCTION
Screen-based desktop computers are beginning to transform into additional electronic gadgetry, such as mobile phones, MP3 players, game consoles, PDAs and of course in the form of Wearable Technologies, which in this paper are called "Wearable Expressions". This nomenclature emphasises the usability, ergonomics and user-centred perspective rather than the technology itself, looking towards engagement, usefulness, ease and enjoyability of use. Hence, the central issue in Wearable Expressions is comprehension from the user's perspective, i.e. both comprehensibility of content and also of controls, manipulators and other interactive elements of the interface and representation (display).

It is very important to state in the beginning that Wearable Expressions is Wearable Technology. However, there are instances that need to be acknowledged in order to avoid misinterpretation.

The first instance is Wearable Computing, which is thought to have started when a pocket-sized analogue computer was developed by Edward O. Thorpe in 1961 to predict roulette games results in Las Vegas [10]. However, the important distinction in this early stage is that wearable computers were basically portable gadgets, not worn on the body and not especially correlated or designed with the body-based nature of a wearable device in mind. Essentially these are miniaturised, portable computers following the traditional screen-based desktop computing paradigm.

The second instance is Wearable Art. The main theme and purpose here is more likely - if not always - for purely aesthetic reasons. The reason why Wearable Art is included as Wearable Expressions is because the tendency towards fashion is very strong and also there is a sense of technology embedded. Further, that fashion is very much related with the world of garments and materials, reflects the technological culture of the world we live in today [10].

Therefore, we emphasis that Wearable Expressions mentioned in this paper should be perceived as smart gadgets or devices that are wearable on the user's body, not limited to a fashion ensemble but which also embed certain computing intelligence in the wearable device itself. Technology as art that has no user-centred functionality to impart, gather, communicate or interpret information is not the kind of expression explored in this paper.

2. USER CENTERED DESIGN IN WEARABLE EXPRESSIONS
The public has not responded the emergence of Wearable Expressions in the commercial market field positively. An example is the reception of the earphone-embedded Oakley THUMP sunglasses. These sunglasses have MP3 players and earpieces embedded into them. However, there are several common issues, such as the six-hour power supply and also the reasonably high market price might be a significant issue for users [9].

Figure 1. Oakley THUMP Pro [9]

The paucity of wearable technology take-up in the consumer marketplace is also evidenced by the lack of wearable expressions in our everyday life. For instance, we are still very often choosing to hold our phone to our ears when there are numerous and various wireless or non-wireless mobile phone hands-free headsets available on the market. There are simple yet often taken for granted reasons and explanations. For example, issues that would very commonly appear include cost, comfort and appearance. Where many researchers have focused on the capabilities of the technology, this research also emphasises the ergonomics, usability, usefulness and aesthetic

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
NIME2010, June, 2010, Sydney, Australia
Copyright remains with the author(s).

possibilities of the Wearable Expression in trying to understand people's receptiveness and take-up of new designs.

2.1 The Importance of User Centered Design in Wearable Expressions

The understanding of the user cannot be ignored in the design process of wearable expressions or technology, which place the user in the epicentre of experiencing Wearable Expressions [13]. The fact that the technology is worn on user's body invites multiple layers of considerations in designing Wearable Expressions.

Comfort and appearance are amongst other important key factors, which if broken down piece by piece, creates a complex matrix of understanding that requires full attention by the designers in the process of building, creating and improvising Wearable Expressions. Therefore it is very important and essential to discuss the matter in order to allow Wearable Expressions to expand and be embraced by more users. Some of these overlooked attributes have led to Wearable Expression being misunderstood as a portable, miniaturisation of the desktop or even hand-held computing paradigm. Qualities derived from desktop computing such as screens, hard surfaces, textual communication do not always translate as the best mechanism for communication in a body-worn, washable, flexible, expressive modality.

3. SHAPING FACTORS

For the purposes of categorising and evaluating Wearable Expression, these shaping factors loosely group attributes of the design, recognising that there is significant interaction between these attributes and that some attributes are measured quantitatively while others are measured using a qualitative, relatively individual scale. Overall, the objective is to understand Wearable Expression using design paradigms closer to the user's which, therefore may lead to the design of more comfortable, intuitive, aesthetically-pleasing, helpful and ultimately wearable outcomes.

3. 1 Shaping Factors to Evaluate and Understand User Experience Design in Wearables

Within this section, it is very important to state beforehand that these factors do not oppose each other and we acknowledge that there are significant overlaps or interplays.

3.1.1 Size/dimensions

The dimensions of the device play a significant role in the design of Wearable Expressions. Levisohn argues that an integral element of interactive systems should be the body [5]. Therefore, the Wearable Expressions device dimensions should not exceed the user's expectation and anatomy otherwise the design could be considered a failure. Adding load to the body may affect the user's physical factors. The mechanics of the musculoskeletal system is altered immediately once load is added to the user's body [1]. Moreover, the effects of the device on the user's comfort and freedom of movements plays an important part in making the design fabrication decisions.

3.1.2 Device Positions

The positioning of the device is one of the most important factors in designing Wearable Expressions, since this may strongly affect the user's comfort, appearance, and sensation. It also affects the ways in which we interact with it (voice recognition, buttons, vibro-tactile, visible, etc.). The design approach should consider ergonomics and anatomy of the human body. One example from one of the simplest designs of Wearable Expressions is the wristwatch. It is worn on the user's wrist, which provides basic comfort and ability to effectively view time information for the user. Despite various attempts in history, including the pocket-watch or clocks worn elsewhere on the body, we return to the wrist-worn device.

3.1.3 Power Source

There are several aspects to the issue of power source. The first one is the type of device power source. This first element also determines the following essential element, which is longevity. It is also very important to consider whether the device power source is rechargeable or not.

Another element, which should not be overlooked, is the question of whether the device power source requires a power point in order to function. In other words, the question of corded or cordless power source strongly corresponds to issues of usability and function and mobility.

3.1.4 Heat

The issue of Heat is very crucial in designing or assessing Wearables. Heat affects the user's comfort (and ultimately safety) in wearing the device because it will certainly involve contact with the user's body.

3.1.5 Weight

The weight of the wearable device affects the user's comfort. This particular issue is interwoven with other issues: Power Source, Size/Dimensions and Device Position. The size and type of Power Source determines the Size and Dimensions of the device, and also the positioning of the device affects the user's comfort.

In order to illustrate the element of weight, Graves et al. and Miller et al. discovered that using wrist-weights (of 2.3 kg and 1.3kg, respectively) would increase muscular and physiological activity to move the arm about the elbow [3, 8]. A greater amount of muscular activity is obviously needed to move the elbow once the weight is increased. The issue of physical constraints of a human body affects the success in designing Wearable Expressions.

3.1.6 Durability/Resistance

The resistance and durability of the device(s) worn on the user's body is strongly dependent upon the quality and the robustness of the enveloping material. There are a few elements that require thoughtful design decisions, such as: flexibility, absorbency of user's body natural excretion, heat distribution and robustness, for example water resistance for designs intended for outdoor use, e.g. GPS devices, sports devices, etc.

3.1.7 Washability

The washability factor should be considered in the process of making design decisions or while evaluating Wearable Expression devices in order to respond to hygiene issues that may arise after usage.

3.1.8 Enveloping/fabrication

The choice of enveloping or fabricating material of a wearable device is relevant to the two factors mentioned before.

Washability and Durability need to be anticipated by design decisions about the enveloping of a wearable device. Enveloping/fabrication includes the choice of materials, flexibility, and the way in which it covers the internal electronics, and provides accessibility to controls or sensors and displays.

3.1.9 Functionality

The Functionality of a wearable device is contextual depending on its purpose. According to Rens Meijkamp design can be defined as 'the creation of value for people' [7]. Kelvin J. Lancaster defined it as 'the creation of objects, information, environments, services etc that afford the opportunity for people to create value in their use' [4]. Therefore it is obvious and important in any kind of design field to acknowledge and fulfil a client's need. In the case of wearables, it is very important for a device to serve its purpose upon creation. For instance, if the user is intending to use a wearable GPS sensor that is able to monitor heart rate, then it is very important for the device to deliver the results demanded by the user while wearing or using the device. Safety and health products, for example, also exact a higher degree of accuracy and reliability that entertainment and playful-purpose devices.

3.1.10 Usability

The Usability of a Wearable Expression device can be correlated with the word "navigation". A user's ability to navigate his/her way in using the device influences the user's engagement and impression of interactivity and responsiveness of the device. Therefore, it is very important for the designers of Wearable Expressions to observe simplicity in creating a user-friendly device. There is always a balance between control and simplicity. An increase in number/granularity of controls increases complexity, risking increased confusion.

We believe John Maeda's *Law of Simplicity* applies best in providing a guideline in designing the Usability in Wearables. For instance, four out of the entire ten *Laws of Simplicity* would already create quite a demanding set of design guidelines: Reduce [size, waste, visibility and clunkiness], Organize [structure and hierarchies], Time [reduce and use efficiently time to achieve a goal or task], and Learn [6]. The idea of reducing controls to achieve the purposed task of a wearable will benefit the user with simplicity. In order to achieve a thoughtful reduction in design, the designer must carefully organize the functions of each control. The fourth law, which is Time, discusses how the amount of time needed for a task to be performed or executed would affect simplicity in design and can be leveraged to maximise efficiency and pleasure of experience, responsiveness. In designing Wearables, it is very important for the device to be able to deliver the task it is purposely designed to do within an effective period of time, considering the fact that the device is worn on the body.

3.1.11 Sensation (see, hear, etc.)

The idea of enhancing the body's functionality and ability is the purpose of wearable expressions. It is essential to consider what sort of sensations the user might receive while using the device. These sensations could be in many and various forms creating levels of engagement and interactivity between the user and the Wearable Expressions device. For instance, the sensation of hearing, seeing, touching, vibrating and, maybe one day, smell.

Stelarc is an Australian artist who has performed extensively in Japan, Europe and the USA – including new music, dance festivals and experimental theatre. He has used medical instruments, prosthetics, robotics, virtual reality systems and the Internet to explore alternative, intimate and involuntary interfaces with the body. He has performed with a third hand, a virtual arm, a virtual body, a stomach sculpture, and exoskeleton, and a six legged walking robot. His work as an artist is very much themed with the bodily prosthetic issue [11].

One of his works, which will be shortly discussed here, is *The Third Hand.* In this work, he mimics the substitution of the body by a technological construct. *The Third Hand* may be regarded as a form of physical extension of the body, which is connected to an attempt to represent discomfort of this kind of technology [2].

Another very interesting aspect of this piece is the interpretation of computer technologies as sterile and non-organic which have evolved by their pairing with the human body. In addition, the human body is seen as increased and augmented by its attachment to technology (Cyborg notion). With this project, Stelarc viewed *The Third Arm* as a prosthesis of his own body, thus exposing it as a structure that may be assembled or disassembled. These extra 'body parts' somehow evoke a new questioning of the prosthetic body parts as a means of articulating loss [2].

Figure 3. Stelarc and The Third Hand [11].

The idea of extending the body by using *The Third Hand* in Stelarc's work reflects the sensation of adding bodily functions and ability. We believe if Stelarc's *Third Hand* is used simultaneously, it will create the sensation of having three hands, instead of two, which if later on replaced will create the sensation of loss.

3.1.12 Social Connectivity

With the rise of the Internet age and wireless communication technology it is impossible to separate this factor in designing wearable expressions. Levels of social connectivity gained by the user while wearing Wearable Expressions has the potential to increase levels of engagement between the user and the device and also with the social sphere.

In order to elaborate on this subject, consider the social micro-blogging website: Twitter. It has created a new way of communicating and socializing among its users and Twitter can create social connectivity in terms of Wearable Expression device. A recent example of the "marriage" between them would be the Twitter dress worn by an artist known as Imogen Heap during the Grammy Awards 2010 [12].

Walter Moritz and Imogen Heap created the Twitter dress. It allows Imogen Heap to receive tweets from her fans and the

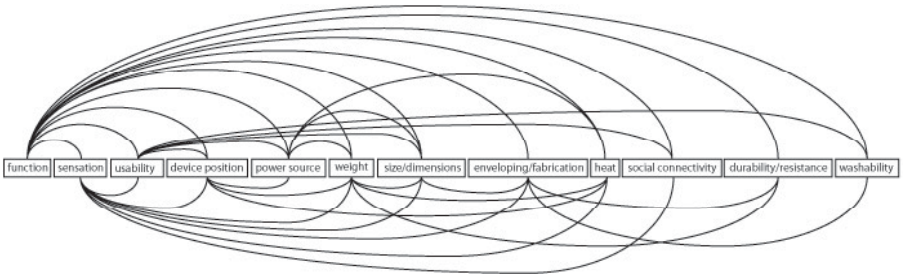

Figure 4. Diagram describing the overlapping relationship of shaping factors of Wearable Expressions

LED collar of the dress and images are displayed on an iPod Touch built in a Fendi purse she carries. The wearable device is connected to a wireless router that connects the Twitter dress to the virtual world [12].

The idea of 'including the fans' to the Grammy Awards stage creates a two-way connection between the fans and the artist, through the medium of Wearable Expression devices. The fact that in order to create the new level of engagement with her fans she was wearing a form of Wearable Expression, there is a sense of engagement and levels of sensation between her and her fans.

Figure 5. Imogen Heap at the Grammy Awards 2010 and the LED collar of the Twitter dress [12].

4. FUTURE DEVELOPMENT

This first step has involved a survey of existing wearable technologies, devices and wearable artworks to arrive at this framework of attributes important in the design and evaluation of the user experience for Wearable Expression, particularly guided by a design and user-centred approach. The next step will be to evaluate designs and assess the efficacy of this framework for analysis and evaluation on a small group of prototypes for different purposes, exhibiting distinct physical characteristics (e.g. flexibility, location on the body, type of sensors and information conveyed). Our evaluation will look at a) how the Wearable Expressions perform for the user, assessed in several different ways to correlate the results, e.g. observation and reflection on a goal-oriented task and questionnaires/interview to gather more qualitative impressions; and b) how the Framework performs as a metric of important design criteria. We will examine the relationship of scores for design attributes in our Framework against users' impressions and performance in the corresponding dimensions. The second iteration of the Framework will be modified and improved accordingly. The outcome will be a Framework that can be used by designers in the prototype and iterative stages of new Wearable Expression product design to hopefully achieve a more user-centred and taken-up generation of Wearable Expression devices.

5. REFERENCES

[1] Baber, C., Knight, J., Haniff, D., Cooper, L. *Ergonomics of Wearable Computers*. In Mobile Networks and Applications 4 (1999) 15-21.

[2] Clarke, J. 'The Human/Not Human in the Work of Orlan and Stelarc'. In *The Cyborg Experiments: the Extensions of the Body in the Media Age*, ed. J. Zylinska, Continuum, New York, 2002.

[3] Graves, J. A., Martin, A. D., Miltenberger, L. A., Pollock M. L. *Physiological responses to walking with hand weights, wrist weights, and ankle weights.* In Medicine and Science in Sports and Exercise 20 (1988) 265-71.

[4] Lancaster, K. J. A New Approach to Consumer Theory. In Modern Consumer Theory, ed. E. Elgar. Aldershot. United Kingdom. 1991.

[5] Levisohn, A. *The Body as a Medium: Reassesing the Role of Kinesthetic Awareness in Interactive Applications*. In Proc. MM'07, Augsburg, Bavaria, Germany. 2007.

[6] Maeda, J. *The Laws of Simplicity.* The MIT Press, Cambridge, MA, 2006.

[7] Meijkamp, R. *Changing Consumer Behaviour through Eco-efficient Services*. Thesis TU Delft-Design for Sustainability Research Programme publication 3, Delft, The Netherlands. 2000

[8] Miller, J. F., Stamford, B. A. *Intensity and energy cost of weighted walking vs. running for men and women*. In Journal of Applied Physiology 62 (1987) 1497-1501.

[9] Miller, P. *Oakley THUMP PRO debuts, reviewed*. Retrieved from: http://www.engadget.com/2006/11/07/oakley-thump-pro-debuts-reviewed/ on 1 February 2010.

[10] Ryan, S. E. *What is Wearable Technology Art?*. Retrieved from: http://www.intelligentagent.com/archive/ia8_1_SocialFabrics_WearableTechnologyArt_Ryan.pdf on 21 October 2009.

[11] *Third Hand.* Retrieved from http://www.stelarc.va.com.au/third/third.html on 1 February 2010.

[12] Waldemeyer, M., *Imogen Heap wears Twitter dress at the Grammys*. Retrieved from: http://waldemeyer.blogspot.com/2010/02/imogen-heap-wears-twitter-dress-at.html on 2 February 2010.

[13] Wilde. D. *The hipdiskettes: Learning (through) Wearables*. In Proc. OZCHI'08, Cairns, Australia. 2008.

BIBLIOGRAPHY

2001: Space Odyssey 1968, motion picture, MGM, Australia.

007, *M-Dress + Cute Circuit*, Cute Circuit, viewed at 8 October 2011, <http://www.cutecircuit.com/products/mdress/>.

Assuach, A. 2003, *My Trousers*, viewed 5 October 2011, <http://www.assaashuach.com/>.

Atunez, M. 2010, artist's weblog, viewed 5 October 2011 at: <http://marceliantunez.blogspot.com/>.

Baber, C., Knight, J., Haniff, D. & Cooper, L. 1999, 'Ergonomics of Wearable Computers', *Mobile Networks Applications*, vol 4, pp. 15-21.

Bailey, C. A. 1996, *A Guide to Field Research*, Pine Forge Press, Thousand Oaks, CA.

Barnard, M. 2002, *Fashion as Communication*, Routledge, London.

Barrie, J. M. 2003, *Peter Pan (100th Anniversary Edition)*, Henry Holt and Company, New York, USA.

Baudelaire, C. 1859-1861, *Le Peintre de la moderne.*

Beloff, L. 2008, 'The Curious Apparel: Wearables and The Hybronaut' in *Social Fabrics: Intelligent Agent Volume 8 No: 1*, Dallas.

Benjamin, W. 1999, *The Arcades Project*, trans. H. Eiland & Kevin McLaughlin, Belknap/Harvard University Press. Cambridge, MA.

Bentz, V. M., & Shapiro, J. J. 1998. *Mindful Enquiry In Social Research*, Sage Publishing, Thousand Oaks, CA.

Berzowska, J., 2005, 'Electronic Textiles: Wearable Computers, Reactive Fashion, and Soft Computation', in *Textiles: The Journal of Cloth and Culture, Volume 3, Issue 1*. London: Berg Publishers. (pp. 101-113).

Berzowska, J. and Coelho, M., n. d. *Kukkia and Vilkas: Kinetic Electronic Garments*. [pdf] Available through XSLABS website

<http://www.xslabs.net/papers/iswc05-berzowska.pdf > [Accessed 18 December 2013].

Boehner,K., David, S., Kaye, J. & Sengers, P., 2005, 'Critical Technical Practices as a Methodology for Values in Design'. *CHI 2005 Workshop on Quality, Values and Choices*, Portland, Oregon.

Bolton, A. 2002, *The Supermodern Wardrobe*, V&A Publications, London.

Bowery, L. & Greer, F. 2005, *Leigh Bowery Looks*, Violette Editions, London.

Bryman, A & Burgess, R. 2002, *Analyzing Qualitative Data*, Routledge, New York

Chalayan, H. 2007, *111*, website, viewed at 12 December 2011, <http://husseinchalayan.com/#/past_collections.2007.2007_s_s_one_hundred_and_eleven/>.

Cho, G. 2004, *New High-Tech Textiles*, Sigma Press, Seoul, Korea.

Co. E. 2000, 'Computation and Technology as Expressive Elements in Fashion', PhD Thesis, MIT, viewed at 6 October 2011, <http://acg.media.mit.edu/people/elise/thesis/index.html>

Clark, A. 2003, *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence*, Oxford University Press, New York.

Clarke, J. 2002, *'The Human/Not Human in the Work of Orlan and Stelarc'* in J. Zylinska (ed.), *The Cyborg Experiments: the Extensions of the Body in the Media Age*, Continuum, New York.

Cross, N. 1998, 'Natural Intelligence in Design', in *Design Studies 20*, pp. 25-39.

Cross, N. 2006, *Designerly Ways of Knowing*, Springer-Verlag, London.

Clynes, M. E. & Kline N. S. 1960, 'Cyborgs and Space', in C. H. Gray (ed.), *The Cyborg Handbook*, Routledge, New York.

Collaizi, P. 1978, 'Psychological Research as a Phenomenologist Views It', in R. Valle & M, King (eds.), *Existential-Phenomenological Alternatives for Psychology*, Oxford University Press, New York.

Darke, J. 1979, 'The Primary Generator and the Design Process in Engineering and Architecture', *Design Studies*, vol. 1, no. 1, pp. 36-44

Drugge, M., Nilsson, M., Parviainen, R. & Parnes, P. 2004, 'Experiences of Using Wearable Computers for Ambient Telepresence and Remote Interaction', *ACM SIGGM Workshop on Effective Telepresence 2004*, ACM Press, New York, USA.

Dorst K. 2006, *Understanding Design*, BIS Publishers, Amsterdam.

Dorst, K. 2009, 'Layers of Design: Understanding Design Practice', *International Association of Societies of Design Research*, Seoul, Korea, pp. 157-166.

Dunne, L.E., Smyth, B., Ashdown, S.P., Sengers, P. & Kaye J. 2005. 'Configuring the User in Wearable Technology Design', *Proceedings of the 1st Wearable Futures Conference*. Newport, Wales.

Dybwad, B. 2010, *Grammys: Imogen Heap Accepts Award Wearing "Twitter Dress",* website, viewed at 5 October 2011, <http://mashable.com/2010/01/31/grammys-imogen-heap-twitdress/>.

Eve8 1991, motion picture, MGM, USA.

Ford, P. 2009, What is Aesthetics?, website, viewed at 15 November 2012, <http://paulford.com/what-is-aesthetics/ > .

Furbank, P.N. & Cain, A. M. 2004, *Mallarme on Fashion: A Translation of the Fashion Magazine La Derniere Mode with Commentary*, Berg Publishers, New York, USA.

Gao, Y. 2007, *Walking City*, artist's website, viewed at 3 October 2011, <http://yinggao.ca/interactifs/walking-city/>

Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., Martin, R., 1998, 'Design for Wearability', *2nd International Symposium on Wearable Computers*, Pittsburgh, PA, USA, pp. 116-122.

G. I. Joe: Rise of the Cobra 2009, motion picture, Paramount Pictures, Belgium.

Gibson, W. 2007, *Neuromancer*, Ace Trade Publishing, New Jersey.

Giorgio, R. & McNeil, P. (eds) 2010, *The Fashion History Reader: Global Perspectives*, Routledge, Abingdon, Oxon.

Grau, O. (ed.) 2010, *Media Art Histories*, MIT Press, Cambridge, Massachusetts, USA.

Graves, J. A., Martin A. D., Miltenberger, L. A., Pollock M. L. 1988, '*Physiological Responses to Walking with Hand Weights, Wrist Weights, and Ankle Weights'*, *Medicine Science in Sports and Exercise*, vol. 20, pp. 265-71.

Gronewald, T. 2004, 'A Phenomenological Research Design Illustrated', *International Journal Of Qualitative Methods*, vol: 3 (1), viewed at 13 September 2012, <http://www.ualberta.ca/~iiqm/backissues/3_1/pdf/groenewald.pdf >.

Haraway, D. J. 1991, *Simians, Cyborgs, and Women: The Reinvention of Nature*, Routledge, New York.

Harte, N. 2010, 'The Study of Fashion and Dress', in The Fashion History Reader: Global Perspectives, Routledge, Abingdon, Oxon, pp. 15-17.

Hayles, N. K. 1999, *How We Became Posthuman: Virtual Bodies In Cybernetics, Literature, and Informatics*, The University of Chicago Press, London.

Heller, S.-G. 2010, 'The Birth of Fashion', in *The Fashion History Reader: Global Perspectives*, Routledge, Abingdon, Oxon, pp. 25-29.

Henni, K. 2008, Motion Response Sportswear, weblog, viewed at 8 October 2011, <http://khenni.wordpress.com/2008/09/24/motion-response-sportswear/>.

Hillier, B. & Leaman, A. 1976, 'Architecture as a Discipline'. *Journal of Architecture Research*, vol. 5, no. 1, pp. 28-32.

Hull, M., Neaves, P., Bedford-Roberts, J. 1997, 'Towards Situated Computing', *First International Symposium on Wearable Computers*, Cambridge, MA, USA, viewed at 15 September 2012, <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=629931>.

Hycner, R. H. 1999, 'Some guidelines for the phenomenological analysis of interview data', in A. Bryman & R. .G. Burgess (Eds.), *Qualitative Research*, vol. 3, pp. 143-164.

iRobot 2004, motion picture, 20th Century Fox Films, USA.

Iron Man 2008, motion picture, Paramount Pictures, Sydney, Australia.

Jefferies, J. 2012, 'Wires and Wearables', in J. Pitt (ed.), *This Pervasive Day, The Potential and Perils of Pervasive Computing*, Imperial College Press, United Kingdom, pp. 151-162.

Kant, I. 1997, *Critique of Pure Reason*, trans. P. Guyer and A. E. Woods, Cambridge University Press, New York.

Kant, I. 2000, *Critique of the Power Judgment*, trans. P. Guyer and E. Matthews, Cambridge University Press, New York.

Kensit, D. A. 2000, 'Rogerian Theory: A Critique Of The Effectiveness Of Pure Client-Centred Therapy', in *Counselling Psychology Quarterly*, vol. 13, no. 4, pp.345-342.

Kortuem, G., Segall, Z. and Bauer, M. 1998, 'Context-Aware, Adaptive Wearable Computers as Remote Interfaces to Intelligent Environments'*, IEEE International Symposium on Wearable Computers*, IEEE CS Press, Los Alamitos, California, pp. 58-65.

Kruger, D. 1988, *A Introduction to Phenomenological Psychology* (2nd edition), Juta Publishing, Cape Town, South Africa.

Kuniavsky, M. 2003. *Observing The User Experience: A Practitioner's Guide to User Research*. Morgan Kauffman Publishers. San Francisco, CA.

Kunzru, H. 1997, 'You Are Cyborg', *Wired Magazine*, Issue 5. 02, February 1997, viewed at 13 December 2012, <http://www.wired.com/wired/archive/5.02/ffharaway.html?topic=&topic_set=>.

Kvale, S. 1996, *Interviews: An Introduction to Qualitative Research Interviewing*, Sage Publishing, Thousand Oaks, CA.

Lancaster K. J. 1991, 'A New Approach to Consumer Theory' in E. Elgar (ed.), *Modern Consumer Theory*, Aldershot, United Kingdom.

Lawson, B. 1980, *How Designers Think,* Architectural Press, London, UK.

Lee, Y., Cho, H.-S., Lee, Y.-J. & Cho, H.-K. 2010, 'Designing Technology for Smart Clothing' in G. Cho (ed.), *Smart Clothing: Technology and Applications*, CRC Press, Boca Raton, FL.

Lehmann, U. 2000, *Tigersprung: Fashion in Modernity*, MIT Press, Cambridge, MA.

Levisohn, A. 2007. *The Body as a Medium: Reassessing the Role of Kinesthetic Awareness in Interactive Applications*. Proceedings of ACM Multimedia '07, Augsburg, Bavaria, Germany.

Lipovetsky, G. 1994, *The Empire of Fashion Dressing Modern Democracy*, Princeton University Press. Princeton.

Mackinney-Valentin, M. 2010, Snapshot: Trends, in *Berg Encyclopedia of World Dress and Fashion: Volume 10 – Global Perspectives*, viewed at13 February 2014,< http://www.bergfashionlibrary.com/view/bewdf/BEWDF-v10/EDch10022.xml >

Manovich, L. 2001, *Fashion Sites*, viewed at 16 November 2011, <http://www.manovich.net/DOCS/art_fashion.html>.

McLuhan, M. 1994, *Understanding Media: The Extensions of Man*, MIT Press, USA.

McNeil, P. (ed.) 2009*, Fashion: Critical and Primary Resources Volume 4: The Twentieth Century to Today*, Bloomsbury, London.

Maeda, J. 2006, *The Laws of Simplicity*, MIT Press, Cambridge, MA.

Meijkamp, R. 2000, 'Changing Consumer Behaviour through Eco-efficient Services', PhD Thesis, TU Delft, Delft, The Netherlands.

Merriam-Webster Incorporation 2013, *Technology,* viewed at 10 January 2013*,* <http://www.merriam-webster.com/dictionary/technology>.

Minority Report 2002, motion picture, 20th Century Fox Films, Sydney, Australia.

Mitchell, W. J. 2003, *Me++: the Cyborg Self and the Networked City*, MIT Press, Massachusetts.

Miller, J. F. & Stamford, B. A., 1987, 'Intensity and Energy Cost of Weighted Walking vs. Running for Men and Women', *Journal of Applied Physiology*, vol. 62, no. 4, pp. 1497-1501.

Mizell, D. 2001, 'Boeing's Wire Bundle Assembly project', in Barfield, W., Caudell, T. (ed.), *Fundamentals of Wearable Computing and Augmented Reality*, Lawrence Erlbaum Associates, New Jersey, pp. 447-467.

Munz, L. & Kunster, G. 1966, *Adolf Loos: Pioneer of Modern Architecture*, Thames & Hudson, London.

Mura, G. 2004, 'Intelligent Interfaces: Transformation of Self-expression, Communication and Fashion with Wearable Technologies', ISEA Symposium 2004, Helsinki, Finland, viewed 15 December 2013, <http://m-cult.org/sites/m-cult.org/files/ISEA2004_proceedings.pdf>

Nicolai, T., Sindt, T., Witt, H., Reimerdes, J., Kenn, H. 2006, 'Wearable Computing for Aircraft Maintenance: Simplifying the User Interface', *3rd International Forum on Applied Wearable Computing*, Bremen, viewed at 5 October 2011, <http://spring.bologna.enea.it/ifawc/2006/proceedings/IFAWC2006_3.pdf >.

Orth, M.A. 2001, 'Sculpted Computational Objects with Smart and Active Computing Materials', PhD Thesis, MIT, California, MA.

O'Mahony, M. 2002. *Cyborg: The Man-Machine*. Thames & Hudson, London.

O'Sullivan, D. & Igoe, T. 2004, *Physical Computing: Sensing and Controlling the Physical World with Computers*, Thomson, Boston, 2004.

Paek, J. Y. 2008, *Joo Youn Paek: Self-Sustainable Chair*, video recording, viewed at 6 October 2011 at: <http://www.youtube.com/watch?v=5MCVTatYhLU>

Parvus Corporation. Year unavailable, *Parvus - Zypad WL 1000-Wrist Wearable Computer*, viewed at 13 August 2012, <http://www.parvus.com/product/overview.aspx?prod=WL1000>

Paul, C. 2003, *Digital Art*, Thames & Hudson, London UK.

Pollio, H. R., Henley, T. B. & Thompson, C. J. 1997, *The Phenomenon of Everyday Life*, Cambridge University Press, UK.

Reynolds, H. 1993-2007, *The Memorial Dress*, viewed at 11 October 2011, <http://hunterwreynolds.com/section/42991_The_Memorial_Dress.html>.

Rhodes, B. No date, *A Brief History of Wearable Computing*, viewed at 4 October 2011, <http://media.mit.edu/wearables/lizzy/timeline.html>.

Rhodes, B. 2000, *Just-In-Time Information Retrieval*, doctoral dissertation, Media Laboratory, Massachusetts Institute of Technology, Massachusetts.

Rhodes, B. & Mase, K. 2005, 'Wearables in 2005', *Pervasive Computing*, Vol. 5, No. 1, pp. 92-95.

Rittel, H. & Weber, M. 1973, 'Dilemmas in a General Theory of Planning', *Policy Sciences*, vol. 4, pp. 155-196.

Ryan, S. E. 2008, 'What is Wearable Technology Art?' in *Social Fabrics: Intelligent Agent Volume 8 No: 1*, Dallas.

Schatzman, L. & Strauss, A. L. 1973, *Field Research; Strategies for a Natural Sociology*, Prentice-Hall, Englewood Cliffs, NJ.

Science Daily 2012, *Clothing the Body Electric: Cotton T-Shirt Fabric Can Store Electricity, Maybe Keep Your Cell Phone Charged*, viewed 10 January 2014, <http://www.sciencedaily.com/releases/2012/06/120629211540.htm>.

Scrivener, S.A.R. 2002, *The Art Object Does Not Embody a Form of Knowledge*, viewed 13 February 2014, <https://www.herts.ac.uk/__data/assets/pdf_file/0008/12311/WPIAAD_vol2_scrivener.pdf>.

Seymour, S. 2008, *Fashionable Technology: The Intersection of Design, Fashion, Science and Technology*, SpringerWienNewYork, Austria.

Shaeffer, C. B. 2001, *Couture Sewing Techniques*, Taunton Press, Newtown, CT.

Shanks, M. 2006, *Hearts: A Cyborg Manifesto*, viewed at 7 October 2011, <http://documents.stanford.edu/67/1516>.

Shelley, M. 2005, *Frankenstein*, viewed at 6 October 2011, <http://www.literature.org/authors/shelley-mary/frankenstein/>.

Snow, C. P. 2008, *The Two Cultures*, Cambridge University Press, New York, USA.

Sokolowski, R. 2000, *Introduction to Phenomenology*, Cambridge University Press, Cambridge, UK.

Star Trek 2009, motion picture, Paramount Pictures, Sydney, Australia.

Starner, T. 2001, 'The Challenges of Wearable Computing: Part 1', *IEEE Micro*, vol. 21, viewed at 5 October 2011, <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.153.9668&rep=rep1&type=pdf >.

Stelarc, 1980, *The Third Hand*, artist's website, viewed 2 October 2011, <http://stelarc.org/?catID=20247>.

Stelarc, 2011, *Stelarc//Bio Notes,* website, viewed at 5 October 2011, <http://stelarc.org/?catID=20239 >.

Stephenson, N. 2000, *Snow Crash*, Bantam Books, New York.

Strauss, A. & Corbin J. 1990, *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, Sage Publishing, New York.

Tanaka, A. 1956, *Electric Dress*, website, viewed at 12 October 2012, <http://nymag.com/nymetro/arts/art/reviews/9937/> .

Tao, X. 2001, *Smart Fibers, Fabrics and Clothing*, CRC Press, USA.

Terminator 1984, motion picture, MGM, Sydney, Australia.

Turkle, S. 2003, 'Who Am We?', *Wired Magazine*, viewed at 3 October 2011, <www.wired.com/wired/archive/4.01/turkle.html>

Vidler, A. 1990, 'Homes for Cyborgs: Domestic Prostheses from Salvador Dali to Diller and Scodifio', *Ottagono 9*, p. 36-55.

Villani, T. 1995, *Athena Cyborg. Per Una Geografia Dell'espressione: Corpo, Territorio, Metropolis*, Mimesis, Milan, Italy.

Vinken B. 1993, *Mode nach der Mode: Geist und Kleid am Ende des Jahrhunderst*, Fischer, Frankfurt.

Visue, A. 2005. 'Augmented Bodies: The Visions and Realities of Wearable Computers', PhD thesis, University of Toronto, Toronto.

Watier, K. 2003. 'Marketing Wearable Computers to Consumers: an examination of early adopter consumer feelings and attitudes toward wearable computers', Masters thesis, Georgetown University, Washington DC.

Weiser, M. 1991. 'The Computer for the Twenty-First Century', *Scientific American*, vol. 265, No. 3, September, pp. 94-104.

Wigley, M. 1995, *White Walls, Designer Dresses: The Fashioning of Modern Architecture*, MIT Press, Cambridge, MA.

Wilde, D. 2008, The Hipdiskettes, website, viewed at 10 November 2011, <http://www.daniellewilde.com/dw/hipdiskettes.html>.

Wilde, D. 2008, 'Hipdisk: Using Sound To Encourage Physical Extension, Exploring Humour in Interface Design', *International Journal of Performance Arts and Digital Media (IJPADM),* vol. 4 no. 1, Pp.7-26. Intellect Ltd., viewed at 10 November 2010, <http://www.daniellewilde.com/dw/publications_files/wilde_hipDisk_IJPADM.pdf>

Wilson E. 2003, *Adorned in Dreams: Fashion and Modernity*, Rutgers University press, New Brunswick: New Jersey.

XSLABS n.d., viewed 10 January 2014, <http://www.xslabs.net/theory.html>.

Yoon, J. 2011, 'The Future. Where Is It?', *SLAMXHYPE Blog*, weblog, viewed at 7 October 2011, http://slamxhype.com/blogs/the-future-where-is-it/