EXPLORING FICTIONAL SCENARIOS OF PERVASIVE COMPUTING TO IDENTIFY MEANINGFUL GESTURES FOR INTUITIVE INTERACTIONS

by

Daniel Abs da Cruz Bianchi

A thesis submitted to
the Faculty of Graduate and Postdoctoral Affairs
in partial fulfillment of the requirements for the degree of

Master of Design

In

Industrial Design

Carleton University
Ottawa, Ontario

ABSTRACT

Technological advances in pervasive computing have expanded the possibilities of seamless interactions between people and technology through the use of gestures. However, gesture-based interactions challenge designers who need to understand people’s preferences when dealing with technology-enabled environments. Limitations of current technologies complicate the exploration of gesture-based interactions. This research examines fictional scenarios of possible futures for pervasive computing intending to identify opportunities for gestures that can replace traditional inputs. The examination of future technologies through fiction and centred on users' preferences contributes to understanding the potential of interactions focused on body movement and grounded in users’ context. Applying gestures that reflect people’s preferences may lead to the design of intuitive interactions. This study reveals a correlation between gestures observed in fiction and those generated by users. It also reveals issues and opportunities for improving gesture-based interactions.

Keywords: gesture-based interactions, embodied interactions, pervasive technologies, design fiction

ACKNOWLEDGMENTS

Someone's achievements are never just the result of individual effort, and no one can ever succeed if not surrounded by inspiring people.

I would like to thank Professor Lois Frankel and Professor Anthony Whitehead for their support and valuable guidance. I am thankful for their time, dedication and insightful feedback, without which this research would not be possible. I would like to express my gratitude to my colleagues and to the staff of the School of Industrial Design for sharing many moments of this long journey.

Thanks to all participants of the workshops and surveys for being available and agreeing to participate in this study.

I also would like to thank my friends at Halogen Software for their encouragement throughout the final months of this research. Thanks to all of my friends at the Canadian Dental Hygienists Association, particularly Mike Roy, Angie D'Aoust and Ondina Love for their unquestionable support from the beginning.

Thanks to my great friends Lucas Lacerda and Gabi Sanches for leading the way and inspiring me to succeed in this master's level program.

Thanks to my family for the love and care they have provided me through my entire life.

Finally, I would like to thank my wife Eliza and my son Gabriel for always being there for me, for believing in me and for making me a better person. They are my greatest motivation to pursue my dreams.

Thank you.

TABLE OF CONTENTS

Abstract i

Acknowledgments ii

Table of Contents iii

List of Figures vii

List of Tables ix

List of Appendices x

CHAPTER

1. INTRODUCTION 1

  1.1 Background 1

  1.2 Purpose of the Research 2

  1.3 Contribution 3

  1.4 Hypothesis 4

  1.5 Structure of the Thesis 5

2. LITERATURE REVIEW 7

  2.1 Pervasive Technologies 7

    2.1.1 Visions of ubiquitous computing 7

    2.1.2 Experiencing ubiquitous computing 8

    2.1.3 Interactions with and in the physical space 10

  2.2 Tangible Embodied Interactions 13

    2.2.1 Embodied interactions 13

2.2.2 The role of body in interaction 13

2.2.3 Approaching movement-based interactions 15

2.3 Gesture-based Interactions 19

2.3.1 Taxonomy of gestures 19

2.3.2 Gestures and touchless interactions 23

2.3.3 User-defined gestures 24

2.4 Critical Design 26

2.4.1 Design and fiction 26

2.4.2 Speculative design and potential futures 28

2.4.3 Imagination and design 30

2.5 Framing the Research 31

3. METHODS 34

3.1 Ethics Considerations 35

3.2 Movie Analysis 36

3.2.1 Setting 36

3.2.2 Subject selection procedure 36

3.2.3 Data collection procedures 38

3.2.4 Data analysis 39

3.3 Experience Simulation Workshop 40

3.3.1 Setting 41

3.3.2 Participants 42

3.3.3 Experience simulation workshop 43

3.3.4 Data analysis 46

3.4 Validation Questionnaire 47

3.4.1 Setting.. 48

3.4.2 Participants 48

3.4.3 Data collection procedures 48

3.4.4 Data analysis.. 50

4. RESULTS 51

4.1 First Method: Movie Analysis 51

4.1.1 Contexts of gestural interactions in fiction.. 51

4.1.2 Inputs and outputs 53

4.1.3 Taxonomy of gestures 56

4.2 Second Method: Experience Simulation Workshop 61

4.2.1 Enactment of the gestures.. 61

4.2.2 Gesture generation... 66

4.2.3 Review of gestures and discussion of the experience 69

4.3 Third Method: Validation Questionnaire 72

4.3.1 Likert scale questions 73

4.3.2 Open-ended questions 73

4.4 Summary of Findings 75

5. DISCUSSION 79

5.1 First Research Question.. 79

5.1.1 Contexts of pervasive technology 80

5.1.2 Attributes of gesture-based interactions 83

5.2 Second Research Question 85

5.2.1 Enactment of gestures and the movie analysis 86

5.2.2 Insights from participants' conversations.. 89

5.2.3 How participants perceive the gestures 91

5.3 Third Research Question 91

5.3.1 Intuitive gestures 92

5.3.2 Ample versus small gestures. 93

5.3.3 Gestures to support the design process.. 93

5.4 Main Research Question.. 94

5.4.1 The fictional scenario 94

5.4.2 Design opportunities.. 95

6. CONCLUSION 97

6.1 Contributions 99

6.2 Limitations.. 100

6.3 Future Research 101

REFERENCES 103

APPENDICES 106

LIST OF FIGURES

Figure **Page**

01. The three perspectives in the design methodology……………….…..………….16

02. Diagram of key activities……………………………………………………...18

03. The possible futures…………………………………………………...…29

04. Gesture-based interaction……………………………………………………...39

05. The experience simulation workshop setting……………………………..………42

06. Experience simulation workshop diagram……………………………..………44

07. Gestures created in the workshop………………………………………………..49

08. Co-occurrence of gestures…………………………………………………..…52

09. Reference area for interaction…………………………………………………53

10. Handedness………………………………………………………………………57

11. Amplitude of gestures……………………………………………………………57

12. Dynamic Pose with Path……………………………………………...……..58

13. Metaphorical gestures……………………………………………………………59

14. World-dependent gesture binding………………………………………………..60

15. Continuous flow………………………………………………………..…………61

16. Nature of gestures………………………………………………………………..64

17. Familiar gestures…………………………………………...……………….68

18. Technology mediating conversations……………………………...………….80

19. Engaging interaction…………………………………………………….……….81

20. Tangible interfaces…………………………………………………...………..82

21. Body as expression……………………………………………...………….83

22. Correspondence of gestures……………………………………..………….87

23. Symbolic gestures…………………...……………...………………………88

24. User-defined area for interaction……………………...………………………89

LIST OF TABLES

Table **Page**

01. Taxonomy of gestures……………….…..……………………….……….……….…..21

02. List of movies analyzed…………………….…………..….………………….38

03. Inputs and outputs of gestural interactions……………….….………………….55

04. Taxonomy of enacted gestures…………………………………………………...65

05. Similar gestures created by the groups…………………………...…...………66

06. Summary of findings from the gesture generation….…………………………...69

07. Summary of findings from the workshop review….……………….….………...72

08. Validation questionnaire scores……………………………………...……...…73

09. Feasible and unfeasible gestures………………………………….…………...75

10. Summary of findings…………………………………………….….………77

LIST OF APPENDICES

Appendix **Page**

A. Letter of Invitation of Experience Simulation Workshop……..………………….107

B. Letter of Invitation of Validation Questionnaire..……………………………....110

C. Consent Form for Experience Simulation Workshop……………………..……113

D. Consent Form for Validation Questionnaire..…………………………………...117

E. Invitation Poster……………….…….…………………………………..……...…121

F. Script of Experience Simulation Workshop……………………………………....123

G. Script of Validation Questionnaire ………………………………….………128

CHAPTER 1

INTRODUCTION

This research intends to develop a better understanding of gesture-based interactions with pervasive computing, acknowledging people's preferences when interacting with such technologies. Taking into consideration the potential for innovative possibilities in technology-enabled environments, as well as the technical limitations of current technologies, it proposes the exploration of fictional, future scenarios as the starting point for the study. The research examines fictional scenarios of gesture-based interactions, searching for opportunities that can provoke discussions about preferred gestures for touchless interactions. The goal is to identify gestures and aspects of gestures that can inform the process of designing interactions with pervasive technologies that require body movement as input.

1.1 Background

Over twenty years ago, Mark Weiser (1991) imagined a future filled with computational devices. In his vision, technology would be both pervasive and invisible to people. Ubiquitous computers would be woven into the fabric of people's lives.

The idea of ubiquitous computers as invisible entities merged into everyday life has expanded since Weiser's (1991) seminal work was first published. Recent innovations in technology have expanded the possibilities of interaction, and the development of pervasive computing, wearable and sensor technologies has changed the environment in which people live.

The physical space and the human body are surrounded by devices that can read and respond to inputs such as location, pulse, gestures and movement patterns (Loke & Robertson, 2011). As interactions become more embedded in the everyday environment, designers are required to design new types of interactions, enabling people to use their innate skills (Hornecker, 2011). Moreover, pervasive technologies should provoke people, engaging them in creative interactions (Rogers, 2006). As Vertegaal (2011) suggests, pervasive technologies should enhance the sensory and motor skills of the human body in the physical space.

In this context, the body should be at the centre of design considerations for interactive technologies (Hornecker, 2011; Loke & Robertson, 2011) because the human body plays a vital role in shaping everyday activities (Klemmer, Hartmann, & Takayama, 2006). First, the body is the means by which people communicate, learn about and adapt to the world. Second, through gestures, movements and postures, the body is able to express [or convey] a person’s understanding of their world (Loke & Robertson, 2011). Third, the use of gestures reduces people's cognitive load (Klemmer et al., 2006), and they facilitate the interaction with technology when performed in conditions that are familiar to the users (Grandhi, Joue, & Mittelberg, 2011).

One of the challenging areas of study that has received relatively little attention from researchers is learning about gestures that are intuitive, natural and meaningful for the users in specific contexts (Grandhi et al., 2011).

1.2 Purpose of the Research

The purpose of this research is to gain an understanding of the gestures that people intuitively choose to perform when interacting with technology-enabled environments. The identification of the attributes that characterize those preferred gestures is essential to achieving the goal of this study. It is also important to understand the reasoning behind the choice of gestures.

A second objective is to identify opportunities for replacing traditional touch inputs with gestures that resonate with users' contexts, creating more intuitive interactions.

Gestures, in the context of this research, comprise body movements performed with the limbs and used consciously and deliberately as input to interact with technologies. Although the analysis in this study encompasses touch and touchless gestures, the main focus of this research is gestures used to interact with interfaces that do not require touch as input.

Considering that the technologies that require body movement as input still have to overcome technical challenges before becoming established in everyday life, this research speculates about future technologies through an exploration of fictional scenarios of pervasive computing. The examination of the vision of future scenarios allows for a more extensive analysis of the possibilities of gesture-based interaction, free of technical constraints.

1.3 Contribution

The findings from this research may contribute to new knowledge about the possibilities and limitations of interaction based on gestures. The contributions might also facilitate a categorization of gestures that are more intuitive for users, with the identification of attributes of gestures that are suitable for interacting with technology-enabled environments. It is expected that this knowledge will support researchers and practitioners in improving current technology. It may also support the development of new technologies that reflect users' preferred gestures, possibly leading to more intuitive and easy to use input features.

1.4 Hypothesis

In this research, the hypothesis is that the exploration of fictional scenarios of pervasive computing can identify opportunities for gesture-based interactions that reflect people's preferred body movements for interacting with technology-enabled environments.

The investigation of future scenarios depicted in fiction movies may point to a set of gestures that are more suitable and preferable for interacting intuitively with technologies that require body movement as input. This set of gestures should reflect people's preferences and may replace more traditional inputs, such as touch. The approach of taking into account people's predilections diverges significantly from the current practice of having the technology dictate the interactions, most of which are defined by the limitations of the technology. Ultimately, this user-centred approach will offer researchers and practitioners an important frame of reference when devising interactive devices.

To elucidate the ideas proposed in this hypothesis, it is necessary first to explore the topic of ubiquitous computing and the perspectives on the future of pervasive technologies. In addition, it is important to understand how people relate to technology embedded in their physical space and the role of the body in this relationship. In analyzing the role of the body, it is essential to learn about the use of gestures as a form of interaction with technology-enabled environments and to understand aspects of gesture-based interactions. Lastly, in order to bridge the perspectives on future technologies with the opportunities for gestural interactions it is important to examine how the study of fictional scenarios can be used as a form of critique of the current situation.

1.5 Structure of the Thesis

This work is divided into six chapters that reflect the structure of the research. Each chapter presents a portion of the study and is summarized as follows:

The first chapter briefly introduces the object of the study. The research context is delineated, along with the rationale for undertaking the study. The first chapter also introduces the scope of the topic broken down into objectives that are framed by the research. Additionally, the first chapter describes the contributions that this research expects to make to the field.

The second chapter is a literature review that provides the theoretical framework for the research. The literature review explores the existing research with the intention of categorizing the topics that this study will take into account. To that end, the topics in the second chapter are subdivided and present theories about ubiquitous computing, tangible and embodied interactions, studies on gesture-based interaction, and theories about critical design.

The third chapter provides a detailed description of the research methodology. It justifies the choice of a qualitative research approach and explains the triangulation of methods as a way to identify patterns and uncover the findings from data collection: movie analysis; experience simulation workshop; and validation questionnaire. Moreover, chapter three explains the reasoning behind the choice of each of these three methods, describing for each the sample, the setting, and the procedures for data gathering and analysis.

Chapter four presents the findings from each of the research methods in the same sequence as these methods were introduced in chapter three. Chapter four starts by describing the results of the analysis of the use of gesture in science fiction movies. Then, it discusses the findings of people's preferences when creating gestures, and it finishes with the results of the validation of those findings.

Chapter five explores the insights that emerged from the data collected and documented in chapter four based on the knowledge obtained from the current research as described in chapter two. In addition, chapter five attempts to answer the research questions of this thesis.

The sixth chapter is the conclusion, which summarizes the extensive analysis conducted during this research. It highlights the most important points of the study, its findings, contributions, limitations and opportunities for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter presents an extensive review of academic literature and explores diverse perspectives on topics that delineate the conceptual framework of this research. This literature review examines seminal work that influenced the research direction in the field of human–computer interaction and design. In addition, this review considers recent research in the field that enlightens opportunities for further study.

2.1 Pervasive Technologies

To understand how the study of pervasive technologies framed the research on gestural interactions, it is important first to explore the topics of ubiquitous computing that have impacted the field of human–computer interaction (HCI). The following sections review some of the most influential work in the field.

2.1.1 Visions of ubiquitous computing

In his influential article, Mark Weiser (1991) articulated a vision for the future that has been informing a great part of the development of ubiquitous computing since it was published (Bell & Dourish, 2006).

Weiser (1991) suggests a future with invisible technology that would dissipate into the background of people's everyday lives. This technology would exist in the physical world, but it would not be an obstacle to human interaction. According to Weiser, the invisibility of technology would be essentially a consequence of human learning. He argues, "whenever people learn something, they cease to be aware of it" (Weiser, 1991, p.94). Additionally, Weiser identifies two essential factors for making technology invisible: scale and location. He further explains that ubiquitous computers would come in different sizes and that rooms would be filled with hundreds of devices that would actively adapt to the surroundings. In Weiser's vision, ubiquitous computers would help to reduce information overload, and people would interact with them seamlessly (Weiser, 1991).

As Bell and Dourish (2006) note, the concept of ubiquitous computing with seamless interactions described by Weiser was inspired mostly by the possibilities of the future rather than the problems of the past. The authors recognize that visions of the future are often helpful to analyze the present but argue that, by focusing on the future, Weiser's vision puts its possible accomplishments out of reach. Moreover, for Bell and Dourish, the vision of a future of seamless interaction is misleading because everyday life is inescapably messy.

Bell and Dourish (2006) propose instead a ubiquitous computing vision of the present. The authors explain that Weiser's vision has, to a certain extent, already been realized. Computers are already embedded into everyday life, and people already interact with them without thinking of them as computational devices (Bell & Dourish, 2006; Vertegaal, 2011). Therefore, according to the authors, there is an opportunity for a pervasive technologies research agenda that focuses on the "messiness of everyday life" and takes into account the social and cultural needs of people (Bell & Dourish, 2006).

2.1.2 Experiencing ubiquitous computing

In another seminal work, Weiser and Brown (1996) expand the vision of the future of ubiquitous computing by introducing the concept of calm technology. The authors suggest that the main challenge for the technology of the twenty-first century is how to create calm technology.

For Weiser and Brown (1996), technologies are very often disturbing and overwhelm people with information. In contrast, calm technologies would also be able to inform but in a more calm and subtle manner that would also bring some comfort. According to the authors, what differentiates calm technology is that it "engages both the center and the periphery" of attention, making people more aware of the information that surrounds them.

Additionally, the authors (Weiser & Brown, 1996) describe three aspects that define calm technology:

- Calm technologies allow people to switch the focus of attention, moving what is in the centre to the periphery and vice versa. When people bring information from the periphery to the centre, they can act on it;
- Calm technologies reduce cognitive load by enabling people to receive more information about what is in the periphery without having to concentrate on it;
- By increasing the awareness of the surroundings, calm technologies make people seamlessly connected to the world around them (Weiser & Brown, 1996).

Weiser and Brown (1996) advocate that empowering computational artefacts in the world would reduce the need for attention, freeing individuals to be with other people.

Similarly, Ishii and Ullmer (1997) also intend to expand the opportunities for interaction between people and information through the empowerment of everyday objects and environments. For Ishii and Ullmer, augmenting the physical world would lead people to richer digital experiences. Their ambition is to transform “each state of matter” into tangible interfaces. Investing in such technologies would reduce the gap between the digital and physical worlds.

However, the idea of proactive computational artefacts that take the initiative on behalf of individuals, making people's digital experiences smoother, has encountered some resistance from researchers in the field. For example, Yvonne Rogers (2006) suggests that research on ubiquitous computing should aim to engage people rather than augment technology. In her opinion, the efforts to realize Weiser's (Weiser & Brown, 1996) vision of ubiquitous calm technology focus excessively on the development of technologies. Moreover, despite all technical advances, ubiquitous computing is far from being calm. According to Rogers, the issue is that these efforts do not capture the diversity of people's behaviours and motivations when interacting with technology.

For this reason, Rogers (2006) proposes creating ubiquitous technologies that engage people in more creative and provocative interactions. She explains that technology "should enable people to do what they want, need or never even considered before by acting in and upon the environment.” Moreover, Rogers (2006) affirms that people are very resourceful in exploring their environment and that technology should serve to augment human intellect rather than the environment. Therefore, she advocates for research that investigates how people use and adapt their tools to their environments.

2.1.3 Interactions with and in the physical space

Building on the ideas proposed by Rogers (2006), this section explores notions of space, place and their roles in the interaction with technology-enabled environments. Weiser (1991) stresses the importance of location for ubiquitous computing to adapt to people’s behaviours, while Ishii and Ullmer (1997) intend to reduce the gap between "physical space" and "cyberspace." Rogers (2006) also proposes a research agenda with a focus on people's action in and upon the environment. The notion of space to make ubiquitous technology viable is common in the work of these authors.

Nonetheless, it is the work of Harrison and Dourish (1996) that provides deeper insights into space and introduces the notion of place for interaction with the environment. These authors observe that the notion of space assists and structures the creation of interaction through the use of spatial metaphors. The notion of space provides the affordances that designers use to create interactions, such as the desktop metaphor in personal computers. These affordances give people cues for how to structure their behaviour when interacting in the digital space or, as the authors put it, the affordances provide "appropriate behavioral framing." Harrison and Dourish (1996) explain that systems designed based on the notion of space support the emergence of patterns of behaviour that reflect people's interactions with objects in the physical world.

However, Harrison and Dourish (1996) argue that this notion of space is too simplistic. They contend that, in everyday life, space is filled with cultural expectations and social meanings. For them, this space "invested with understandings" is called "place." The authors state the difference between space and place as follows: "Space is the opportunity: place is the understood reality." Moreover, people are "located in space, but act in place," meaning that space is turned into place by the individuals acting on it (Harrison & Dourish, 1996).

According to Harrison and Dourish (1996), understanding the notions of space and place can impact technology adoption. People turn houses into homes by adding things that reflect their values (pictures on the wall, furniture, etc.). A similar process of appropriation occurs with people's digital spaces. For Harrison and Dourish (1996), technology cannot turn space into place; only users can do it. At best, designers can provide the users with the means to do it.

Similarly, Lentini and Decortis (2010) observe that the separation between space and place influences the development of interactive systems. They believe that technology can support meaningful experiences of the physical space, and they identify five dimensions that describe ways of perceiving the environment:

1. *Geometrical and geographical experience* encompasses the comprehension of spatial qualities of the environment;
2. *Sensorial experience* relates to the perception of sensorial qualities of the environment such as colours and textures;
3. *Cultural experience* involves the comprehension of behaviours, cultural expectations, and understandings;
4. *Personal experience* represents the "experiences-in-place" on a more individual scale, offering opportunity for reflection and self-understanding;
5. *Relational experience* concerns the opportunities for interpersonal relationships between individuals (Lentini & Decortis, 2010).

In contrast, Hornecker’s (2005) perspective on space and place pays special attention to the role of the human body. Hornecker submits that humans are spatial beings and that interaction with space offers the opportunity to employ the full body. Moreover, she states that the body is the "central reference point" of people's perception. People perceive the spatial qualities of the environment through their bodily movements.

2.2 Tangible Embodied Interactions

2.2.1 Embodied interactions

When Ishii and Ullmer (1997) introduced the term "Tangible User Interfaces (TUI)," they imagined a world in which people would be able to "grasp and manipulate" digital information. Their vision focused on connecting digital data with everyday objects, creating a new interaction style (Shaer & Hornecker, 2010).

Similarly, many of the human–computer interaction researchers who explored the early stages of TUI concentrated on the artefacts, investigating technical possibilities (Shaer & Hornecker, 2010). It was not until the work of Dourish (2004) that the notion of "embodied interaction" was clearly expressed in TUI research, although it was implicit in most of the early work on TUI (Shaer & Hornecker, 2010). Dourish (2004) argues that embodied interaction is part of everyday activity, contributing to an engaged presence in the world that creates meaning. Hornecker (2011) suggests that one's body influences one's experience of the world and that "active bodily experiences" affect how people "perceive, feel and think."For Hornecker (2011), research in embodied interaction needs to take into account experiences that may include ergonomic and aesthetic aspects of body movement.

2.2.2 The role of body in interaction

Taking Dourish's (2004) and Hornecker's (2011) considerations on embodied interaction research further, this section examines the role of the body in interaction design.

Concepts of the body. For Loke and Robertson (2011) the body has a fundamental role in molding everyday activity. The way the body moves serves as a means of communication with the world around it. Loke and Robertson (2011) argue that is essential for designers to develop a deep knowledge of the body in order to understand how pervasive technologies mediate the communication between individuals and the world.

In an effort to help designers reflect on how the understanding of the body can support design process, Loke and Robertson (2011) introduce six concepts of the body:

1. *Body as anatomy and physiology*. The body is a set of anatomical and physiological systems that instigate specific skills and limit what is physically achievable. Technology can connect to these systems (through wearable technology, for example), supporting the emergence of new behaviours.
2. *Body as expression*. The body is a channel of communication with the world that has expressive and aesthetic attributes. In communicating with the world, the body is open to adaptation through learning and creativity.
3. *Body as knowledge*. The body can support the creation of knowledge and meaning as a result of the reflective exploration of movement.
4. *Body as physical skill*. The body is capable of dexterous action as a consequence of its physicality.
5. *Body as felt experience.* The body is the agent of sensory perception of the external world as well as the internal state of the body.
6. *Body as social, cultural entity*. The body exists in social and cultural contexts. Its actions gain meaning "within patterned systems of interaction with others" (Loke & Robertson, 2011).

Relationship between body and space. With the intention to expand on the ideas of the role of the body in interaction, Larsen, Robertson and Edwards (2007) investigate how the body builds relationships with the environment. Their work concentrates on exploring how bodily senses (haptic and kinaesthetic) contribute to experiencing technology or, in their words, "the feel dimension of technology." They explain that "the feel dimension of technology" is a continuous process of perceiving the world through body movement.

Larsen, Robertson and Edwards (2007) argue that, through bodily senses and movement, individuals perceive the space around them and establish relationships with it. This spatial perception, which the authors call bodily space, is what develops people's potential for action in space. Moreover, the potential for action is different for each person because it depends on the individual's body experiences and skills (Larssen et al., 2007).

2.2.3 Approaching movement-based interactions

According to Hornecker and Buur (2006), in the field of tangible interfaces, there is a need for approaches that support research grounded in social contexts of use. Specifically, movement-based studies need methods that take into account expressive movement and embodied skills focusing on the interactions rather than the interfaces.

Likewise, Loke and Robertson (2013) recognize the opportunity in research for approaches, methods and tools that enable designers to delve into the subtleties of body movements used as input to interact with technologies. As a result, the authors propose a body-centred approach that supports the evaluation of movement-based interaction called "Moving and Making Strange." "Making Strange" relates to a strategy of defamiliarization with habitual perceptions to stimulate participants to reflect on their actions. Loke and Roberston (2013) describe the proposed approach as a "nonprescriptive, open process of inquiry and exploration."

One of its main contributions is the analysis of movement-based interactions from three distinct perspectives: the mover, the observer, and the machine (Figure 01).

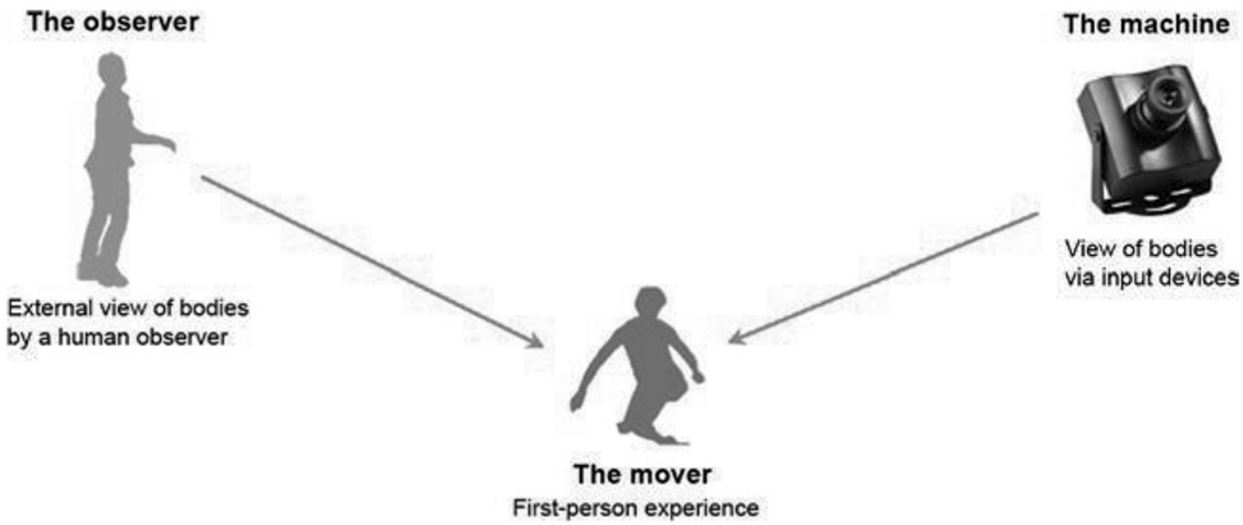

Figure 01: The three perspectives in the design methodology. Adapted from “Moving and making strange: an embodied approach to movement-based interaction design,” by L. Loke and T. Robertson, 2013, *ACM Transactions on Computer-Human Interaction, 20(1)*, p. 7:10.

The analysis of movement-based interactions from the mover's standpoint provides "first-hand, first-person experience of the moving body." The perspective of the mover supports the notion of body as knowledge (Loke & Robertson, 2011) as it is where the skills are unfolded (Loke & Robertson, 2013).

The perspective of the observer affords an outside view of the body. It allows designers to insert the moving body in different contexts of use. Knowledge about the body from this perspective takes into account complementary views such as body as expression and body as social and cultural entity (Loke & Robertson, 2011, 2013).

The perspective of the machine encompasses the sense and interpretation of the movement of the body by the technology and comprises the proper mappings of the user activity and computer interpretation of inputs (Loke & Robertson, 2013).

To assist in the development of research from each of these perspectives, Loke and Robertson (2013) create a structure of activities for data collection and analysis (Figure 02). The authors assign a number to each activity to facilitate correspondence between each activity and each perspective. For example, the activities 1, 2 and 3 correspond to the mover perspective; activities 4 and 5 relate to the observer perspective; and activities 6 and 7 pertain to the machine perspective.

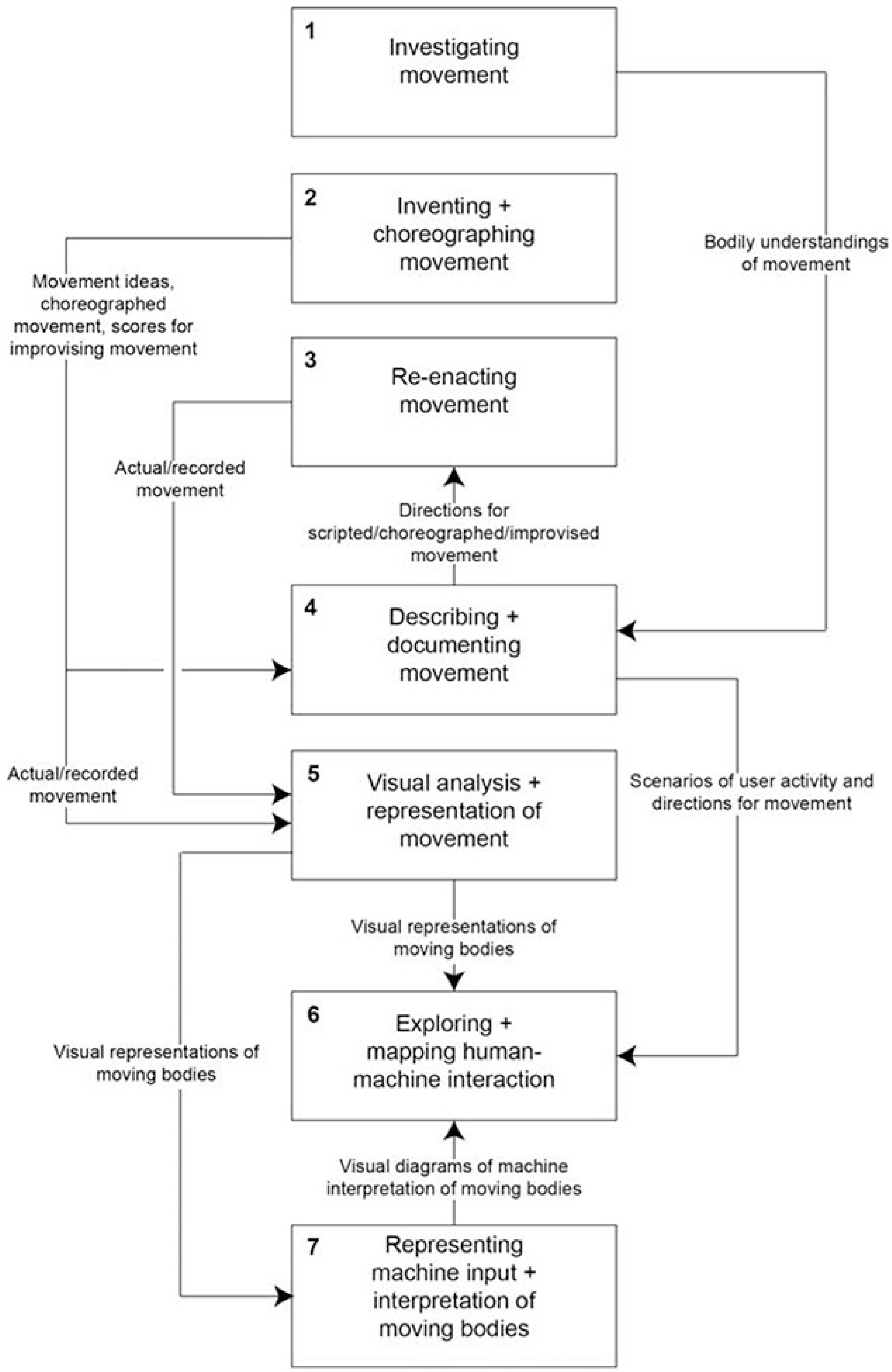

Figure 02: Diagram of key activities. Adapted from “Moving and making strange: an embodied approach to movement-based interaction design,” by L. Loke and T. Robertson, 2013, *ACM Transactions on Computer-Human Interaction, 20(1)*, p. 7:11.

2.3 Gesture-based Interactions

In their work about the role of the body in shaping everyday actions, Loke and Robertson (2011) observe that the body communicates with, learns about and adapts to the world through gestures, movements and postures. Additionally, gestures help to reduce the cognitive load of interactions (Klemmer, Hartmann, & Takayama, 2006) and make it easier to interact with technology when performed in conditions that are familiar to users (Grandhi, Joue, & Mittelberg, 2011). In that regard, as Cassell (1998) suggests, designing gestures that provide better user experiences is one of the main concerns in human–computer interaction research.

2.3.1 Taxonomy of gestures

Gestures and communication. The study and classification of hand gestures normally takes into consideration the identification of patterns of movement of the hands (Eisenstein & Davis, 2004). This approach is useful to capture features like speed, trajectory and number of fingers; it does not encompass communication aspects that are part of the performance of a gesture (Eisenstein & Davis, 2004). According to Eisenstein and Davis (2004), gestures are fundamentally "multimodal entities" and involve not only physical attributes but also linguistic contexts. Similarly, Cassell (1998) points out that the majority of natural gestures are inserted into the context of speech. This close relationship between spontaneous gestures and the spoken language is an important consideration for those who want to design natural and intuitive gesture-based interactions (Cassell, 1998).

Before discussing the role of gestures in human–computer interaction, Cassell (1998) suggests a more detailed analysis of the role of the gesture in human–human communication.

According to her, gestures have a communicative function, supporting the production and the comprehension of language.

Cassell (1998) proposes a taxonomy that takes into account what gestures communicate and how they support speech. It is described as follows:

- *Emblematic gestures* are culturally specific, consciously produced and, therefore, easy to remember. Examples of emblematic gestures are “thumbs-up” and “V-for-victory.”
- *Iconic gestures* depict some feature of the action and specify the way in which the action is carried out. They also specify the viewpoint of the person who is performing the action. An example of an iconic gesture would be a person describing how to handle an object.
- *Metaphoric gestures*. Like iconic gestures, metaphoric gestures represent concepts, but the concepts they represent have no physical form. Cassell (1998) gives as an example a hand indicating rolling motion accompanying the sentence “and the meeting went on and on.”
- *Deictic gestures* are the ones that locate aspects of the discourse in the physical space. These aspects can physically exist or can be an entity that, once introduced, continues to be referenced. An example of a deictic gesture is someone pointing left and then right and saying “Roberto was looking at Pietro across the table.”
- *Beat gestures* are small baton-like gestures. Beat gestures do not change in form with the content of the speech (Cassell, 1998).

Additionally, Cassell (1998) argues that gestures co-occur with spoken language, often manifesting a communication intent that the speaker is not able to articulate in speech. Gestures fill the empty spaces of speech. Gestures do not replicate speech nor do gestures replace the speech. Rather, they are the result of the same reasoning process of communicating.

In their work about gestures for surface computing, Wobbrock, Morris and Wilson (2009) propose a different approach to the classification of gestures. Their research explores the gestures defined by users, and their proposition is that the taxonomy should draw from user behaviour in order to define the gesture design space (Wobbrock et al., 2009). The taxonomy they present divides the gestures into four dimensions: form, nature, binding and flow. Each dimension contains multiple categories (Table 01).

TAXONOMY OF SURFACE GESTURES		
Form	*static pose*	Hand pose is held in one location.
	dynamic pose	Hand pose changes in one location.
	static pose and path	Hand pose is held as hand moves.
	dynamic pose and path	Hand pose changes as hand moves.
	one-point touch	Static pose with one finger.
	one-point path	Static pose & path with one finger.
Nature	*symbolic*	Gesture visually depicts a symbol.
	physical	Gesture acts physically on objects.
	metaphorical	Gesture indicates a metaphor.
	abstract	Gesture-referent mapping is arbitrary.
Binding	*object-centric*	Location defined w.r.t. object features.
	world-dependent	Location defined w.r.t. world features.
	world-independent	Location can ignore world features.
	mixed dependencies	World-independent plus another.
Flow	*discrete*	Response occurs *after* the user acts.
	continuous	Response occurs *while* the user acts.

Table 01: Taxonomy of gestures. Adapted from "User-defined gestures for surface computing," by J. O. Wobbrock, M. R. Morris and A. D. Wilson, 2009, *Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09*, p. 1086.

The authors (Wobbrock et al., 2009) explain the proposed dimensions and subcategories as follows:

- *Form dimension* regards the physical interaction between the hand and the surface. It analyzes the posture and movement of each hand individually.
- In the *nature dimension*, the symbolic gestures are visual representations of an idea. For example, gesturing O.K. over the table indicates "accept." Symbolic gestures are the equivalent of emblematic gestures in Cassell’s (1998) taxonomy. Physical gestures have the same results in the interface as they would with real objects. Metaphorical gestures, similar to Cassell's definition (Cassell, 1998), represent concepts such as "swiping as if to turn a book page." Abstract gestures do not have symbolic, physical or metaphorical associations.
- In the *binding dimension*, object-centric gestures only need information about the object they affect. An example is pinching an object with fingers with the intent to make it "shrink." The world-dependent gestures rely on affordances from the physical world. An example is dragging an object off the interface. The world-independent gestures do not require information from the physical world; they can "occur everywhere." Mixed-dependencies gestures usually refer to gestures performed with both hands that can be both world-dependent and world-independent at the same time.
- The *flow dimension* describes the progression of a gesture. On the one hand, a discrete gesture “delimited, recognized, and responded to an event.” On the other hand, a continuous flow gesture requires ongoing recognition from the system (Wobbrock et al., 2009).

2.3.2 Gestures and touchless interactions

The study of touchless gesture interactions is helpful to gain an understanding of how people perceive the environment around them, communicate an intent and achieve a goal without using speech to support it (Grandhi et al., 2011; Rateau, Grisoni, & De Araujo, 2014).

According to Rateau, Grisoni and De Araujo (2014), touchless gestures are still poorly understood and are often approached in the same way as touch gestures. In their study of mid-air gestures, Rateau, Grisoni and De Araujo (2014) introduce the concept of "Mimetic Interaction Spaces." The authors explain that "Mimetic Interaction Spaces" are dynamic, user-defined input spaces that are distant from the interfaces. Additionally, Rateau, Grisoni and De Araujo (2014) investigate users' acceptance of the idea of an invisible area to input commands and what kind of gestures would emerge to allow people to interact in such areas.

The results of their study show that:

1. Most people tend to create interaction spaces instinctively and without any experience.
2. People are inclined to turn in the direction of the interaction space when interacting with it.
3. It is possible to identify parameters (geometric features) of gestures for creating and deleting the interaction areas.
4. Individuals have a mental perception of the interaction area they created (Rateau et al., 2014).

2.3.3 User-defined gestures

Hand gestures are a versatile means of interacting with interfaces (Wobbrock et al., 2009). For this reason, great efforts in research are focused on designing gestures that are easy to learn, perform and remember (Oh & Findlater, 2013), and that are intuitive and natural for people performing them (Grandhi et al., 2011).

As Wobbrock, Morris and Wilson (2009) suggest, gestures created to interact with touch interfaces are mostly developed by the designers of those systems. Conversely, many studies indicate that gestures generated by users or those generated jointly by users and experts are preferable to pre-defined gestures (Grijincu, Nacenta & Kristensson, 2014; Nacenta, Kamber, Qiang, & Kristensson, 2013; Oh & Findlater, 2013; Wobbrock et al., 2009). In their seminal article, Wobbrock, Morris and Wilson (2009) investigate the creation of non-expert user-defined gestures for interaction with a tabletop touch display. In their study, the authors present to users a pre-defined list of effects (outputs) of gestures. They ask participants to generate gestures that would cause such effects (inputs). The objective of the study was to collect information about what attributes of gestures were relevant for users. The results of Wobbrock, Morris and Wilson's study (2009) show the following:

- Users almost never care about the number of fingers employed in a gesture.
- Users prefer to use only one hand when interacting with touch surfaces.
- Reusing gestures for related operations, such as enlarge and zoom in, increases the learnability and memorability of gestures.
- Only 60% of the gestures from a pre-defined set created by the authors prior to the experiment matched the preferences of the participants (Wobbrock et al., 2009).

In another study, Oh and Findlater (2013) analyze the feasibility of gestures customized by users in comparison to pre-defined gesture sets. The authors' premise is that an efficient gesture set would need to be "easy to use, easy to remember and easy to recognize." Oh and Findlater's (2013) study asked participants to generate gestures for an open-ended use as well as for a specific action. Later, participants evaluated and created their own set of gestures, indicating the reasoning behind their choices.

The results show that people have a tendency to create gestures based on specific, familiar actions even when they have the freedom to create anything they want. In addition, participants employ two strategies for differentiating between gestures:

1. The first strategy consists of creating variations of a gesture, such as changing the number of fingers, direction or duration;
2. The second strategy considers the scenarios for which the gestures are created. As an example, participants would create a gesture for copying a paragraph and another gesture for copying an object (Oh & Findlater, 2013).

Additionally, Oh and Findlater (2013) observe that the top three reasons participants choose particular gestures are, respectively, intuitiveness; ease of use; and familiarity. Based on the findings from their study, Oh and Findlater (2013) propose a "mixed-initiative approach" for designing gestures. Taking into account the ability of systems to recognize gestures, the authors argue that a mixed approach would allow experts to recommend modifications to reduce the ambiguity of similar gestures.

Still regarding the idea of mixed-initiative and memorability of gestures, Nacenta et al. (2013) compare three types of gestures sets: user-defined gestures; a gesture set developed by the authors; and a random expert-design gesture set (stock gesture set). Nacenta et al. (2013) aim to analyze the memorability properties of the different sets and which set users prefer. The findings from their study (2013) validate the idea that giving users the opportunity to generate gestures produces better, more intuitive gestures. They (2013) conclude that personalized gesture sets created by users are significantly easier to remember, more fun and less effortful to perform. Moreover, users prefer user-defined gestures because they tend to think that it is less time-consuming to produce a new gesture than to learn a pre-defined one.

2.4 Critical Design

As Grandhi, Joue and Mittleberg (2011) point out, the possibilities for gesture-based interaction are vast even though they are still largely unexplored and have several challenges to overcome. Nonetheless, the exploration of possibilities for interactions can be achieved through design and speculation about future scenarios. When design is used to speculate about the potential futures of technology, it contributes to the imagination of a desirable future scenario (Dunne, 2008). Moreover, to make such a contribution, design should be used as a form of critique of the way technologies are deployed in people's lives (Dunne & Raby, 2012). Critical design is speculative, it is a form of collective imagination that brings about the future (Dourish & Bell, 2013) and “offers an alternative to the way things are” (Dunne & Raby, 2012).

2.4.1 Design and fiction

One possible way to speculate about the desirable future of technologies is to examine fiction (Dourish & Bell, 2013). Science fiction describes and imagines technology in a distant future, and it does so free from constraints of the real world (Shedroff & Noessel, 2012).

Similarly, according to Shedroff and Noessel (2012), the design process also speculates about how things should be. Therefore, design and fiction have much in common, and one can learn from the other (Shedroff & Noessel, 2012).

Shedroff and Noessel (2012) suggest that another important aspect that favours the comparison between science fiction and design is the expanding reach of media channels. The authors explain that the diffusion of science fiction content through several media channels creates collective cultural references that provide common touch points for speculating about design.

> If you want to discuss an existing technology, you can reference a real-world interface. But to discuss future technologies, it's easier to reference a movie than to try to define it a priori: 'Kinect is, you know, kind of like that interface from Minority Report, but for gaming' (Shedroff & Noessel, 2012, p.6).

In the same way, Dourish and Bell (2013) propose that the comparative reading of science fiction along with ubiquitous computing research instigates important considerations about the shaping of technology. The analysis of popular culture also adds value to ubiquitous computing research. On the one hand, science fiction anticipates technological futures by shaping the collective imagination and by creating a cultural context in which new technologies are accepted and understood. Science fiction acts as a prototype of future technological scenarios. On the other hand, ubiquitous computing research advocates for a whole new relationship between people and their everyday lives, envisioning technologically enabled environments—another form of collective imagination (Dourish & Bell, 2013).

Moreover, in science fiction as well as in ubiquitous computing research, the visions of possible futures are grounded in assumptions about solutions to contemporary problems (Dourish & Bell, 2013). Therefore, exploring science fiction is valuable for understanding the "contexts in which technology [is] deployed and what motivates specific designs” (Dourish & Bell, 2013, p.778). The analysis of science fiction can inform a critique of the relationship between technology and society, suggesting opportunities and challenges that may impact ubiquitous computing (Dourish & Bell, 2013).

2.4.2 Speculative design and potential futures

The widespread perception of design as a problem-solving discipline stems from design's capacity to deal with issues that range from aesthetics to “wicked problems” (Dunne & Raby, 2012). However, for Dunne and Raby (2012), many of the complex challenges that design faces have shown to be "unfixable"; only possible to be solved through a change of "values, beliefs, attitudes and behaviours.”

Dunne and Raby (2012) argue that the alternative for design is to switch from a problem-solving to a problem-finding discipline. In other words, design should be used as a way to hypothesize how things could be. Designs should be speculative. The authors explain that speculative design "thrives on imagination and aims to open up new perspectives," creating space for discussion and refining people's relationship with reality (Dunne & Raby, 2012, p.2). According to Dunne and Raby (2012), it is possible to have a better understanding of the present through speculation about possible futures. These possible futures are usually presented in the form of provocative and fictional scenarios that require people to explore their imagination. Furthermore, Dunne and Raby suggest that the inspiration for these fictional scenarios comes from speculative cultures such as literature, cinema, fine arts and radical social arts (Dunne & Raby, 2012).

In a deeper analysis of possible futures, Dunne and Raby (2012) categorize the types of futures as probable, plausible, possible and preferable. Figure 03 shows the types of futures represented by cones that have a common origin in the present and expand towards the future. Each cone represents the level of the likelihood for each future type (Dunne & Raby, 2012).

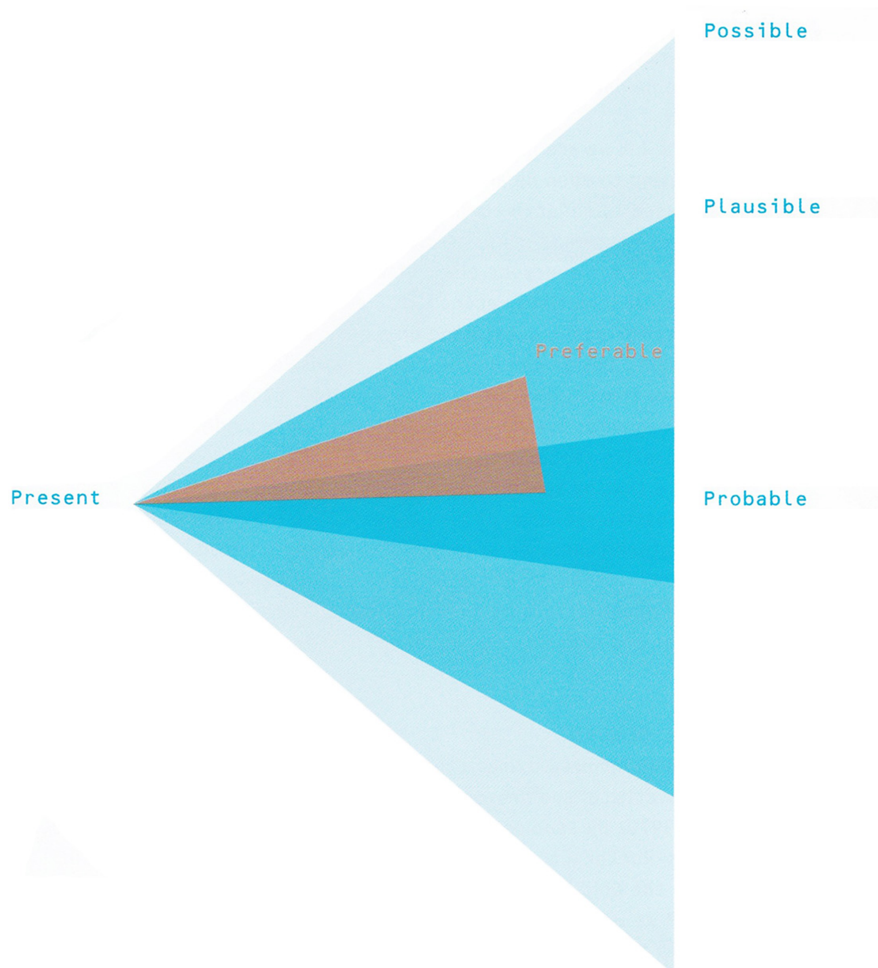

Figure 03: The possible futures. Adapted from *Speculative everything. design, fiction, and social dreaming* (p. 5), by A. Dunne and F. Raby, 2012, MIT Press.

Dunne and Raby (2012) explain each type of future as follows:

- *Probable futures* are very likely to happen unless something unexpected arises, and they are the spaces in which most designers operate.

- *Plausible futures* are about what is planned to happen based on the foresight of some situations.
- *Possible futures* link the present to suggested scenarios that are feasible within the boundaries of current scientific knowledge. The space of the possible futures is the space for the speculation of critical design.
- *Preferable futures* correspond to the space that intersects the probable and the plausible. The idea of preferable futures implies that they are preferable to someone (Dunne & Raby, 2012).

For Dunne and Raby (2012), it is not the role of design to determine the future but rather to give people the means to imagine what the preferable future is. By speculating more today, it is possible to set up the conditions that will lead to the achievement of preferable futures (Dunne & Raby, 2012).

2.4.3 Imagination and design

According to Nelson and Stolterman (2012), design is about creating things in the world that have not yet existed. This notion highlights a great enigma in design concerning the idea of the "not-yet-existing." Nelson and Stolterman (2012) argue that the answer is not in the scientific process alone, as it cannot capture the outcomes of the human imagination.

> The reasoning and logic behind an accurate explanation of an existing reality are not the same as the rationale and imagination used to determine what is desired that does not yet exist (Nelson & Stolterman, 2012, p.127).

Nelson and Stolterman (2012) add that to create something new, one must imagine what the new thing is and how to make it real. In other words, every design outcome is ultimately envisioned through imagination. While Nelson and Stolterman (2012) note that most people relate the design process to creativity, they point out that imagination and creativity are not the same things. Creativity, as they describe, "is the spark that ignites the emergence of novel ideas that have the potential to become normal ideas." Therefore, creativity is situational and related to a particular act.

Imagination, in contrast, gives form to a creative idea (Nelson & Stolterman, 2012). By giving form to an idea, Nelson and Stolterman (2012) mean creating a schema based on the interpretation of aspects that are important for a specific design situation. Imagination is an essential part of every stage of a design process, allowing designers to transform ideas and visions into something that is possible and tangible to other people (Nelson & Stolterman, 2012).

2.5 Framing the Research

The analysis of the literature presented thus far mapped and categorized several contributions from academic research that frame the present study. This review will now examine pervasive technologies, looking for perspectives on the relationship between technology and the physical world. It will then investigate the topic of tangible embodied interactions with the intent to discuss the relationship between the human body and pervasive technologies. Next it will explore the use of gestures as a form of interaction with technology. Finally, the literature review will focus on positioning the critical design approach and its potential contributions to the present study.

Based on the examination of the literature, it is clear that the dominant vision of ubiquitous computing, although still relevant and influential, has undergone important scrutiny. The most significant consequence for the purpose of this study is the recognition that ubiquitous computing cannot completely disappear into the background of people's lives. Pervasive technologies should be provocative and stimulate creativity by engaging people in meaningful interactions that take into account their social and cultural values, as well as their relationship to the physical space around them.

In order to create meaningful interactions, some research streams focus on augmenting the interactive capabilities of the environments and objects placed in the real world. However, other researchers concentrate their efforts on raising the role of the human body in interacting with technology-enabled environments. The body is the means by which people interact with the world around them. More specifically, people perceive and interact with the world through the use of body movements.

Gestures shape people's everyday actions and reflect how they perceive the world. Moreover, the use of hand gestures is very versatile for interacting with the interfaces. Although the study of gestures normally concentrates on identifying physical patterns of movement, there is an important communicative function of hand gestures as well. A gesture taxonomy based on its communicative aspects offers insights into the processes and preferences of user-defined gestures. In general, the literature notes that people prefer user-defined gestures over gestures defined by system designers, placing value, among other things, on gestures that are already familiar in their personal experiences.

Considering that the use of gestures as input for interacting with pervasive technologies has a potential yet to be explored, it makes sense to approach this topic from a critical design perspective. The analysis through critical design allows for an exploration of fictional scenarios of possible futures. These scenarios are free from constraints and create an opportunity for reflection on what would be a desirable future with technology more integrated into people's lives.

Based on the insights obtained from the literature review and considering the hypothesis presented in the introductory chapter, this study is framed by the following research question:

How can the exploration of fictional scenarios of possible futures in pervasive computing drive opportunities for suitable gestures for interacting with technologies that require body movement as input, creating more intuitive experiences?

To facilitate the study of this topic, the main research question is refined by the following three sub-questions:

1. How do fictional scenarios of pervasive computing portray possible futures of gesture-based interactions?
2. How do people relate to the gestures envisioned in fictional scenarios of pervasive computing? Do they perceive them as intuitive?
3. Which intuitive gestures could support the process of designing technologies that require body movement as input?

CHAPTER 3

METHODS

The research questions that guide this study focus on understanding how people relate to the use of gestures in fictional scenarios, and how this understanding can provide insights into new opportunities for gestural interaction. The exploratory and user-centred aspects of this study favour the application of data collection methods that take multiple perspectives on the same topic into account to support the emergence of spontaneous observations. Qualitative methods are the most reasonable way to address the issues in this research, as Bouma, Ling and Wilkinson note:

> Qualitative research allows more continuous reflection on the research in progress and more interaction with the participants in the research, and there is usually more room for ongoing alteration as the research proceeds and new, unexpected observations are made (2012, p. 220).

The first question in this study aims to examine how fictional scenarios depict gesture-based interactions. To answer this question, data collection consisted of a detailed analysis of design fiction movies, allowing the researcher to identify, describe and categorize attributes of gestural interactions.

The second research question seeks to learn how people connect to the gestures imagined in fiction and which of those gestures are perceived as intuitive. The third question in this study aims to identify which of the gestures seen as intuitive could support the emergence of new gesture-based technologies. Two methods were developed to address the second and third questions: experience simulation and a validation questionnaire. These methods explore participants' perspectives when creating and reflecting on the use of hand gestures for interacting with technology-enabled environments.

All three methods— the movie analysis, the experience simulation workshop and the validation questionnaire—supplied the researcher with data that was analyzed separately and comparatively to provide a holistic interpretation of the issue. The process for combining this information was the triangulation of methods. Triangulation is a process of merging the findings of various research methods to comparatively assure the validity of the collected data (Martin, Hanington, & Hanington, 2012). Triangulation is particularly suitable for combining observational methods, such as the movie analysis and the experience simulation workshop, with self-report methods such as the validation questionnaire.

The next section of this chapter will describe in depth how the researcher employed each of the selected methods for collecting data.

3.1 Ethics Considerations

The research methods for the study were reviewed and approved by the Carleton University Research Ethics Board. The board members attested that the study offered minimal risk to participants, and the researcher took all protective measures to reduce risks involved. Participation in this study was completely voluntary. Prior to agreeing to take part in the study, participants received by email (Appendices A or B) an explanation of the research objectives, data collection procedures as well as their right to withdraw. In addition, before each data collection procedure started, the researcher reviewed the consent form (Appendices C or D) making sure that participants understood the research goals and also their right to withdraw. The researcher provided the contact information for Carleton's research ethics board and, also, contact information for the researcher's advisors in case participants wanted to follow up. Lastly, all data collected during this study will be kept securely stored for five years.

3.2 Movie Analysis

The first data collection method consisted of a careful analysis of science fiction movies that presented fictional scenarios of pervasive technology. This analysis was an exploratory exercise aimed at developing an understanding of fictional visions of future technologies and identifying a set of inputs used to interact with these technologies.

3.2.1 Setting

The analysis of science fiction movies took place in the researcher's office. The researcher used his personal computer to watch the selected sample of fiction movies and to edit and store video clips of the analyzed data.

3.2.2 Subject selection procedure

The procedure used to select subjects for the first data collection method was purposive sampling. It focused on selecting audio-visual material such as motion picture films, commercial videos, short films and concept videos that presented human interaction with fictional technologies. More specifically, the selected subjects for this analysis portrayed fictional user interfaces that required the use of hands and arms gestures as input for interaction.

In total, the selected sample consisted of 53 minutes and 19 seconds of audio-visual material divided into 32 video clips. Of those, 26 video clips were excerpts from 11 different motion picture films, 4 were full concept videos and 2 were full commercials videos (Table 02).

The process of selecting the sample included consultation of specialized literature (Shedroff & Noessel, 2012) and research on websites dedicated to cataloguing science fiction movies and discussing fictional user interfaces (“Noteloop,” n.d.; Yuen, n.d.). The selection criteria excluded films entirely made of computer-generated imagery that did not have human actors participating in the scenes.

The selection of the sample started with a preliminary triage that consisted of investigating if the potential movie sample provided examples of gestural interactions in which it was possible to observe the user, the gesture itself, the interface and the response to the interaction. There were no restrictions regarding the number of gestures to be observed in a movie under analysis and the quality of the material offered to analysis the most important aspect for selecting a sample.

In order to capture the most current visions of fictional interfaces, the selection process focused on recently produced films. From the selected sample, 24 of the 32 video clips were produced between 2011 and 2014; another seven films were produced between 2008 and 2010; one film was produced in 2002.

Title	Director	Year	Distributor	Country
A Day Made of Glass	Dave Mackie	2011	Corning	n/a
A Day Made of Glass II	n/a	2012	Corning	n/a
Edge of Tomorrow	Doug Liman	2014	Warner Bros. Pictures	USA
Her	Spike Jonze	2013	Warner Bros. Pictures	USA
Hunger Games	Gary Ross	2012	Lionsgate Films	USA
Iron Man	Jon Favreau	2008	Paramount Pictures	USA
Iron Man II	Jon Favreau	2010	Paramount Pictures	USA
Iron Man III	Shane Black	2013	Walt Disney Studios	USA
Minority Report	Steven Spielberg	2002	20th Century Fox	USA
Nike idNation	JD Hooge	n/a	Grid/plane	USA
Oblivion	Joseph Kosinski	2013	Universal Pictures	USA
Productivity Future Vision	Mason Nicoll	2009	Microsoft	USA
Productivity Future Vision II	Ethan Keller	2011	Microsoft	USA
Quantum of Solace	Marc Forster	2008	Metro-Goldwyn-Mayer Columbia Pictures	USA
The Avengers	Joss Whedon	2012	Walt Disney Studios	USA
The Ender's Game	Gavin Hood	2013	Lionsgate Films	USA
Zazzle the future	Jose Gomez & Tom Green	2012	Shilo	USA

Table 02. List of movies analyzed.

3.2.3 Data collection procedures

The process of collecting relevant data from the selected sample consisted of watching the movies in order to identify scenes that depict the gestural interaction between human characters with interactive interfaces. Once identified, a scene was extracted from the film into a video clip (Figure 04). Each video clip file received a code that allows the researcher to track it back to its source. At that point, there was no distinction made between the collected video clips. They were grouped together regardless of the production year, source or length.

Figure 04. Gesture-based interaction. The analysis of use of gestures in fiction consisted of extracting video clips from movies that depicted gestural interactions with pervasive technologies. Adapted from “Productivity Future Vision II” by E. Keller, 2011, Microsoft.

3.2.4 Data analysis

The analysis of the movie clips was an iterative process, consisting of progressive refinement of the collected data through three rounds of analysis. The first round involved a preliminary description of each gestural interaction in each of the video clips. The purpose was to explore the context of the scene, to identify which character or characters interacted with the interface, to determine the nature of the interface and, finally, to detect the interaction that happened between them.

In the second round, the analysis categorized the interaction in relation to a defined task or an intended goal and highlighted the gestures of the user in each scene performed to complete the task or to achieve the desired goal. The intention was to break the interaction down into gestural inputs and desired outputs in order to determine if the task was completed or the goal was achieved.

The third round of analysis explored the taxonomy of the gestures in each video clip. The objective was to detail physical characteristics such as the choice of hands (right, left or both), the use of fingers, and the movement of the hand (or hands) when performing the gesture.

The gestures were also categorized according to their form, nature, binding and flow. The concepts of these dimension of taxonomies drew from the work of Wobbrock, Morris and Wilson (2009) and Cassell (1998).

After analyzing the movie clips, the data were synthesized and the gestures grouped according to identified patterns. The analysis of the gestures allowed for grouping similar gestures into patterns of inputs for achieving similar goals.

The findings from the first data collection method contributed to the elaboration of the second data collection method of this research.

3.3 Experience simulation workshop

After learning about how fiction depicts gestural interactions with fictional interfaces, this research sought to understand how people create gestures for interacting with technology by simulating an experience similar to the ones analyzed in the fictional movies. The experience simulation workshop is a useful method for investigating how people would respond and behave in a given situation. In experience simulation, participants reveal what is relevant for them when engaging in a particular activity (Kumar, 2012).

This research method stimulated participants to explore the use of hand gestures for interacting with technology-enabled environments without having to be concerned about technological constraints.

3.3.1 Setting

The environment is a key element in the experience simulation workshop. Participants should feel comfortable enough to engage in the experience and to express their creativity. The workshop took place in the graduate design studio at the School of Industrial Design at Carleton University. The design studio is an ample room, and the set-up consisted of isolating part of the room using cardboard sheets to create walls that helped to avoid any distraction that might interfere with the experience. In addition, the cardboard wall created a neutral background that facilitated visualizing the gestures during the posterior analysis of the video recordings of the workshop sessions.

Within the isolated area, one table and three chairs were arranged facing two video cameras and one computer that captured, from different angles, the gestures created by the participants. On the table, pen and paper were provided to support the participants' exploration during the workshop session (Figure 05).

Figure 05. The experience simulation workshop setting. The setting consisted of a desk, three chairs and video cameras.

3.3.2 Participants

In the interest of collecting meaningful data from this workshop, the sampling procedure focused on recruiting participants with previous experience in watching movies at home and in using computers. There were no restrictions in terms of age, gender or educational background.

In total, nine people divided in three groups participated in this workshop, each group at different times. Seven of the participants were women and two were men. Initially, participants contacted the researcher in response to the recruitment poster (Appendix E). After manifesting interest, potential participants received a letter from the researcher (Appendix A) containing a brief introduction to the study and the workshop protocol on which they could confirm or refuse participation.

3.3.3 Experience simulation workshop

The experience simulation workshop was conducted following the script described in Appendix F and illustrated in Figure 06. The participants were divided into three groups of three people each. Each group attended one workshop session scheduled for a date and time that was mutually convenient for participants and the researcher. The primary criterion for organizing the groups was the availability of participants to attend one of the proposed scheduled sessions. Some participants already knew each other and replied to the researcher's invitation as a group; this was another criterion applied to the formation of the groups for the workshop sessions. Given the requirements to enact gestures, the fact that some participants already knew each other was considered as positive, helping to reduce shyness and increase the comfort of those participating in the workshop sessions.

Each session was set to last no more than two hours and was divided into two blocks: Introduction and Simulating the Experience. Each block was subdivided into steps, and each step had an estimated time for completion. The time estimation served for researcher control of the workshop; participants were not informed of how much time they would have to complete a task.

In the first step of the Introduction block at the beginning of the session, participants were welcomed by the researcher and were introduced to the purpose of the study and the overall sequence of events of the workshop session. The researcher distributed the consent forms, making sure that the individuals agreed to participate in the study and that each person understood how to proceed if they wanted to withdraw from the experiment. Once the consent forms were signed, the video cameras were set to record and the workshop started.

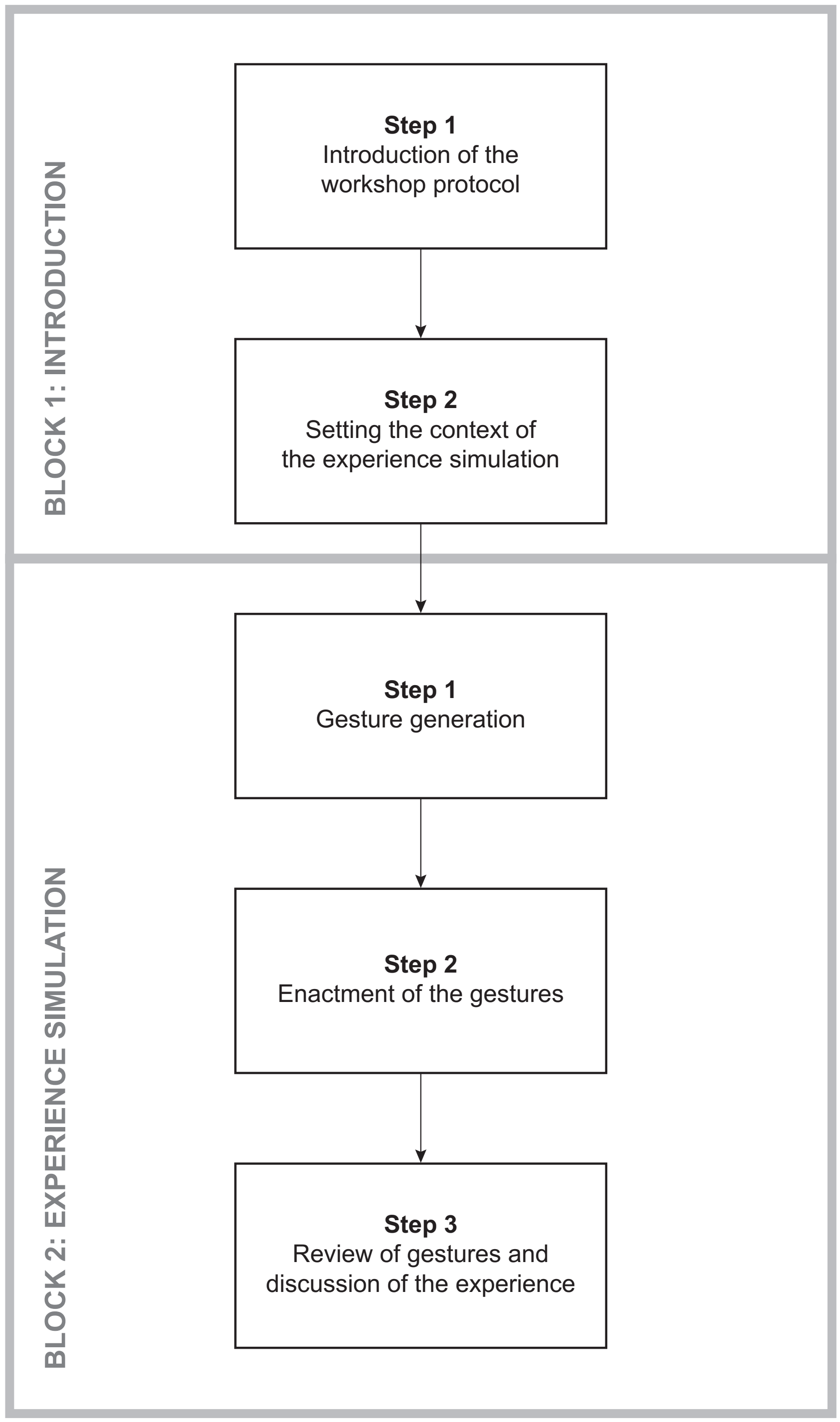

Figure 06. Experience simulation workshop diagram. The workshop was divided in two blocks and a total of five steps.

The second step of the Introduction block started with a short lesson about the importance of creativity and imagination in reshaping the world to respond to human needs. Following this lesson, participants watched three short video clips depicting gestural interactions with fictional interfaces. The intention of this second step was to give participants the context of the research and to make them comfortable to express their creativity and to explore their imagination. The introductory block ended with the researcher evoking the participants to imagine living in a future of technology-enabled environments with no technical limitations. In this future scenario, they would need nothing but their hands to interact with technology.

The second block of the workshop, called Simulating the Experience, consisted of three steps in which the group of participants was asked to create, simulate and reflect on the use of hand gestures as input for interaction. In the first step of the second block (gesture generation), the researcher invited participants to simulate the experience of watching movies in a future scenario of technology-enabled environments. The researcher asked the group to think about how they would use hand gestures to interact with technology in such an environment.

The group received a list of twenty tasks for which they had to create hand gestures. The list of tasks had been generated based on the gestures observed during the movie analysis. The list of tasks was also formatted to correspond to tasks that people typically do when watching movies (e.g., playing movie, pausing, advancing to next scene). Participants were encouraged to write down, to draw and to try out gestures until they agreed on one that would reflect the group's preference. While members of the group worked on the gesture generation, the researcher remained behind the cardboard walls observing the discussions.

Once the participants finished creating gestures for all tasks, the group advanced to the next step in the second block of the workshop: enacting the gesture. The group chose one participant to simulate the experience, enacting all twenty gestures on which the group had agreed. In addition, the researcher asked the person performing the gestures to use “think-aloud” protocol. The person responsible for the enactment thus narrated the scene, describing in detail his or her thinking, actions, feelings and intentions. The other members of the group supported the enactment by adding comments and making suggestions that would help to improve the gesture simulation.

In the third and last step of the second block, which was also the step that closed the workshop session, the group discussed and reviewed the gestures they had created. The researcher proposed questions (Appendix F) to motivate the discussion. These questions were intended to gather participants' opinion about how hard it was to create gestures and how efficient and natural the gestures seemed to be. At that moment, any participant of the group also had the opportunity to suggest changes to the list of enacted gestures.

3.3.4 Data analysis

The analysis of the data from the workshop started with the observation and detailed description of gestures enacted by the participants. In sequence, the researcher reviewed the conversations that participants had while generating gestures, as well as the discussions that happened when the groups reviewed the gestures. The data gathered from all workshop sessions were analyzed at the same time for each of the stages of the workshop described above.

The examination of the enacted gestures was similar to the analysis of the fiction movies. The researcher analyzed the gestures in relation to an intended goal and then characterized the physical attributes of the gestures. The characterization focused on the choice of hands, and movements executed by arms and hands. In addition, this examination captured the vocabulary used to describe the gestures along with quotes that expressed relevant information about the interaction.

The analysis included the conversations among participants during the gesture generation phase as well as the discussions that followed the enactment. These conversations provided insight into the reasoning behind the choice of preferred gestures. This round of analysis captured not only the vocabulary that participants used to describe the gestures, but also the references that participants made when creating gestures, such as reference to a previous experience or an existing technology.

The synthesis consisted of grouping the data into thematic patterns that emerged from the analysis for later comparison to data gathered from the other research methods.

3.4 Validation questionnaire

After gathering data about gestures generated by ordinary people, the researcher had to validate the findings from the experience simulation workshop. This validation was accomplished through the exhibition of a video of the gestures created during the experience simulation workshop and a questionnaire distributed to study participants. The validation intended to corroborate the insights identified through the previous methods. Moreover, the validation questionnaire offered the opportunity to uncover issues and themes that might have been overlooked during the preliminary data analysis, therefore offering new insights and different perspectives on the research topic.

3.4.1 Setting

The setting for the completion of the validation questionnaires was a classroom on the Carleton University campus. This classroom was a quiet room, equipped with a projector and a large screen to exhibit the video of the gestures created by the participants during the experience simulation workshop.

3.4.2 Participants

The method for selecting participants to respond to the validation questionnaire was non-random, purposive sampling. In order to obtain insightful data from the questionnaires, it was essential to recruit participants trained in the field of human–computer interaction or interaction design. For this reason, the participants were a group of ten Carleton University graduate students who were, at the time, enrolled in a course entitled "Interactive Entertainment Technologies." This course is part of the Human–Computer Interaction Master's program at Carleton University, and in the lectures for the course, students learn about interactive aspects of entertainment technologies. The course explores subjects such as films, video games and ubiquitous computing with a focus on the user interface.

3.4.3 Data collection procedures

The distribution and completion of the validation questionnaire happened in one session planned to last 2 hours. It started with the researcher introducing the research study, distributing the consent forms and making sure that participants understood and agreed to take part in the study.

The researcher then briefly described the experience simulation method before exhibiting a video of the gestures created during the enactment portion of the workshop. The video presented the gestures that each group created for each task in sequence in order to compare the gestures (Figure 07).

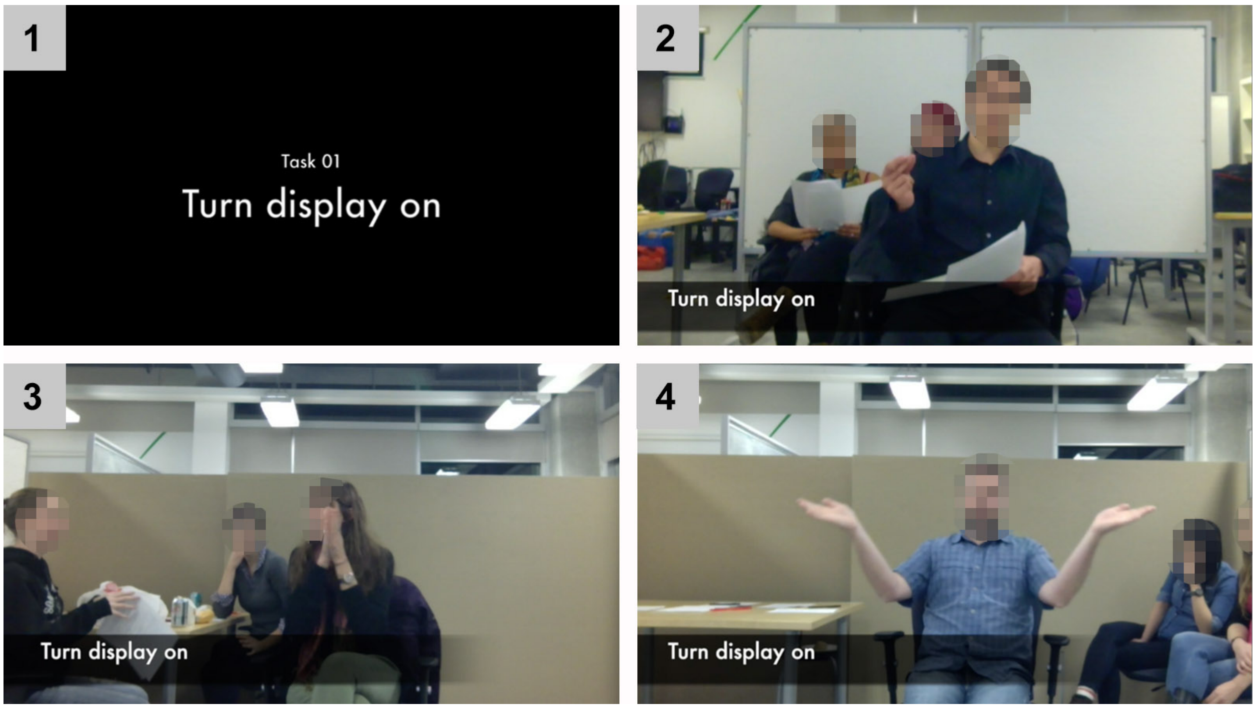

Figure 07. Gestures created in the workshop. The video presented the gestures by task [1] and then by group [2, 3, 4].

After participants watched the video for the first time, they received the questionnaire and were invited to evaluate the gestures presented. The video was then set to play in a loop so participants could review the gestures at any time.

The validation questionnaire (Appendix G) consisted of ten questions. The first half of the questionnaire included five Likert scale questions intended to capture participants' evaluation of the gestures in terms of feasibility, intuitiveness, ease of use, learnability and efficiency. The second half included five open-ended questions that encouraged participants to indicate different contexts, tasks and technologies that could benefit from those gestures. The open-ended questions also sought to identify gestures that stood out as either feasible or unfeasible.

3.4.4 Data analysis

The analysis of data collected from the questionnaire started with the Likert scale questions. All questionnaire responses were compiled into a single spreadsheet, and the answers to the Likert scale questions were summed up in order to generate the question score. The analysis of the open-ended questions consisted of exploring the responses individually with the intention of identifying patterns. Those patterns were then coded and grouped into themed categories.

A second round of analysis consisted of identifying patterns common to more than one participant in the analysis of the open-ended questions and then regrouping those common patterns into broader categories.

The insights gained from the grouping of patterns were compared to the results obtained from the experience simulation workshop. The findings from all research methods are described in the next chapter.

CHAPTER 4

RESULTS

This chapter presents the findings gathered from the three research methods applied in this study. The examination of the data collected from the movie analysis, the experience simulation workshop and the validation questionnaire provided insights that to answer the research questions. The results from each method are presented separately, following the sequence in which they took place. The findings from each method are ordered according to the categories that emerged from data analysis and synthesis.

4.1 First Method: Movie Analysis

The first stage of data collection was the analysis of science fiction movies; the primary goal of this phase was to determine how these movies portray the use of gestures. The focus of this analysis was to identify the agents and contexts of the interactions, as well as to determine inputs and outputs that comprised those interactions. Moreover, this analysis detailed the taxonomy, describing physical attributes such as the choice, pose and number of hands, amplitude, form, nature, binding and flow of the gestures.

4.1.1 Contexts of gestural interactions in fiction

The investigation of the contexts of interaction started with the description of what was happening in the scene, who was performing the task, what was the task, and what interaction supported the task. As expected, the way that contexts of interaction are presented varies greatly from one movie to another mostly because each movie presents a unique story with different visual representations of costumes, characters and scenarios.

However, a common element identified in the context of gestures in fiction movies was that, for the most part, the scene features one single character performing the interaction. Usually, even when there was more than one character acting in the scene, only one of them performed gestures to interact with technology. In addition, all gestures observed in the fiction movies were performed using the upper body, more specifically the full arm (that is, from the shoulders to the hands), the hands and fingers.

Another relevant observation regarded the number of gestures required to execute a task. There were instances in which more than one gesture was combined to perform a single task, for example holding one hand steady and pointing to the display while moving the other hand to drag an object (Figure 08). However, there was no evidence of multitasking, and none of the movies analyzed depicted the co-occurrence of gestures to complete multiple, distinct tasks at the same time.

Figure 08. Co-occurrence of gestures. One hand points to the display while the other hand drags the item off the display. Adapted from “Productivity Future Vision II” by E. Keller, 2011, Microsoft.

Lastly, the analysis of the movies revealed the idea of a reference area for interaction (Figure 09). In other words, characters in the movies were always facing a specific area in the scene where the interaction was taking place, and this area was the target for the gestural interaction during the scene. Although this finding was expected for interfaces that required touch interactions, it was a relevant consideration for understanding touchless gestural interactions.

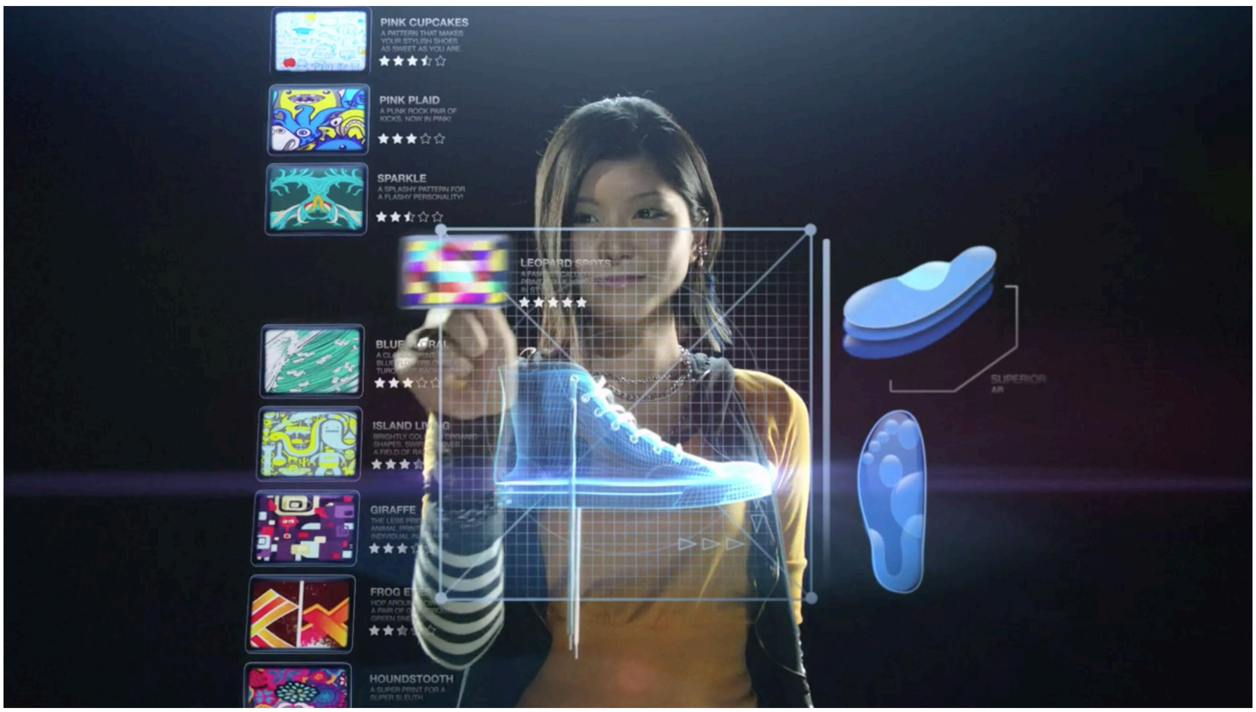

Figure 09: Reference area for interaction. Character facing a delimited area of interaction. Adapted from "Zazzle The Future" by J. Gomez & T. Green, 2012, Shilo.

4.1.2 Inputs and outputs

After describing the context of the interaction in the movies, the next round of analysis detailed the use of gestures in relation to the tasks that were to be accomplished. The intention was to identify which gestures were used when the characters wanted to achieve a goal. The analysis consisted of breaking each interaction into two parts: the first part described the gesture used as the input to the interface; the second part described the output or the consequence of the performed gesture.

The analysis also involved describing the feedback to an interaction provided by the interface. For instance, if the interface feedback to a gesture was to cluster objects on the interface, then it was inferred that the desired goal (the output) for that gesture was to group items. The description of the interface feedback allowed the researcher to identify a list of outputs that reflect the most common goals of gestures portrayed in fiction movies.

In total, 94 gestures were observed and described from all movies analyzed. The findings showed a much greater number of inputs than outputs, identifying a total of 48 inputs and 19 outputs (Table 03).

Inputs	close	delete	drag	drag/move	group	maximize	minimize	move	next	open	pause	previous	rotate	rotate/move	select	turn off	turn on	zoom in	zoom out	Grand Total
bring hands together							1											1		2
clap																	2			2
double tap										1										1
drag finger								1												1
drag fingers								1												1
drag off screen				1																1
drag to left of surface								1												1
drag with fingers				1				1												2
flicking away	2																			2
grab/throw away		3																		3
grab/throw down	1																			1
move hand from top down																1				1
move hands apart				1														3		4
one hand move along arm																		1		1
pinched fingers								1											1	2
pinched fingers, slide hand			1																	1
pinched hand up, open fingers																		1		1
point finger, open hand								1												1
point finger, open hand and move																	1			1
pull apart with arms						1														1
pull apart with fingers																		1		1
pull apart with palms																		2		2
push with hands				1																1
raise both hands																	2			2
raise fingers											1									1
raise hand											1									1
show palm, stop, move hands towards left												1								1
slide finger			4						4									1		9
slide fingers	1				1				2									1		5
slide hand/push								1												1
slide hands counter clockwise rotation													1							1
splay fingers										1								1		2
stretch arms forward			1																	1
swipe fingers								2	2				2							6
swipe fingers up										1										1
swipe hand									2				1							3
swipe hands	1																			1
swipe off to the side		1																		1
tap										1	1				8					10
tap and drag														1						1
tap and drag with palm			1																	1
tap and slide finger										1										1
tap and swipe												1								1
tap twice						1														1
tap with finger										2					2					4
twist fingers	1																	1		2
wave both hands																		1		1
wave hands	1																			1
wave over display																	1			1
Grand Total	**7**	**4**	**7**	**4**	**1**	**2**	**1**	**9**	**10**	**7**	**3**	**2**	**4**	**1**	**10**	**1**	**6**	**14**	**1**	**94**

Table 03. Inputs and outputs of gestural interactions. The analysis of the movies identified 94 gestures distributed into 48 inputs associated with 19 outputs.

The greater number of inputs suggests that fiction depicts gestural interactions in many different ways to achieve a reduced number of objectives. For example, Table 03 shows nine distinct inputs associated with the same output "move" (move an object on the interface). Yet, the opposite is also true, and one single input was used to accomplish different outputs. For example, Table 03 shows five occurrences of the input "slide fingers" applied to accomplish four different outputs (close, group, move and zoom in).

It is worth noting that, at this stage, each gesture was considered a distinct input even if it had characteristics similar to other gestures. For example, if a character performed a swiping hand gesture for browsing the interface, the input was described as "swiping hand" and the output as "browsing." Similarly, if in another movie, a character swiped with the index finger for browsing, then "swiping finger" was considered as a distinct input (even though the gestures were similar, and the output was the same).

4.1.3 Taxonomy of gestures

After the identification of the inputs and outputs of the interactions, the the taxonomy of the gestures was examined. The analysis described the nuances of the inputs, identifying patterns and categorizing the inputs.

The examination started with the detailing of the physical attributes of the gestures, such as handedness and amplitude. Later, the examination concentrated on interpreting the gestures in terms of four taxonomy dimensions: form, nature, binding and flow.

Handedness. The analysis showed a predominant use of the right hand when compared to the use of the left hand and both hands together. Of the 94 gestures identified, 52 were performed with the right hand, 14 with the left hand and 28 with both hands. In cases where the character wanted to "zoom in," the use of both hands was most common. Both hands were also used exclusively for tasks such as "group," "maximize" and "minimize" (Figure 10).

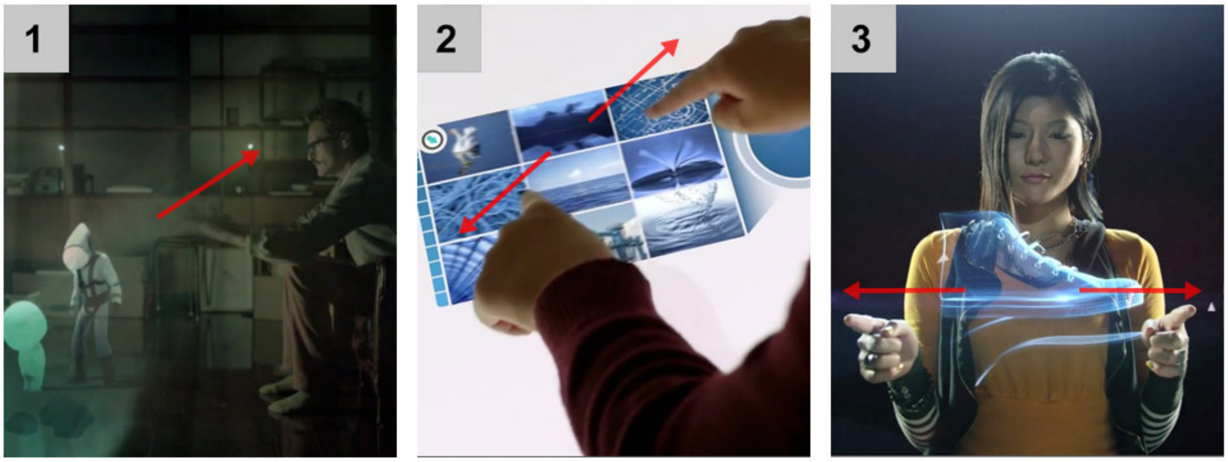

Figure 10. Handedness. Examples of interactions with both hands. Adapted from [1] "Her" by S. Jonze, 2013, Warner Bros. Pictures; [2] "A day made of glass: Same Day", 2012, Corning; [3] "Zazzle The Future" by J. Gomez & T. Green, 2012, Shilo.

Amplitude of the gestures. The extent of the gesture, taking into account the parts of the limb involved in the action (Figure 11), was investigated. The analysis showed that 73 of the 94 gestures were performed using the whole arm and hand (or arms and hands when executed with both limbs). Additionally, 14 of the 94 gestures were performed with hands only while 7 gestures were performed using fingers only.

Figure 11. Amplitude of gestures. The character uses the whole arms and both hands to turn the display on. Adapted from "Ender's Game" by G. Hood, 2013, Lionsgate Films.

Form of the gestures. The classification of the gestures according to their form involved studying the pose and movement of the hand during the execution of the gesture. The gestures were categorized as static if the pose of the hand did not change during the gesture, or as dynamic if it changed. If the hand or arm moved in space from one point to another during the execution of the gesture, the attribute "path" was added to the description (Figure 12). Consequently, the classification in terms of form distributed the gestures into four groups as follows:

- Static Pose with Path: grouping 40 of the 94 identified gestures;
- Static Pose without Path: encompassing 25 of the gestures;
- Dynamic Pose with Path: including 20 of the gestures;
- Dynamic Pose without Path: grouping the remaining 9 identified gestures.

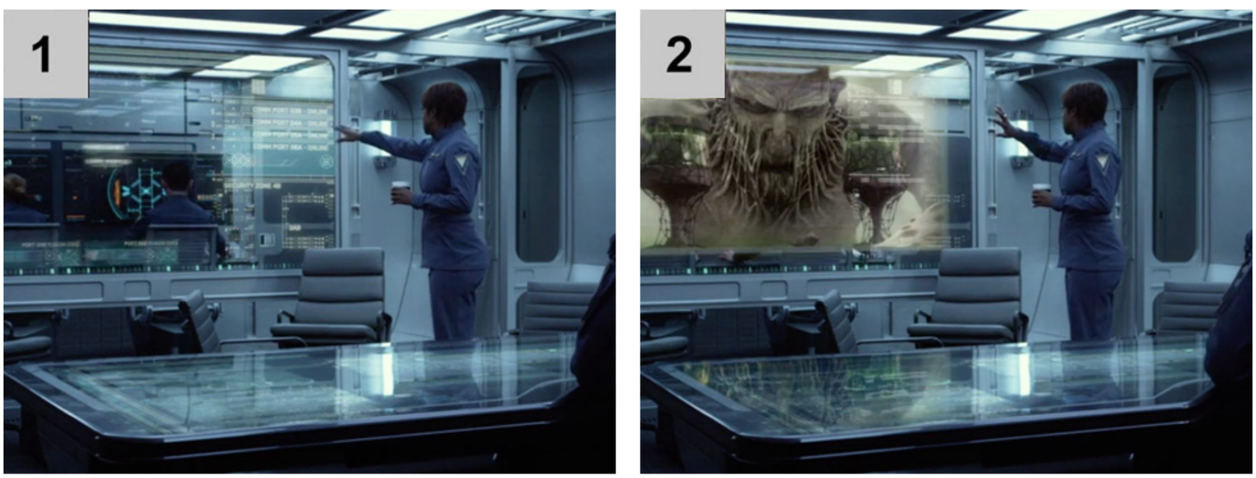

Figure 12. Dynamic Pose with Path. Both the pose of the hand and the position of the arm change during the performance of the gesture. Adapted from “Ender’s Game” by G. Hood, 2013, Lionsgate Films.

Nature of the gestures. In order to categorize gestures in terms of their nature, the researcher assessed the gestures according to their communicative functions. Most of the gestures (49 of 94) identified in the movies were metaphorical. Examples of metaphorical gestures included "tapping to open," "sliding fingers to advance to next item" and "pinching fingers to zoom out" (Figure 13). Another 32 gestures were identified as physical. Some recurring examples of physical gestures were "grab" and "drag" items on the interface. Additionally, 13 gestures were categorized as abstract (e.g., twist fingers, raise both hands) and none of the 94 gestures was symbolic.

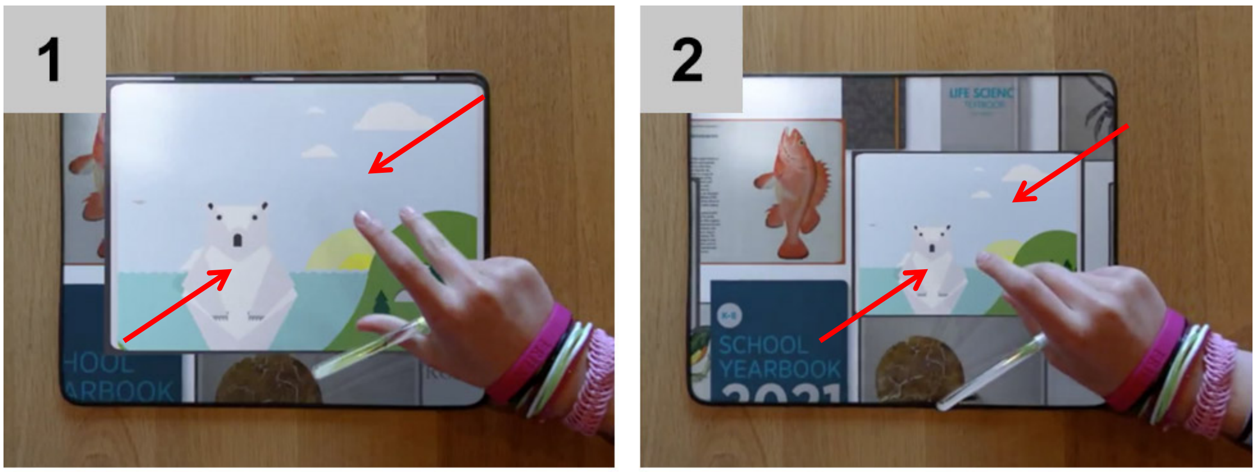

Figure 13. Metaphorical gestures. Pinching the fingers is used for zooming out. Adapted from "Productivity Future Vision II" by E. Keller, 2011, Microsoft.

Binding of the gestures. The researcher then analyzed the gestures to determine their dependency on their surrounding environment. The analysis revealed that 79 of the gestures were object-centric, meaning that they only depended on information about the object they altered (e.g., tapping to select an object). Another 12 gestures were defined as having mixed dependencies, meaning they relied on information about the object as well as the environment (e.g., dragging an object from one display to another). Lastly, three gestures were identified as world-dependent (Figure 14), meaning they required information about the environment exclusively (e.g., snapping fingers to turn a display on).

Figure 14. World-dependent gesture binding. The character uses finger snap gestures to turn the display on. Adapted from “Iron Man II” by J. Favreau, 2010, Paramount Pictures.

Flow of the gestures. The flow dimension describes gestures in terms of their execution and recognition, and the interface response. The flow was defined as discrete if the execution, recognition and response to a gesture were perceived as an event, such as "tapping to select." Likewise, if the response to a gesture and its recognition was ongoing while the gesture was being executed, then the flow was described as continuous (e.g., sliding fingers to drag an object). The analysis identified that 69 gestures had a continuous flow while 25 gestures had a discrete flow.

Most of the continuous flow gestures related to tasks such as drag, zoom in and advance to next. For instance, Figure 15 shows that the object on the display (delineated by the yellow border) rotates while the character performs the drag gesture. Comparatively, most of the discrete flow gestures related to tasks such as select, open and pause.

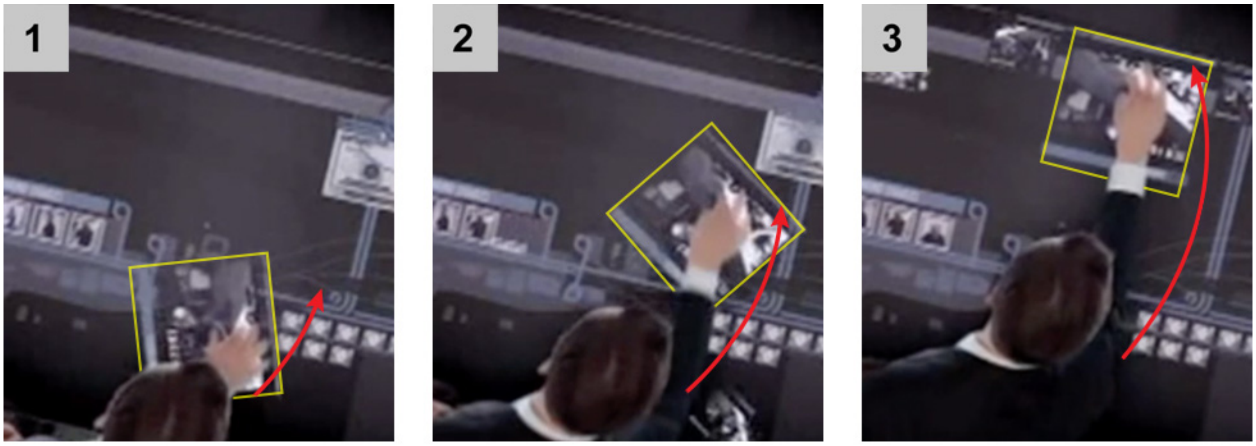

Figure 15. Continuous flow. The object rotates while the character performs the gesture. Adapted from “Quantum of Solace” by M. Foster, 2008, Metro-Goldwyn-Mayer & Columbia Pictures.

4.2 Second Method: Experience Simulation Workshop

The second stage of data collection pertained to the experience simulation workshop, and it intended to capture people's preferences when creating gestures to interact with technology-enabled environments. The analysis of data collected was divided into three blocks that corresponded to three moments of the workshop: the enactment of the gestures, the generation of the gestures, and the discussion about the experience simulation. The analysis also grouped the data collected from all three workshop sessions and explored the findings from each workshop group (A, B and C) together.

4.2.1 Enactment of the gestures

The analysis of the enactment followed a similar approach to the analysis of gestures in the fiction movies. That is, the researcher started by describing the scene with special attention to detailing the gestures used as input for interaction. In sequence, the researcher examined the taxonomy and physical attributes of the gestures using the same categories and dimensions studied during the movie analysis. However, it is important to highlight that in the experience simulation workshop, the context of gestural interaction was the same for all participants. Additionally, the analysis of the experience simulation workshop did not include the investigation of the outputs as the researcher provided participants with a defined a list of tasks based on the findings from the movie analysis.

Diversity and reuse of gestures. One of the first observations about the gestures created by workshop participants concerned the number of distinct gestures each group proposed during the enactment. Participants in group A created 17 distinct gestures, reusing 2 of them, to accomplish all 20 tasks. In contrast, members of group C created 12 gestures for accomplishing the tasks and reused 6 of them to achieve the same 20 tasks. Meanwhile, participants in group B generated 15 unique gestures and reused 4 of them.

Upper body gestures. Similar to what was observed in fiction movies, all of the gestures created and enacted by participants during the workshop sessions were performed with the upper body. More specifically, the gestures were restricted to the use of arms (from the shoulder to the hands), the hands and the fingers.

Handedness. Regarding the choice of hands to accomplish the tasks, the results were significantly different from one group to another. The analysis from group A showed that the participants used both hands in 6 of the gestures and used the right hand in 11 gestures. The results for group B demonstrated that both hands were applied to 7 gestures; the right hand was used for 6 gestures and the left hand was used for 2 gestures. As for group C, the use of the left hand was predominant, being used for 6 gestures, while both hands were used for 3 gestures and the right hand was also used for 3 gestures.

When combined, the results from the three groups revealed the dominant use of the right hand (applied 28 times) over the use of both hands (22 times) and the use of the left hand (10 times).

Amplitude of gestures. In terms of amplitude, participants from group A created 13 gestures that involved the whole arm and the hand, 3 gestures that used only the hands, and 1 gesture involving only the fingers. The results from group B revealed that 13 gestures were performed with the whole arm and hand, while 2 gestures were performed with the hand only. Similarly, group C generated 10 gestures that involved the whole arm and hand, and only 2 gestures that used only the hand. Neither group B nor group C created gestures that required using only the fingers. These findings suggest that ample gestures, requiring the use of the whole arm, were preferred over smaller gestures that involve using only hands or fingers.

Form of gestures. The findings from group A revealed that 9 gestures had a "Static Pose and Path" form. Another 5 gestures had a "Dynamic Pose and Path," and 3 gestures had a "Static Pose" form. The results from group B identified 7 "Static Pose and Path," 4 "Dynamic Pose and Path" and 4 "Static Pose" gestures. At the same time, the observations from group C identified 8 "Static Pose and Path," 2 "Dynamic Pose and Path" and 2 "Static Pose" gestures. The results were similar across all groups, with most gestures having a "Static Pose and Path" form and showing a balance between "Dynamic Pose and Path" and “Static Pose” gestures.

Nature of gestures. The analysis of the nature of the gestures demonstrated that participants in group A created 13 metaphorical gestures and 4 abstract gestures. Participants in group B created 11 metaphorical gestures, 3 symbolic gestures (Figure 16) and 1 abstract gesture. As for group C, participants created only metaphorical gestures.

Figure 16. Nature of gestures. Thumbs-up is an example of symbolic gesture.

Binding of gestures. Regarding the binding dimension, 15 gestures created by group A were "object-centric," 2 gestures were "world-dependent" and 2 gestures had "mixed-dependencies." For group B, 12 gestures were "object-centric," 2 gestures were "world-dependent" and 1 gesture had "mixed-dependencies." Finally, for group C, 10 gestures were "object-centric" and 2 gestures were "world-dependent."

Flow of gestures. With respect to the flow of the gestures, the data gathered from group A indicated that 12 gestures had a continuous flow while 5 gestures had discrete flow. The analysis of all 15 gestures created by group B revealed that 9 of them had continuous flow and the other 6 had discrete flow. Lastly, participants in group C generated 10 gestures with continuous flow and only 2 gestures with a discrete flow.

Table 04 summarizes the distribution of the gestures across the different categories of the taxonomy.

	Group A	Group B	Group C
Total gestures created	17	15	12
Handedness			
Both hands	6	7	3
Right hand	11	6	3
Left hand	-	2	6
Amplitude			
Arm and hand	13	13	10
Hand	3	2	2
Fingers	1	-	-
Form			
Static Pose and Path	9	7	8
Dynamic Pose and Path	5	4	2
Static Pose	3	4	2
Dynamic Pose	-	-	-
Nature			
Symbolic	-	3	-
Physical	-	-	-
Metaphorical	13	11	12
Abstract	4	1	-
Binding			
Object-centric	15	12	10
World-dependent	2	2	2
World-independent	-	-	-
Mixed-dependencies	-	1	-
Flow			
Discrete	5	6	2
Continuous	12	9	10

Table 04. Taxonomy of enacted gestures. Distribution of gestures across the different dimensions of the taxonomy.

4.2.2 Gesture generation

The investigation of gesture generation concentrated on the discussion that the participants had with each other while creating gestures prior to the enactment of the experience simulation. The goal of this analysis was to gain an understanding of the motivations for choosing specific gestures over the others discussed. The results suggested some similarities among the three groups.

Similar gestures. In some instances, during the discussions, the groups generated gestures that were similar those created by the other groups (Table 05). Sometimes these similar gestures were applied to the same task but at other times, these gestures were used to accomplish different tasks. For example, both groups A and C considered using a "waving hand" gesture for the "turn display on" task. However, group A opted for a finger snap gesture for this task, and the finger snap was also the gesture used by group B for turning the display on. Similarly, group B discussed clapping twice as an option for turning the display on; participants in group A also considered using clapping twice but for turning the display off.

	Group A	Group B	Group C
Bring hands close together	•		•
Grab and drag object	•		•
Point with finger and drag	•	•	
Rotate hands	•	•	•
Splay hands	•		•
Tap with hand and drag		•	•
Swipe hands	•	•	•
Halt gestures	•	•	

Table 05. Similar gestures created by the groups.

Describing gestures. The words that participants used to describe the gestures varied greatly both within and among groups. More importantly, participants recognized the difficulty of describing gestures when trying to communicate an idea to other members of the group. A participant in group B, when describing a "tap and swipe hand" gesture, said: “this will eventually become a lingo,” indicating its current unfamiliarity.

Reference to familiar gestures. At some point during the discussion, participants in all groups made reference to gestures with which they were already familiar or that they had used with other applications or technologies. Participants justified these references by drawing a parallel between similar tasks. For example, one participant justified using a full palm gesture for dragging the display by saying that "this is the symbol you have on Adobe Illustrator."

Many of the references were to gestures used to interact with smartphones. For example, when generating gestures for creating a playlist, participants proposed to drag one item over the other "like in the iPhone" or "tap and drag like you would do on an iPhone." Even more frequent were instances when the consideration of gestures reflected a previously known movement, not necessarily linked to a particular technology. For instance, participants in group A suggested a splaying both hands gesture for accessing a library and described the gesture by saying it was "kind of opening a book." Members of group C also used the same gesture (splaying both hands) for similar tasks (Figure 17).

Figure 17. Familiar gestures. Participants perform a gesture that simulates opening a book.

Differentiation and reuse of gestures. As the conversations progressed and the groups agreed on gestures for the enactment, participants started to discuss the differentiation and reuse of the gestures. This topic emerged at different times for each group. It started earlier for members of group A, who were concerned about repeating the same gestures over again. Participants in group B were also concerned about the impact that the lack of differentiation had on the generation of gestures by saying: "It is hard because we cannot say pointing for everything."

For group C, however, reusing gestures was a conscious strategic decision as the group identified similarities between the different tasks. As one of the participants in group C said, when trying the splay both hands gesture for maximizing task, "well, this just becomes always open then." Once participants agreed, they used the splay both hands for tasks such as turn display on, select movie and play movie.

Summary of findings from the gesture generation	
Similar gestures	• Participants created gestures similar to gestures created by other groups • Some of the similar gestures were applied to similar tasks, but also to accomplish different tasks
Describing gestures	• The verbal description of gestures changed significantly from one group to another • Participants faced some challenges in trying to articulate the intention of their gestures
Familiar gestures	• All groups created gestures that were already familiar to them • Most gestures replicated interactions with other technologies such as Smartphones
Differentiation and reuse	• The concern about differentiating similar gestures started at different moments for each group, but it happened to all three groups • Participants in group A opted for the maximum differentiation of gestures to avoid confusion • Participants in group C opted for reusing gestures as much as possible to facilitate memorization

Table 06. Summary of findings from the gesture generation.

4.2.3 Review of gestures and discussion of the experience

The last part of the experience simulation workshop consisted of a discussion during which participants reflected on the process of generating and enacting the gestures. This discussion gave participants the opportunity to review the gestures they created, propose changes and identify issues that only came to light after simulating the experience.

Overall, participants concluded that it was not difficult to create gestures even though they were able to identify some challenging aspects involved. Moreover, from this discussion themes emerged such as differentiation and reuse, issues with the amplitude of the gestures, and multimodal interactions.

Differentiation and reuse of gestures. One of the challenges of the experience simulation was the differentiation of gestures. In particular, members of group A admitted that it was not easy to create unique gestures for different tasks. One of the members of the group pointed out that, because some tasks are similar, it is necessary to do "something really different to distinguish the gestures." This person then referred to Apple Computer's touchpad technology and suggested the use of fingers as a form to differentiate gestures.

Correspondingly, members of group B were also concerned about the ambiguity of some gestures, thinking that gestures such as raising the arm could be misinterpreted as stretching. Reflecting on this issue, a member of the group proposed that making use of fingers could add some uniqueness to the gesture.

Participants in group C also recognized that differentiation of gestures was an issue due the similarity of some tasks. One of the members of group C remembered that they had intentionally borrowed gestures from existing applications, especially touch interfaces such as Smartphones. The goal, according to the group, was to reduce the number of gestures that people would have to learn.

Reviewing the amplitude of gestures. During the gesture generation phase and after the enactment of the gestures, some of the participants expressed a concern for the eventual fatigue caused by performing large gestures. Participants in group C explained the reason for creating larger gestures by saying that they are depicted that way in fiction movies. They also suggested that the hand would be as sensitive as using the whole arm. Additionally, members of group C proposed that interacting with technology-enabled environments should be comparable to using a remote control. In other words, people should be able to use only the hand and have the arm resting. When asked if they would change any of the gestures they had created, members of group C said they would replace all gestures with smaller gestures.

The idea of smaller gestures also emerged from the conversations among group A participants. One of the participants in this group said he was creating gestures for "lazy people" and that he wanted "less hard" movements. This participant then started to try gestures using only the hand and fingers.

Multimodal interactions. According to participants, another challenging aspect of gesture generation concerns the desire for using another mode of interaction in conjunction with gestures. One participant in group B stated that she felt the process of creating gestures was counterintuitive because she wanted to add voice control to complement the gestural interactions. Another participant remarked that the first impulse of the group was to use voice commands and then use gestures.

Another concern that participants had regarded touch interactions. One participant said that, when thinking about interaction, there is always the assumption that the user will be able to touch the interface. Similarly, other participants commented that the hardest part of creating gestures was not being able to touch anything.

Gestures and communication. When participants were asked if the gestures created seemed natural, all groups agreed, saying that gestures are an integral part of human nature. More specifically, participants said that people use their hands to express themselves when communicating. However, participants noted that some of the gestures created seemed more natural than others. More importantly, participants perceived that some degree of artificiality would be necessary to avoid confusion. One of the members of group B said that "gestures should not be too natural, so they are not performed unintentionally."

Summary of findings from the workshop review	
Differentiation and reuse	• It was difficult to create specific gestures for different tasks • It is important to adopt some strategy to differentiate gestures to avoid misinterpretation • Participants borrowed gestures they usually performed with other technologies
Amplitude of gestures	• After reflecting on the enacted gestures, participants were concerned with the potential fatigue caused by ample gestures • The use of ample gestures was inspired by science fiction movies • Smaller gestures performed with one hand may provide the same possibilities as ample gestures
Multimodal interactions	• Participants wanted to use multimodal interactions such as voice control or touch
Gestures and communication	• Creating gestures for interaction with technology-enabled environments seems natural • Some gestures seemed more natural than others • It is necessary that gestures have some degree of artificiality to avoid misinterpretation

Table 07. Summary of findings from the workshop review.

4.3 Third Method: Validation Questionnaire

The third and last phase of data collection involved the validation questionnaire in which participants provided feedback on the findings from the experience simulation workshop. The analysis of the questionnaire was divided into two blocks: the first block examined the responses to the five Likert scale questions; the second block explored the answers to the five open-ended questions, followed by the grouping of the identified patterns into categories of findings.

4.3.1 Likert scale questions

The Likert scale questions sought to capture participants' opinions about the gestures created during the experience simulation workshop. Participants evaluated the gestures according to five criteria: feasibility, naturalness, ease of use, learnability and efficiency. The questionnaire respondents had five options for rating each criterion: not at all, very little, neutral, very and perfectly. Table 08 presents the score for each of the questions.

Evaluation Criteria	Not at all		Very little		Neutral		Very		Perfectly	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Feasibility	-	-	1	10	5	50	4	40	-	-
Ease of use	-	-	1	10	2	20	7	70	-	-
Naturalness	-	-	3	30	5	50	2	20	-	-
Learnability	1	10	5	50	4	40	-	-	-	-
Efficiency	-	-	2	20	-	-	8	80	-	-

Table 08. Validation questionnaire scores. Respondents' evaluation of gestures created during the workshop sessions.

The results from the questionnaire were not conclusive for criteria such as feasibility (Question 1) and naturalness (Question 3). In contrast, the responses suggested that the gestures were easy to use (Question 2) and were efficient to accomplish the tasks for which they were designed (Question 5). The responses also indicated that the gestures were not likely to be performed without previous learning (Question 4).

4.3.2 Open-ended questions

The analysis of the open-ended questions aimed to deepen the evaluation of the gestures created by workshop session participants. The questions captured respondents' perceptions of contexts, tasks and technologies that could benefit from the gestures created during the experience simulation. This second part of the validation questionnaire also intended to collect respondents' detailed feedback on aspects of the gestures.

Contexts, tasks and technologies. Overall, the responses to the open-ended questions validated using the gestures in the context of pervasive computing and with technology-enabled environments. Some of the words used by respondents to describe other contexts of use include smart homes, virtual reality and augmented reality environments, internet of things, video editing and gaming.

The list of tasks proposed by respondents was very similar to the tasks performed by workshop participants. The differences pertained mostly to the contexts. For example, instead of browsing through a playlist, respondents suggested browsing through a book. Similarly, instead of zooming in on a scene of a movie, respondents suggested zooming in for navigating a map.

Feasible and unfeasible gestures. Respondents were also asked to provide detailed feedback on which gestures stood out as feasible or unfeasible (Table 09). The list of gestures that respondents perceived as feasible included the swiping gesture (either with hand or fingers), halting gestures (used for pause) and splaying hands for zoom in. The gestures perceived as unfeasible included the thumbs-up for selecting, splaying hands like a book and all gestures used to accomplish the play movie task. Respondents justified these choices by saying that these gestures seemed awkward or inappropriate for the task.

Additionally, respondents also listed gestures that seemed unfeasible due their lack of differentiation and potential for misinterpretation. Examples of these gestures are the splaying hands for the zoom in and out and also for minimize and maximize (used by groups A and B).

Feasible	Unfeasible
Swiping hand or fingers left and right for advancing to the next or returning to the previous scene	Crossing finger to make and 'X' for removing items from playlist
Press and slide fingers for drag and move items	Flick away to remove items from playlist
Splaying hands or fingers for zoom in and zoom out	Thumbs-up for selecting item in the playlist
Halting gesture for pause movie	Closing hands like closing a book for minimizing
--	Opening hands like opening a book for playing a movie
--	Clapping for playing a movie
--	Waving for playing a movie

Table 09. Feasible and unfeasible gestures. List of gestures that stood out as feasible or unfeasible to questionnaire respondents.

Preference for smaller gestures. Another topic that emerged from the analysis of questionnaire responses and that was extensively debated by the respondents was the amplitude of the gestures. Respondents strongly agreed that ample gestures, such as the ones enacted in the workshops, are not preferable and are not feasible. The main issue, according to the respondents, is fatigue. In their opinion, smaller gestures would be easier to use and would favour more precise movements and refined interactions.

4.4 Summary of Findings

Taking into account the data collected from all three research methods—the fiction movie analysis, the experience simulation workshop and the validation questionnaire—the main findings of this study are discussed below and summarized in Table 10.

Despite the expected diversity of plots, there were similarities in how different fiction movies depicted the use of hand gestures for interaction. The scenes featuring gestural interactions presented one character as the main agent performing the gesture and interacting with the interface predominantly. Gestures were used to accomplish tasks one at a time, but in some instances several gestures were combined to accomplish one task. Additionally, the characters performed the gestures facing and interacting with a delimited area.

The analysis of the interactions describing the desired outputs and the input applied to achieve this goal showed a greater number of gestures (inputs) in contrast to the number of desired goals (output). In total, the analysis identified 94 gestures and 19 desired goals. In addition, the examination of the different dimensions of the taxonomy revealed that most of the gestures were executed using the right hand, followed by the preferred use of both hands. In general, the gestures in fiction movies are ample and are performed with the whole arm and hand.

The form of the gestures was predominantly a static pose with a path, although static pose without path and dynamic pose with path were also represented in significant numbers. In regards to the nature of gestures, most were categorized as metaphorical, followed by physical gestures and gestures of an abstract nature. No symbolic gestures were identified.

The gestures were for the most part bound to the objects with which they interacted, and the flow of the gestures was mostly continuous.

The experience simulation workshop revealed the preferences of participants when creating gestures. The results indicated that the dimensions of the taxonomy of participants' gestures were similar to the dimension observed in fiction movies. However, the results showed different proportions across the different categories.

Moreover, the discussions that participants had while creating gestures and later, while reviewing the enacted gestures, revealed that the similarities between different gestures was challenging. It would be difficult to generate gestures that are unique enough not to be confused with others. In that respect, participants indicated their desire for creating multimodal interactions by adding voice or touch to the gestural interactions. At a certain point during the conversations, participants also realized that ample gestures could become exhausting and that gestures with smaller amplitude could be more efficient. Moreover, workshop participants agreed that using gestures as input for interaction felt natural because gestures are already an integral part of human communication.

Lastly, the data obtained from the validation questionnaire showed that, according to people trained in human–computer interactions, the gestures generated in the workshops were easy to use and efficient even though training would be required to learn them. The questionnaires suggested that not all gestures were feasible and pointed to smaller gestures as preferable over larger gestures. Finally, questionnaire respondents identified other contexts of use, tasks and technologies that could benefit from gestures generated in the workshops.

Summary of findings	
Contexts of gesture-based interactions in movies	• Different fiction movies depict the use of hand gestures in similar ways • Usually one character as the main agent performing the gesture • Gestures are applied to accomplish tasks one at a time • In some cases several gestures are combined to accomplish one task • The character performing the gesture faces and interacts with a delimited area • All gestures are performed with the upper body, more specifically, the arms, hands and fingers.

Taxonomy of gestures in fiction	• The number of gestures observed is much greater than the number of desired goals • The analysis identified 94 gestures and 19 desired goals • Most of the gestures use the right hand, followed by the preferred use of both hands • Most of the gestures are ample, being performed with whole arm and hands • Regarding their form, most gestures have static pose and path • Most of gestures are metaphorical • Regarding their binding, most gestures are object-centric
Experience simulation workshop	• In general, the taxonomy of the enacted gestures matches the taxonomy of gestures observed in fiction • Participants had problems in generating gestures that are unique enough not to be confused with others • Participants wanted to add voice or touch to the gestural interactions • After reflecting on the enacted gestures, participants indicated that ample gestures could become exhausting and that gestures with smaller amplitude could be more efficient • Gestures as input for interaction feel natural because gestures are part of human communication
Validation questionnaire	• Gestures generated in the workshop are easy to use and efficient • Gestures created in the workshop may require prior training to learn them • Not all gestures created by participants are feasible • Smaller gestures are preferred over ample gesture due the potential for fatigue • The gestures created in the workshop have potential to be used with other applications and contexts of use

Table 10. Summary of findings.

CHAPTER 5

DISCUSSION

This chapter synthesizes the data collected and analyzed during the study. It discusses the findings from the research methods, comparing and contrasting them to the insights that emerged from the review of the academic literature. The objective here is to identify the contributions of this study to the field of interaction design.

The structure of this chapter corresponds to the research questions presented in the introductory chapter. It discusses the results related to the three sub-questions before concluding with insights into the main question that motivated this research project.

5.1 First Research Question

The first research question of this study is:

How do fictional scenarios of pervasive computing portray possible futures of gesture-based interaction?

This question seeks to unveil science fiction's vision of interactions with technology in a possible future. For this reason, the answer to this question is based primarily on the findings gathered from the first method of data collection: the movie analysis. The discussion starts by comparing the contexts of interactions seen in fictional scenarios to the visions of ubiquitous computing found in the literature. It then moves to a discussion of the attributes of gesture-based interactions. Later, it considers what the vision of a possible future of interaction science fiction may be proposing.

5.1.1 Contexts of pervasive technology

Human–human interactions. The findings from the movie analysis reveal that, concerning the contexts of use, science fiction movies frequently feature one character as the main agent of the interaction. Even when the scenes include more than one character, usually only one is interacting with the interface. To a certain extent, and regarding gestural interactions, these contexts of use diverge from Weiser's (Weiser & Brown, 1996; Weiser, 1991) vision of invisible and calm pervasive technologies.

For Weiser and Brown (1996), calm technologies would fade in the background of people's lives, raising the awareness of the world around them yet leaving people free to interact with each other. What was observed in the fiction movies is that technology is always present and visible. When the movies depict people connecting to each other, technology is either mediating or at the centre of that connection (Figure 18).

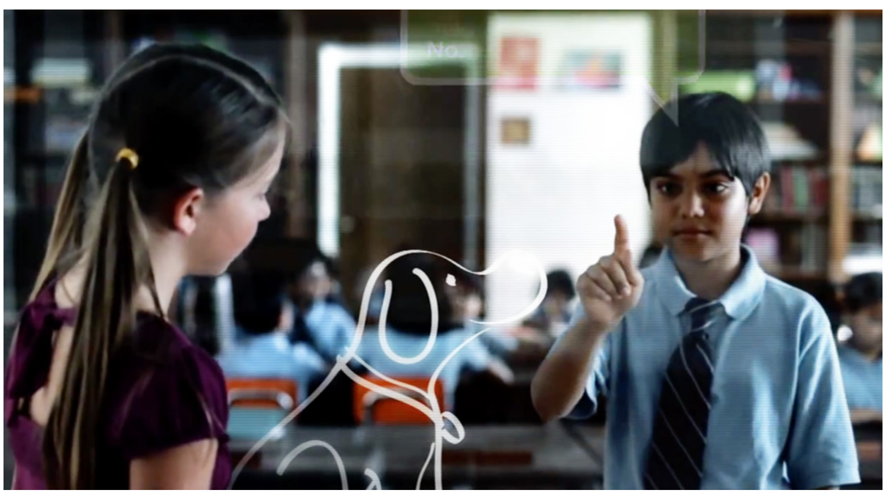

Figure 18. Technology mediating conversations. In the movies, technology often mediates human–human interactions. Adapted from “Productivity Future Vision” by Nicoll, 2009, Microsoft.

Engaging technologies. The interactions detailed in the science fiction movies align with Rogers' (Rogers, 2006) notion of engaging ubiquitous computing. Rogers advocates for interactions that provoke and stimulate people's creativity (Rogers, 2006). In several movies, the gestural interactions are portrayed as playful, allowing characters to explore their innate skills. Some examples of contexts of use in which the movies portray engaging interactions are found in the classroom, work collaboration, cooking and shopping (Figure 19).

However, even though interactions with technology are not necessarily calm, Weiser and Brown's (1996) notions of centre and periphery of attention are represented in the movies. In several scenes, characters are surrounded by information but are paying attention to only part of it. As indicated in Chapter 4, gestures are applied to achieve one task at a time.

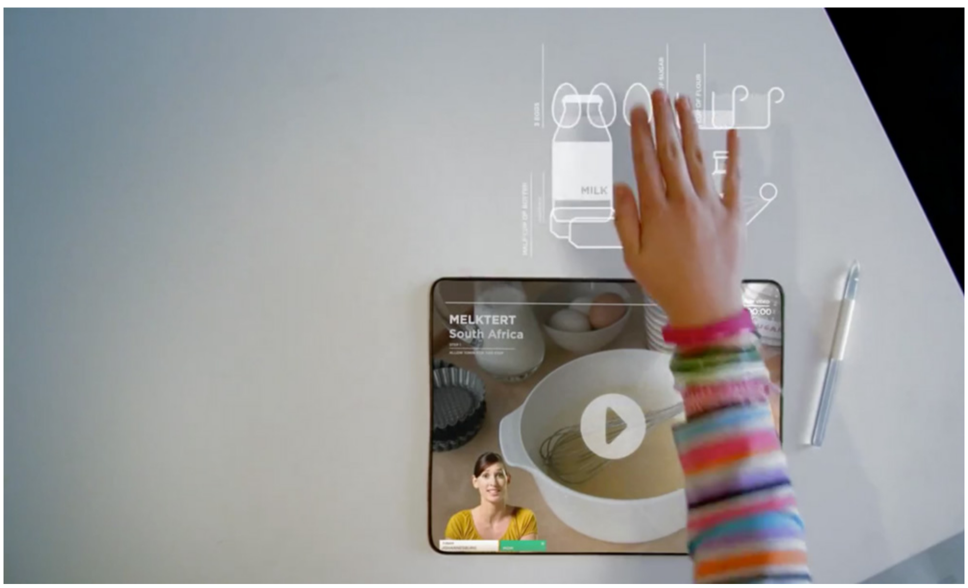

Figure 19. Engaging interaction. An example of engaging interaction seen in fiction movies. Adapted from “Productivity Future Vision II” by E. Keller, 2011, Microsoft.

Another important aspect of engaging technologies is that fiction movies align with the idea of augmented physical objects and environments (Ishii & Ullmer, 1997; Weiser & Brown, 1996; Weiser, 1991). In order to support and create opportunities for engaging interactions, the scenes show that objects in the real world and the physical environment are augmented, becoming tangible interfaces. For instance, in some of the movies analyzed, present interfaces are embedded in fridge doors and kitchen countertops (Figure 20).

Figure 20. Tangible interfaces. Very often the fiction movies focus on the augmented environments. Adapted from [1] “Productivity Future Vision II” by E. Keller, 2011, Microsoft. [2,3,4] “A Day Made of Glass” by Mackie, 2011, Corning.

Reference area for gestural interaction. As noted in the findings from the movie analysis, the gestural interactions always happen with the characters facing a defined area. Although this is expected for tangible interfaces such the ones illustrated in Figure 20, it is also true of depictions of touchless interactions. These findings corroborate the concept of mimetic interaction spaces (Rateau et al., 2014) which states that people tend to create spaces for touchless interaction and are inclined to turn to theses spaces when performing gestures.

5.1.2 Attributes of gesture-based interactions

The use of body and the amplitude of gestures. Insights from the literature review indicate that the body plays a fundamental role in shaping everyday actions (Dourish, 2004; Hornecker, 2011; Loke & Robertson, 2011). Eva Hornecker (2011) argues for interactions that take into account aesthetic aspects of body movement. Loke and Roberston (2011) introduce the concept of body as expression—one that describes expressive and aesthetic attributes of the body.

These lessons from academic literature confirm the findings from the fiction movie analysis. In the movies, gestures are predominantly performed by the whole arms and hands. Moreover, the framing of the camera does not only focus on the limbs performing the gestures. Rather, it very often captures a great portion of the body of the character (Figure 21). This suggests that, in fiction, not only the physical attributes of movement of the gesture are important but also the body expression of the character performing the action.

Figure 21. Body as expression. The movies often seek to capture the movement of the body. Adapted from "Ender's Game" by G. Hood, 2013, Lionsgate Films

Nature of gestures. The investigation of the nature of the gestures in fiction movies was based on the taxonomy proposed by Wobbrock, Morris and Wilson's study (2009) as well as the research of Cassell (1998). While the former proposed a taxonomy that considers user behaviour, the latter categorizes gestures according to their communicative functions. The analysis of the results of the movies correlate with both the descriptions of Cassell (1998) and some of the results obtained by Wobbrock, Morris and Wilson (2009).

The classification of the gestures according to their nature identified most gestures as metaphorical; that is, gestures that represent some feature of the action. But more importantly, none of the gestures was identified as symbolic, which may suggest that none of the gestures was invested with cultural meaning.

Handedness. Regarding the preferences of use, Wobbrock, Morris and Wilson (2009) reveal that users are in favour of using only one hand for interacting. In addition, users do not pay attention to the number of fingers employed in a gesture.

The analysis of the movies shows that the majority of gestures are performed with only one hand (66 of 94). Only 7 of 94 gestures feature the use of fingers.

The predominant use of one hand, as well as the almost non-existent use of fingers, may indicate that a strategy for the differentiation of gestures is not a concern in fiction movies. This observation contrasts with the results obtained by Oh and Findlater (2013) in their study about the feasibility of user-defined gestures. The authors note that one of the strategies people use to differentiate gestures consists of changing the number of fingers (Oh & Findlater, 2013).

Form and flow of gestures. The data collected from the movie analysis about the form of the gestures indicates that in 60 of the 94 gestures, the hand follows a path, moving from one point to another. Conversely, in only 9 gestures out of 94, the hand changes its pose. Moreover, in regards to the flow, the majority of the gestures represent a continuous rather than a discrete flow, meaning that the interface's feedback happens simultaneously to the interaction.

These findings about the form and flow, aligned with the insights about the amplitude of gestures, reinforce the idea that fiction movies value the expressive aspects of the action or interactions. In addition, the remarkably low number of gestures in which the hand changes its pose suggests a lack of concern for nuances of gestures, corroborating that fiction movies do not take strategies for differentiation into consideration.

Dependencies on the environment. The analysis of the binding of the gestures demonstrates that the majority of the gestures (79 of 94) depend on the object with which they are interacting. This finding indicates a correlation with the concepts of augmented objects and environments (Ishii & Ullmer, 1997; Weiser & Brown, 1996; Weiser, 1991) and the insights about engaging technologies. Moreover, the high number of object-centric gestures confirms that the fiction movies depict interactions that are heavily dependent on the interfaces and augmented objects presented in the scenes.

5.2 Second Research Question

The second research question in this study is:

How do people relate to the gestures envisioned in fictional scenarios of pervasive computing? Do they perceive them as intuitive?

The answer to this question lies mostly in the triangulation of data collected from the experience simulation workshop, the validation questionnaire and the movie analysis. Insights also emerged from the comparison of the data collected with the knowledge acquired from the literature review.

In line with the "moving and making strange" approach (Loke & Robertson, 2013), the discussion of the results from the experience simulation workshop considered the perspective of both the participants (the movers) and the researcher (the observer). Similarly, the respondents to the validation questionnaire evaluated the gestures from the perspective of the observer.

The discussion of the results takes both perspectives (mover and observer) into account. It provides insight into the different notions of body that come into play when generating gestures for interacting with fictional, pervasive technologies.

5.2.1 Enactment of gestures and the movie analysis

The results obtained from the analysis of the enactment of gestures in the experience simulation demonstrate that, in general, people's perception of gesture-based interactions is very similar to the one portrayed in fiction (Figure 22). Indeed, more than one group performed, with the same intent, some of the gestures seen in fiction. These similarities may indicate, as suggested by Shedroff and Noessel (2012), the existence of a collective of cultural references due to the circulation of fiction content in media channels.

Similar to the findings from the movie analysis, participants in the experience simulation workshop also created ample gestures in which the hands followed a path without changing their pose, and to which the flow of interactions was imagined to be ongoing. Insofar as the binding is concerned, the gestures created by participants were object-centric, suggesting a dependency to augmented environments (Ishii & Ullmer, 1997; Wobbrock et al., 2009).

Regarding the handedness, participants in the experience simulation, as in the fiction movies, preferred interacting with only one hand, matching the conclusions of Wobbrock, Morris and Wilson (2009).

Figure 22. Correspondence of gestures. Many gestures enacted during the experince simulation workshop correspond to gestures depicted in fiction. Adapted from [1a] “Her” by S. Jonze, 2013, Warner Bros. Pictures; [2a] “Ender’s Game” by G. Hood, 2013, Lionsgate Films [3a] “Iron Man III” by S. Black, 2013, Walt Disney Studios.

Nature of gestures. Most of the gestures that the participants performed were also metaphorical. Interestingly, workshop participants, unlike characters in fiction movies, also created symbolic gestures. Some examples of symbolic gestures generated are the halt gesture, the halt gesture with closed fist (a reference from military hand signals) and the thumbs-up (Figure 23). Considering that symbolic gestures carry cultural meanings (Cassell, 1998), this finding supports the idea that gesture and body movement interactions should take into account social and cultural aspects of people (Bell & Dourish, 2006; Cassell, 1998; Hornecker & Buur, 2006).

Figure 23. Symbolic gestures. Gestures like [1] the halt gesture, [2] the halt gesture with closed fist, and [3] the thumbs-up carry cultural meanings.

Reference area for interaction. Workshop participants also interacted with a user-defined reference area (Figure 24), corroborating the work of Rateau, Grisoni and De Araujo (2014). Moreover, all groups naturally faced the same wall to enact the gestures they generated. It is possible that the set-up of the workshop space (with participants facing an empty wall), and the context of the experiment (watching a movie) favoured the creation of reference area for interaction.

Figure 24. User-defined area for interaction. A user-defined area for interaction was observed in the movies as well as in the workshops. Adapted from [1] "Iron Man II" by J. Favreau, 2010, Paramount Pictures.

5.2.2 Insights from participants' conversations

Differentiation and re-use of gestures. The discussions that participants had before and after enacting the gestures also provide insights into how people relate to gestures depicted in fiction. From these insights emerged topics that corroborate observations from the literature review. such as the preference for familiar gestures, differentiation and re-use of gestures.

While generating gestures for the enactment, all participants sought inspiration from previous experiences with technologies and familiar gestures. The familiar gestures mostly replicate interactions with smartphones, but participants also drew from their experiences with computer applications or, in fewer cases, from gestures not related to the use of technology (for example, the opening book gesture). These findings support the studies showing that people tend to create and value gestures that are already familiar to them (Nacenta et al., 2013; Oh & Findlater, 2013; Wobbrock et al., 2009).

During the generation phase, two topics were also of concern to participants: differentiation and re-use of gestures. While some participants opted for creating as many distinct gestures as possible to avoid confusion, others re-used gestures as part of a conscious strategy to improve learnability. However, in both cases, participants struggled to create gestures that were different enough. The respondents to the validation questionnaire also addressed some concerns about the dilemma of the differentiation and re-use of gestures, using these aspects to define gestures as either feasible or unfeasible.

These findings reflect what Oh and Findlater (2013) observe, namely that, even though people consciously look for strategies for creating unique gestures, differentiation is a recurrent issue for user-defined gestures.

Multimodal and communicative aspects of gestures. The search for ways to differentiate the gestures may have incited in workshop participants the wish for multimodal interactions. As described in the findings chapter, participants manifested the desire for another mode of interaction to complement the gestures. Notably, they mentioned voice command and touch as interactive modalities that they wanted to add. While the need for touch-based interactions resonates with the idea of direct manipulation of tangible interfaces (Hornecker, 2005; Ishii & Ullmer, 1997; Shaer & Hornecker, 2010), the use of voice command aligns with the notion that gestures have communicative functions linked to speech (Cassell, 1998; Eisenstein & Davis, 2004).

Considering the two studies about linguistic functions of gestures (Cassell, 1998; Eisenstein & Davis, 2004), the difficulty that participants had may have been due a initial focus on physical attributes of a gesture rather than first trying to communicate an intent.

5.2.3 How participants perceive the gestures

Considering that the gestures enacted by participants largely reflect the gestures observed in the fiction movies, it is possible to say that people relate to gestures imagined in fiction scenarios. However, the issues and concerns that emerged during the generation and after—during the review of the gestures—indicate that gestures in fiction do not comprise all essential aspects of gestural interactions.

In spite of these limitations, participants manifested a positive impression about the gestures they created. Their overall perception that the process of generating gestures is easy and fun, as well as their evaluation of the participant-defined gestures as natural, corroborate the results from several studies about user-defined gestures (Grandhi et al., 2011; Nacenta et al., 2013; Oh & Findlater, 2013).

5.3 Third Research Question

The third research question in this study is:

Which intuitive gestures could support the process of designing technologies that require body movement as input?

The intention of this question is, to some extent, to move the focus from fiction and place it on real possibilities for gesture-based interactions. The answer to the third questions draws mostly on the discussion among workshop participants when reviewing the gestures and also from the data collected from the validation questionnaire.

5.3.1 Intuitive gestures

The first part of the third research question refers to the gestures that people perform intuitively. As previously indicated, the workshop participants perceived the gestures they created as natural, feasible and efficient. The analysis of the generated gestures also corresponds to the gestures seen in the fiction movies.

These findings may lead to an extensive list of preferred gestures that simply correlates the gestures from fiction with the ones from the workshop. But the issues that emerged from participants' discussion along with the evaluation from respondents of the validation questionnaire warrant further analysis.

The results from the Likert scale questions indicate that the notion of intuitiveness may not be easily assessed. In fact, none of the workshop participants used the word "intuitive" to describe the gestures they created. Similarly, the results from the validation questionnaire were not conclusive in that respect.

However, the respondents to the validation questionnaire, like the workshop participants, perceived the gestures developed during the simulation as efficient and easy to use.

In addition, the respondents identified that some gestures created by participants stood out as more feasible while others were perceived as unfeasible. The list of feasible gestures encompasses many gestures identified by participants as familiar based on previous experience with other technologies. The list of unfeasible gestures contains those that the respondents perceived as awkward or out of context. Interestingly, among the unfeasible gestures are those that have a symbolic nature. As already observed, the fiction movies studied did not depict symbolic gestures.

5.3.2 Ample versus small gestures.

Another topic addressed by both the workshop participants and the respondents to the questionnaire concerns the amplitude of gestures.

Even though participants enacted interactions using ample gestures, later in the discussions they realized that the same interactions could be accomplished using smaller gestures employing only the hands and fingers. The participants were also concerned with the possible fatigue caused by performing ample gestures for long periods of time. Likewise, the respondents to the questionnaire criticized the use of ample gestures, also because of the potential for fatigue, and indicated that smaller gestures would provide more precise movements.

The controversy over ample versus small gestures not only contrasts with the vision depicted in the fiction movies, but it also contradicts the primary choice of participants who enacted ample gestures.

5.3.3 Gestures to support the design process

Even though participants have an overall positive impression of the gestures they generated, and even though the analysis of these gestures matches the gestures in fiction, without subsequent review, some issues may have gone unnoticed. To a certain extent, this resonates with the argument for a mixed-approach for developing gestures as proposed by Oh and Findlater (2013).

Nonetheless, it is plausible to affirm that gestures identified as familiar and used to interact with other technologies tend to be perceived as easy to transfer to other applications. The gestures that emerge from cultural situations, such as symbolic gestures, tend to be seen as awkward if observed out of context. Lastly, gestures that employ smaller movements might provide more refined, feasible and more efficient interactions.

5.4 Main Research Question

The main research question in this research is:

How can the exploration of fictional scenarios of possible futures in pervasive computing drive to opportunities for suitable gestures for interacting with technologies that require body movement as input, creating more intuitive experiences?

The insights to address this question synthesize the discussions that explored each of the three research questions. Moreover, this main research question offers the opportunity for a critical discussion of future possibilities for gestural interactions and for developing them.

5.4.1 The fictional scenario

Possible future. The findings and insights from this research allow for speculation about the possible future of gesture-based interactions with technology-enabled environments. In this future, technology does not disappear into the background of everyday life but, instead, technological artefacts and environments mediate the interaction between people. The objects and environments in the real world are augmented with technologies, and people do not interact with the augmented world passively. Instead, people engage with technology actively through touch and gestures. Moreover, in the gestural interactions, the movements of the body are truly expressive, the gestures and movements are ample and noticeable so that they can leverage the interactions with the interface.

In summary, the possible futures of fiction scenarios present potential new technologies at the centre. It is a technology-centric future. Gestures and embodied interactions exist to support and leverage tangible interfaces and pervasive technologies.

Finding problems. Reflecting on this possible future and taking into consideration Dunne and Raby's (2012) proposition to turn design into a problem-finding discipline, it is necessary to speculate about the issues surrounding gesture-based interactions. The vision of a future that exists around technological advances repeats an issue that has already been identified and debated in the literature (Bell & Dourish, 2006). Furthermore, when the possible future depicts the use of gesture and embodied interactions as means to support the interfaces, it fails to address the subtleties that will ultimately impact the experience of the new technologies. The discussion during the experience simulation showed that, although people initially adopted gestures demonstrated in fiction, once they reflected on those gestures, many issues emerged. In addition, in focusing too much on the technologies, the vision of the possible future fails to consider people's cultural and social contexts in which gestures are embedded.

5.4.2 Design opportunities

Considering the potential issues for the future development of gesture-based interactions, what are the opportunities for design? It seems clear that the research into embodied interactions needs to focus more on people. The designing of interactions should consider how cultural and social contexts influence communication intent, therefore, modifying how gestures are used. Referring to existing gestures that are already in use with other technologies has shown value, but it is also essential to consider familiar gestures that arise from other, personal contexts.

Moreover, there are still opportunities for deeper analysis of physical attributes of gestures. When do gestures need to be ample and expressive, and when are smaller gestures preferred? Furthermore, there are subtleties in smaller gestures that are yet to be fully explored. A possible challenge is to discover if the interaction with only one hand and fingers can offer the same possibilities for rich experiences as the ones employing both arms and hands.

It is also important to take into account the role of multimodality in gesture-based interactions. If gestures are inserted in a communicative context in which people try to articulate intent before acting on it, maybe gestures need to be coupled with other interactive modes.

These insights may support the creation of more meaningful interactive experiences involving gestural interactions and pervasive technologies.

CHAPTER 6

CONCLUSION

After an extensive literature review of pervasive technologies, embodied interaction, gesture-based interaction and critical design, it became clear that there was a gap in the research related to gesture-based interactions with technologies that use body movement as input.

The analysis of previous research on pervasive technologies revealed a dominant vision of the future of ubiquitous computing in which technological artefacts would disappear into the background of people's lives. In order to accomplish this vision, much of the research has focused on methods and tools to leverage the potential of technology. In contrast with this dominant vision, the literature review explored several other studies that advocated for research on pervasive technologies that go beyond technological possibilities. According to those studies, pervasive technologies should be provocative, considerate of people's social values, and should engage people in meaningful interactions through the exploration of their body movements.

Taking the limitations of the current technologies and the unexplored potential of gesture-based interactions into account, this research examines the issue from the perspective of science fiction and critical design.

Three methods of data collection were used to support the examination of the subject of this research. The first method consisted of analyzing futuristic scenarios in movies with the intent to identify gesture-based interactions envisioned by science fiction. The analysis of fiction movies resulted in a list of twenty tasks that were used in the experience simulation workshop. The goal of this second research method was to investigate how people relate to the gestures depicted in fiction and which gestures people prefer performing when interacting with pervasive technologies. The third method of data collection consisted of inviting people trained in the fields of human-computer interaction and interaction design to evaluate the gestures generated by workshop participants.

The results from the analysis of movies provide insights into the vision that fiction offers about the future of gesture-based interaction. The analysis reveals contexts of use and attributes of gestures. The results from the experience simulation workshop show how people relate to the gestures proposed in fiction. Moreover, the results also expose the reasoning behind people's choice of gestures, as well as people's reflection about issues identified after reviewing such gestures. The findings from the third research method provide an objective evaluation of gestures and issues generated during the experience simulation from a perspective other than the researcher’s and that of the workshop participants.

Finally, the comparison and contrast of the information gathered from the academic literature with the data collected from the three research methods underpins the final discussion surrounding the research questions. In summary, the discussion notes that, in general, people's preferences for choosing gestures to interact with pervasive technology match the gestures envisioned in science fiction. However, in the process of generating and reflecting on the use of such gestures, people identified issues concerning not only the physical attributes of the gestures but also their communicative and cultural aspects. These insights point to the contributions of this research, its limitations and directions for future work.

6.1 Contributions

The findings from this research offer contributions to the field that may support the development of technologies that require gesture-based interaction as input. Drawing from the research questions, the contributions of this research include:

- The discovery that people prefer familiar gestures that take into account cultural and social contexts.
- The need for awareness of the multimodality aspects and communicative functions of the gestures.
- The need for strategies to differentiate gestural interactions and the difference between large and small gestures.
- The definition of design opportunities to support the development of future research and to provide insights for current studies on the use of gesture-based interactions.
- A description of a possible future for pervasive technologies and embodied interactions.
- The novelty of the methodology applied to this research project. This methodology innovates by reflecting on the future from the perspective of fiction, but it also advocates for the participation of the user of future technologies to speculate about the preferred ways to interact with it. This methodology is innovative, particularly for designer researchers and practitioners who intend to learn more about the creation and use of gestural interactions.

6.2 Limitations

For the benefit of the critical analysis of the present study and out of respect for future studies, it is important to consider the limitations of this research.

The limitations start with the selection of the sample for the movie analysis. The analysis of fiction movies is a fundamental part of this study and, as previously noted, fiction builds the cultural references that support design speculation. Therefore, the choice of movies to analyze has a direct impact on the results. Moreover, the movies selected may have depicted fiction according to the perspective of North American cinema. Although North American cinema is widely spread around the world, it does not necessarily capture the cultural diversity that can contribute to different visions of the future.

The next consideration regards the sample of participants for both the experience simulation workshop and the validation questionnaire. First, the size of the sample might be relatively small if the intention is to take the results of this study further. Second, the participants share, to a certain extent, the same context. Most participants were students in the same age range. At the time of this study, all participants lived in Canada, in the same cultural context in which the movies were created. It is possible that all of these associations contributed to some of the congruencies revealed in the research results.

Lastly, the context for gesture generation proposed in the experience simulation workshop may have limited the results. Participants were invited to create gestures for watching movies in a technology-enabled environment. It is possible that this context may have directed some of the interactions by evoking previous experiences related to tasks associated with it.

6.3 Future Research

The findings, contributions and limitations of this study offer insights that can be explored further in future research on gesture generation and pervasive technologies.

The design opportunities identified here offer themes that can lead to future research, namely:

- How can cultural and social contexts, and communicative functions of gestures influence the development of interactions that require body movement as input?
- Which aspects of contexts of use influence the amplitude of gestures? When is the use of smaller gestures preferred over ample gestures and vice versa?
- Do the interactions through smaller gestures offer the same possibilities for interaction as ample gestures?
- How can multimodal interactions support the development of gesture-based interactions?

Another possibility for future research involves addressing some of the limitations of this study. For example, there is room for researchers to validate the results of this study by applying the same methodology but with a different sample. New research could also analyze other fictional visions of the future and choose a different group of participants who come from different cultural contexts.

There is also the possibility of analyzing the use of gesture-based interactions with technology-enabled environments in contexts of use other than watching movies. For example, would the gestures be the same if similar tasks were applied to the context of cooking?

Lastly, there is an opportunity for future research on the methodological approach of this study. Is it possible to refine the methodology to generate faster results? Can this methodology benefit the development of pervasive technologies and gesture-based interactions in professional practice?

REFERENCES

A Day Made of Glass II [Motion Picture]. (2012). USA: Corning.

Bell, G., & Dourish, P. (2006). Yesterday's tomorrows: notes on ubiquitous computing's dominant vision. *Personal and Ubiquitous Computing*, *11*(2), 133–143.

Black, S. (2013). *Iron Man III* [Motion Picture]. USA: Walt Disney Studios.

Bouma, G., Ling, R., & Wilkinson, L. (2012). *The research process* (2nd ed.). New York, NY: Oxford University Press.

Cassell, J. (1998). A framework for gesture generation and interpretation. In R. Cipolla & A. Pentland (Eds.) *Computer Vision in Human-Machine Interaction* (pp. 191–216). Cambridge, MA: Cambridge University Press.

Dourish, P. (2004). *Where the action is: The foundations of embodied interaction*. Cambridge, MA & London, UK: MIT Press.

Dourish, P., & Bell, G. (2013). "Resistance is futile": reading science fiction alongside ubiquitous computing. *Personal and Ubiquitous Computing*, *18*(4), 769–778.

Dunne, A. (2008). *Hertzian tales: electronic products, aesthetic experience, and critical design.* Cambridge, MA & London, UK: MIT Press.

Dunne, A., & Raby, F. (2012). *Speculative everything: design, fiction, and social dreaming*. Cambridge, MA & London, UK: MIT Press.

Eisenstein, J., & Davis, R. (2004). Visual and linguistic information in gesture classification. In *Proceedings of the 6th International Conference on Multimodal Interfaces* (pp. 113–120). New York, NY, USA.

Favreau, J. (2010). *Iron Man II* [Motion Picture]. USA: Paramount Pictures.

Forster, M. (2008). *Quantum of Solace* [Motion Picture]. USA: Metro-Goldwyn-Mayer Columbia Pictures.

Gomez, J., & Green, T. (2012). *Zazzle The Future* [Motion Picture]. USA: Shilo.

Grandhi, S. A., Joue, G., & Mittelberg, I. (2011). Understanding naturalness and intuitiveness in gesture production. In *Proceedings of the 2011 annual conference on human factors in computing systems - CHI '11* (pp. 821–824).

Grijincu, D., Nacenta, M. A., & Kristensson, P. O. (2014). User-defined interface gestures : dataset and analysis. In *Proceedings of the 9th ACM International Conference on Interactive Tabletops and Surfaces,* (1), 25–34.

Harrison, S., & Dourish, P. (1996). Re-place-ing space : the roles of place and space in collaborative systems. *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work*, *7*, 67–76.

Hood, G. (2013). *The Ender's Game* [Motion Picture]. USA: Lionsgate Films.

Hornecker, E. (2005). Tangible interaction design, space, and place. In *HCI' Workshop at Interact 2005*.

Hornecker, E. (2011). The role of physicality in tangible and embodied interactions. *Interactions*, *18*(2), 19–23.

Hornecker, E., & Buur, J. (2006). Getting a grip on tangible interaction: a framework on physical space and social interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 437–446).

Ishii, H., & Ullmer, B. (1997). Tangible bits: towards seamless interfaces between people, bits and atoms. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, (March), 241.

Jonze, S. (2013). *Her* [Motion Picture]. USA: Warner Bros. Pictures.

Keller, E. (2011). *Productivity Future Vision II* [Motion Picture]. USA: Microsoft.

Klemmer, S. R., Hartmann, B., & Takayama, L. (2006). How bodies matter : five themes for interaction design. In *Proceedings of the 6th Conference on Designing Interactive Systems*, (pp. 140–149).

Kumar, V. (2012). *101 design methods: a structured approach for driving innovation in your organization*. Wiley.

Larssen, A. T., Robertson, T., & Edwards, J. (2007). The Feel Dimension of Technology Interaction: Exploring Tangibles Through Movement and Touch. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction* (pp. 271–278). New York, NY, USA

Lentini, L., & Decortis, F. (2010). Space and places: when interacting with and in physical space becomes a meaningful experience. *Personal and Ubiquitous Computing*, *14*(5), 407–415.

Loke, L., & Robertson, T. (2011). The lived body in design: mapping the terrain. *Proceedings of the 23rd Australian Computer-Human Interaction Conference,* (pp. 181–184).

Loke, L., & Robertson, T. (2013). Moving and making strange: an embodied approach to movement-based interaction design. *ACM Trans. Comput.-Hum. Interact.*, *20*(1), 7:1–7:25.

Mackie, D. (2011). *A Day Made of Glass* [Motion Picture]. USA: Corning.

Martin, B., Hanington, B., & Hanington, B. M. (2012). *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions*. Beverly, MA: Rockport Publishers.

Nacenta, M. A., Kamber, Y., Qiang, Y., & Kristensson, P. O. (2013). Memorability of pre-designed and user-defined gesture sets. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, 1099.

Nelson, H. G., & Stolterman, E. (2012). *The design way: intentional change in an unpredictable world*. Cambridge, MA: MIT University Press Group Limited.

Nicoll, M. (2009). *Productivity Future Vision* [Motion Picture]. USA: Microsoft.

Noteloop. (n.d.). Retrieved November 20, 2014, from http://www.noteloop.com/kit/fui/

Oh, U., & Findlater, L. (2013). The Challenges and potential of end-user gesture customization. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13* (pp. 1129–1138).

Rateau, H., Grisoni, L., & Araujo, B. De. (2014). Mimetic interaction spaces: controlling distant displays in pervasive environments. *Proceedings of the 19th International Conference on Intelligent User Interfaces*, 89–94.

Rogers, Y. (2006). Moving on from Weiser's vision of calm computing: engaging UbiComp experiences, 404–421.

Shaer, O., & Hornecker, E. (2010). Tangible user interfaces: past, present, and future directions. *Found. Trends Hum.-Comput. Interact.*, *3*(1), 1–137.

Shedroff, N., & Noessel, C. (2012). *Make it so: interaction design lessons from science fiction*. Brooklyn, NY: Rosenfeld Media.

Vertegaal, R. (2011). The (re)usability of everyday computational things: why industrial design will be the new interaction design. *Interactions*, *18*(1), 38–41.

Weiser, M. (1991). The computer for the 21st century. *Scientific American*, *265*(3), 94–104.

Weiser, M., & Brown, J. S. (1996). Designing calm technology. *PowerGrid Journal*, *1*(1), 75–85.

Wobbrock, J. O., Morris, M. R., & Wilson, A. D. (2009). User-defined gestures for surface computing. *Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09*, 1083.

Yuen, J. (n.d.). HUDs and GUIs. Retrieved November 20, 2014, from http://www.hudsandguis.com/

APPENDIX A

Letter of Invitation for Experience Simulation Workshop

Carleton
UNIVERSITY
Canada's Capital University

Letter of Invitation

Title: Exploratory Research About Intuitive Use of Gestures for Interacting in Smart (Technology-Enabled) Environments.

Date of ethics clearance: February 19, 2015

Ethics Clearance for the Collection of Data Expires: May 31, 2015

February 19, 2015

Dear [Insert Name],

My name is Daniel Bianchi and I am a Master's student in the School of Industrial Design at Carleton University. I am working on a research project under the supervision of Professor Lois Frankel and Professor Anthony Whitehead.

I am writing to you today to invite you to participate in a study on the intuitive use of gestures for interacting in smart (technology-enabled) environments. This study aims to gain an understanding about gestures that reflect users' preferences when interacting with technologies in smart environments.

This study involves an up to 2-hour workshop that will take place in a mutually convenient, safe location. In this workshop you will be asked to work in a group with other people to explore how you would use hand gestures to interact with a smart environment.

With your consent, the workshop session will be video-recorded for subsequent analysis. Please, be advised that the subsequent analysis involves presenting the videos recorded in this workshop session to other participants of this study.

This project does not involve professional or emotional risks. Please note that, because this study requires working with other people, you will not be anonymous during this research. You may request that certain responses not be included in the final project.

You will have the right to end your participation in the study at any time, for any reason, up until March 06, 2015. If you withdraw from the study, your image will be omitted from all videos.

As a token of appreciation, I will be providing you with refreshments during the workshop. No other compensation will be provided.

All research data, including video-recordings and any notes will be securely stored and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at Carleton University. Research data will be accessible by the researcher and the research supervisor. All data gathered might used to produce additional research work on the same topic of this study such as research paper, books or for conferences.

All research data will be stored and might be used as described above, until May 31, 2020. On this same day, all research data will be securely destroyed. (Electronic data will be erased and hard copies will be shredded).

This ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Louise Heslop, Chair
Professor Andy Adler, Vice-Chair
Research Ethics Board
Carleton University
511 Tory
1125 Colonel By Drive
Ottawa, ON K1S 5B6
Tel: 613-520-2517
ethics@carleton.ca

If you would like to participate in this research project, or have any questions, please contact me at 819-923-9051 or daniel.bianchi@carleton.ca.

Sincerely,

Daniel Bianchi

APPENDIX B

Letter of Invitation for Validation Questionnaire

Carleton
UNIVERSITY
Canada's Capital University

Letter of Invitation

Title: Exploratory Research About Intuitive Use of Gestures for Interacting in Smart (Technology-Enabled) Environments.

Date of ethics clearance: February 19, 2015

Ethics Clearance for the Collection of Data Expires: May 31, 2015

February 19, 2015

Dear [Insert Name],

My name is Daniel Bianchi and I am a Master's student in the School of Industrial Design at Carleton University. I am working on a research project under the supervision of Professor Lois Frankel and Professor Anthony Whitehead.

I am writing to you today to invite you to participate in a study on the intuitive use of gestures for interacting in smart (technology-enabled) environments. This study aims to gain an understanding about gestures that reflect users' preferences when interacting with technologies in smart environments.

This study involves an up to 2-hour workshop that will take place in a mutually convenient, safe location. In this workshop you will be asked to work with in a group with other people to explore how people would use hand gestures to interact with a smart environment.

This project does not involve professional or emotional risks. Please note that, because this study requires working with other people, you will not be anonymous during this research. You may request that certain responses not be included in the final project.

You will have the right to end your participation in the study at any time, for any reason, up until February 27, 2015. If you withdraw from the study, all information you have provided as part of the group exercise cannot be destroyed because other participants of the workshop might have heard and responded to it.

As a token of appreciation, I will be providing you with refreshments during the workshop. No other compensation will be provided.

All research data, including video-recordings and any notes will be securely stored and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at Carleton University. Research data will be accessible by the researcher and the research supervisor. All data gathered might used to produce additional research work on the same topic of this study such as research paper, books or for conferences.

All research data will be stored and might be used as described above, until May 31, 2020. On this same day, all research data will be securely destroyed. (Electronic data will be erased and hard copies will be shredded).

This ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Louise Heslop, Chair
Professor Andy Adler, Vice-Chair
Research Ethics Board
Carleton University
511 Tory
1125 Colonel By Drive
Ottawa, ON K1S 5B6
Tel: 613-520-2517
ethics@carleton.ca

If you would like to participate in this research project, or have any questions, please contact me at 819-923-9051 or daniel.bianchi@carleton.ca.

Sincerely,

Daniel Bianchi

APPENDIX C

Consent Form for Experience Simulation Workshop

Carleton UNIVERSITY
Canada's Capital University

Consent Form

Title: Exploratory Research About Intuitive Use of Gestures for Interacting in Smart (Technology-Enabled) Environments.

Date of ethics clearance: February 19, 2015

Ethics Clearance for the Collection of Data Expires: May 31, 2015

I ____, choose to participate in a study on the intuitive use of gestures for interacting in smart (technology-enabled) environments. This study aims to gain an understanding about gestures that reflect users' preferences when interacting with technologies in smart environments. **The researcher for this study is Daniel Bianchi in the School of Industrial Design.** He is working under the supervision of Professor Lois Frankel in the School of Industrial Design and Professor Anthony Whitehead in the School of Information Technology.

This study involves an up to 2-hour workshop that will take place in a mutually convenient, safe location. In this workshop you will be asked to work in a group with other people to explore how you would use hand gestures to interact with a smart environment.

With your consent, the workshop session will be video-recorded for subsequent analysis. Please, be advised that the subsequent analysis involves presenting the videos recorded in this workshop session to other participants of this study.

This project does not involve professional or emotional risks. Please note that, because this study requires working with other people, you will not be anonymous during this research. You may request that certain responses not be included in the final project.

You have the right to end your participation in the study at any time, for any reason, up until February 27, 2015. You can withdraw by phoning or emailing the researcher or the research supervisor. If you withdraw from the study, your image will be omitted from all videos.

As a token of appreciation, I will be providing you with refreshments during the workshop. No other compensation will be provided.

All research data, including video-recordings and any notes will be securely stored and password-protected. Any hard copies of data (including any handwritten notes

This document has been printed on both sides of a single sheet of paper.
Please retain a copy of this document for your records.

or USB keys) will be kept in a locked cabinet at Carleton University. Research data will be accessible by the researcher and the research supervisor. All data gathered might used to produce additional research work on the same topic of this study such as research paper, books or for conferences.

All research data will be stored and might be used as described above, until May 31, 2020. On this same day, all research data will be securely destroyed. (Electronic data will be erased and hard copies will be shredded).

The ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Louise Heslop, Chair
Professor Andy Adler, Vice-Chair
Research Ethics Board
Carleton University
511 Tory
1125 Colonel By Drive
Ottawa, ON K1S 5B6
Tel: 613-520-2517
ethics@carleton.ca

Researcher contact information:
Daniel Bianchi
School of Industrial Design
Carleton University
Tel: 819-923-9051
Email: daniel.bianchi@carleton.ca

Supervisor contact information:
Lois Frankel
School of Industrial Design
Carleton University
Tel: 613-520-5675
Email: lois_frankel@carleton.ca

Supervisor contact information:
Anthony Whitehead
School of Information Technology
Carleton University
Tel: (613) 520-2600 ext. 1696
Email:
anthony.whitehead@carleton.ca

Do you agree to be video-recorded: ___Yes ___No

This document has been printed on both sides of a single sheet of paper. Please retain a copy of this document for your records.

Signature of participant Date

Signature of researcher Date

APPENDIX D

Consent Form for Validation Questionnaire

Carleton UNIVERSITY
Canada's Capital University

Consent Form

Title: Exploratory Research About Intuitive Use of Gestures for Interacting in Smart (Technology-Enabled) Environments.

Date of ethics clearance: February 19, 2015

Ethics Clearance for the Collection of Data Expires: May 31, 2015

I ____, choose to participate in a study on the intuitive use of gestures for interacting in smart (technology-enabled) environments. This study aims to gain an understanding about gestures that reflect users' preferences when interacting with technologies in smart environments. **The researcher for this study is Daniel Bianchi in the School of Industrial Design.** He is working under the supervision of Professor Lois Frankel in the School of Industrial Design and Professor Anthony Whitehead in the School of Information Technology.

This study involves an up to 2-hour workshop that will take place in a mutually convenient, safe location. In this workshop you will be asked to work with in a group with other people to explore how people would use hand gestures to interact with a smart environment.

This project does not involve professional or emotional risks. Please note that, because this study requires working with other people, you will not be anonymous during this research. You may request that certain responses not be included in the final project.

You have the right to end your participation in the study at any time, for any reason, up until April 3, 2015. You can withdraw by phoning or emailing the researcher or the research supervisor. If you withdraw from the study, all information you have provided as part of the group exercise cannot be destroyed because other participants of the workshop might have heard and responded to it.

As a token of appreciation, I will be providing you with refreshments during the workshop. No other compensation will be provided.

All research data, including video-recordings and any notes will be securely stored and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at Carleton University. Research data will be accessible by the researcher and the research supervisor. All data gathered might used to produce additional research work on the same topic of this study such as research paper, books or for conferences.

All research data will be stored and might be used as described above, until May 31, 2020. On this same day, all research data will be securely destroyed. (Electronic data will be erased and hard copies will be shredded).

The ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Louise Heslop, Chair
Professor Andy Adler, Vice-Chair
Research Ethics Board
Carleton University
511 Tory
1125 Colonel By Drive
Ottawa, ON K1S 5B6
Tel: 613-520-2517
ethics@carleton.ca

Researcher contact information:
Daniel Bianchi
School of Industrial Design
Carleton University
Tel: 819-923-9051
Email: daniel.bianchi@carleton.ca

Supervisor contact information:
Lois Frankel
School of Industrial Design
Carleton University
Tel: 613-520-5675
Email: lois_frankel@carleton.ca

Supervisor contact information:
Anthony Whitehead
School of Information Technology
Carleton University
Tel: (613) 520-2600 ext. 1696
Email:
anthony.whitehead@carleton.ca

Do you agree to be video-recorded: ___Yes ___No

Signature of participant Date

Signature of researcher Date

This document has been printed on both sides of a single sheet of paper.
Please retain a copy of this document for your records.

APPENDIX E

Invitation Poster

Carleton
UNIVERSITY

Participate in a study on

GESTURAL INTERACTIONS FOR SMART ENVIRONMENTS

This is a 45-minute study. You will be asked to discuss and demonstrate how you would use hand gestures to interact with a smart environment.

To participate in this study you must:

1. Have experience in watching movies at home;
2. Basic knowledge in using computers
3. Comfortable with English language

Participants will be compensated with a $10 Coffee Shop gift card.

The ethics protocol for this project has been reviewed and cleared by the Carleton University Research Ethics Board at 613-520-2517 or ethics@carleton.ca.

Please contact the researcher, Daniel Bianchi, for more details on this study at daniel.bianchi@carleton.ca.

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

Daniel Bianchi
daniel.bianchi@carleton.ca

APPENDIX F

Script of the Experience Simulation Workshop

Carleton UNIVERSITY
Canada's Capital University

Workshop "1": Experience Simulation

Description: The Experience Simulation is useful for researchers to understand how people imagine they may behave and interact in a specific situation. In this workshop, participants are invited to simulate gestural interactions in a Smart (technology-enabled) Home environment.

Objective: To observe and understand participants' use of gestures when interacting with interfaces in the environment.

Sample Size: 7 to 9 participants divided in groups of 3 participants.

Duration: 2 hours per group.

Material required:

- Quiet room
- 03 video cameras
- Pen and paper

SCRIPT

1. Introduction

Step 1: Welcoming participants
Duration: 10 minutes

Thank you for taking part in this workshop. I am Daniel Bianchi, the researcher for this study.

I invited you here today to participate in a study on the intuitive use of gestures for interacting with technology interfaces in smart environments. This study aims to gain an understanding of gestures that reflect users' preferences when interacting with technologies in home environments.

Before we begin, please read and sign the consent forms I am providing. We can read through them together [read and sign consent form].

The workshop will take no more than 2 hours and you will be asked to work as a member of a small group.

As per your consent, this workshop will be video recorded to facilitate the analysis.

Step 2: Lesson
Duration: 15 minutes

[The researcher tells the participants]

"Creativity is in the essence of human nature. The history of mankind is full of examples of inventions and things people created to improve the world around them and to make life easier and more comfortable.

The desire to reshape the world very often makes people envision how life would be in the future. In some of these visions, advanced technology will enable smart environments to naturally respond to the movement of the human body. Like in these two movies:

[Researcher plays two short science fiction video-clips to give]

Dear participants, in this workshop, imagine that you are living in this future of technology-enabled environments. Imagine that anything in your environment responds to your hand gestures. Imagine that touching an interface or an object will no longer be necessary to interact with technology. Only hand gestures will be enough.

I invite you, as a team, to explore how you would use hand gestures to interact with the environment and you wanted to watch movies.

Don't be shy. Use your creativity. There is no right or wrong."

2. Simulating the experience

Step 1: Generating gestures
Duration: 45 minutes

[Researcher gives participants pen and paper]

Dear participants,

In the first step of this workshop, your team is asked to explore how you would use hand gestures to perform the tasks in the following scenarios. Feel free discuss, to draw, to write or to try different gestures. Remember, there is no right or wrong:

Imagine that anything in your environment responds to hand gestures. You don't need to touch anything, neither use any device. Only hand gestures will be enough.

You are at home and you want to watch movies…

1. *How would you turn a display on?*
2. *How would you access a movie library?*

Imagine that you want to watch more than one movie…

3. *How would you group multiple movies into a playlist?*
4. *How would you rearrange the order of movies in the playlist?*
5. *How would you remove/exclude one of the movies from the playlist?*
6. *How would you select a movie from the playlist?*

Imagine that you choose one movie from the playlist and now you are watching it…

7. *How would you access setting options for the selected movie (e.g: subtitles, audio settings)?*
8. *How would you play the selected movie?*
9. *How would you pause the movie that you are watching?*

Imagine that you are searching for a specific scene in the movie….

10. *How would you advance to the next scenes in the movie?*
11. *How would you go back to the previous scenes in the movie?*

Imagine that you want to look more closely at a detail in a scene…

12. *How would you zoom into the screen?*
13. *Once you are done looking, how would you zoom out of the screen?*

Imagine that you want to access other elements on the screen…

14. *How would you minimize the movie screen?*
15. *How would you maximize the movie screen?*

Imagine that you can play the movie anywhere in the room…

16. *How would you drag the movie screen over to another place in the room?*

Imagine that you can change the orientation of the movie screen (vertical, horizontal, upside down)…

17. *How would you rotate the movie screen?*
18. *How would you rotate it back to the original orientation?*

Imagine that you want to stop watching the movie…

19. *How would you close the screen of the movie you just watched?*
20. *How would you turn the display off?*

Step 2: Enacting gestures
Duration: 30 minutes

In the second step of the workshop, one or more of the participants in the group should enact, in an imaginary room, the gestures generated in step one.

The participant enacting the gestures or another team member is asked to say aloud whatever he/she is looking at, thinking, doing, and feeling while performing the tasks.

The other participants are asked to observe and make comments if they want to.

Step 3: Discussing and reviewing gestures
Duration: 20 minutes

In the third and last step of the workshop, we will all discuss and review the gestures you created.

1. How hard it was to create the gestures? Why?

2. After enacting/observing the gestures in action, do you think the gestures would be efficient for performing those tasks? Why?

3. Do the gestures seem natural?

4. Would you change any of the gestures? Which? Why? How?

5. Do you have any additional comments?

APPENDIX G

Script of the Validation Questionnaire

Carleton UNIVERSITY
Canada's Capital University

Workshop "2": Validation Workshop

Description: The Validation Workshop consists of presenting video-clips showing the findings from a previous experience simulation workshop in this study to participants trained in the field of Human-Computer Interaction and asking for their expert opinion. Participants of this workshop will be requested to respond to a questionnaire as described below.

Objective: To collect participants' opinions about the feasibility, intuitiveness, complexity and probability of the use of gestures created by the participants of a previous workshop.

Sample Size: 15 to 20 participants.

Duration: 1 hour.

Material required:

- Hard copies of questionnaire.
- Pen.

SCRIPT

1. Introduction

Step 1: Welcoming participants
Duration: 10 minutes

Thank you for taking part in this workshop. I am Daniel Bianchi, the researcher for this study.

I invited you here today to participate in a study on the intuitive use of gestures for interacting with technology interfaces in smart environments. This study aims to gain an understanding of people's preferred gestures for interacting with technologies in home environments.

Before we begin, please read and sign the consent forms I am providing. We can read through them together [read and sign consent form].

The workshop will take no more than 2 hours and you will be asked to watch a series of video-clips and to answer to a short questionnaire.

Step 2: Video-Clips Presentation
Duration: 20 minutes

Dear participants,

Previously in this study, participants were invited to take part in a workshop in which they were asked to imagine themselves living in a future of technology-enabled environments. In this future, anything in their environment would respond to hand gestures. It would not be necessary to touch an interface or an object to perform a task. Only hand gestures would be used as input.

The video-clips you are going to watch now, show the sets of gestures those participants created when asked to simulate the experience of watching movies in this technology-enable future scenario.

Please, watch it carefully.

[The researcher plays series of video-clips]

2. Questionnaire
Duration: 30 minutes

[Researcher gives participants pens and hard copies of the questionnaire]

Dear participants, now that you watched the video-clips, please respond to this questionnaire and provide your opinion about the gestures shown in the videos.

Questionnaire

You have just watched a series of video-clips in which people simulated gestures they would use to interact with technology-enabled environments in an imaginary scenario with no technical constraints.

In the following questionnaire, please evaluate the feasibility of those gestures, based on your knowledge of the field,.

1. Considering the context of interacting with technology-enabled environments, how feasible are most of the gestures presented in the video-clips?

Not at all	Very little	Neutral	Very	Perfectly
O	O	O	O	O

2. Considering ease of use, how easy would it be for people to perform most of those gestures?

Not at all	Very little	Neutral	Very	Perfectly
O	O	O	O	O

3. Considering intuitiveness, how natural would it be for people to perform those gestures to interact with technology-enabled environments?

Not at all	Very little	Neutral	Very	Perfectly
O	O	O	O	O

4. Considering intuitiveness, how probable would it be for people to perform those gestures without preliminary learning?

Not at all	Very little	Neutral	Very	Perfectly
O	O	O	O	O

5. Considering efficiency in accomplishing a given task, how efficient are most of those gestures in relation to the tasks they were created for?

Not at all	Very little	Neutral	Very	Perfectly
O	O	O	O	O

6. Can you identify different contexts of use for those gestures other than the ones presented in the video-clips (watching movies in a technology-enabled environment)? Please, specify.

____

____

____

____

7. Can you identify tasks, different from the ones presented in the videos-clips, for which those gestures would be applicable?

8. Can you identify one or more products and/or technology for which those gestures would be applicable?

9. In your opinion, do any of the gestures stand out as either really feasible or really unfeasible? Which ones? Why?

10. Please, feel free to add any additional comment regarding the gestures presented in the video-clips.