Moving and Making Strange:

A Design Methodology For Movement-based Interactive Technologies

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Certificate of Authorship/Originality

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

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Abstract

This thesis develops and presents a design methodology that enables designers to work with the moving body in the design and evaluation of interactive, immersive environments built on motion-sensing technologies. The notion of *making strange*, that underpins the methodology, calls for designers to re-examine and revitalise their assumptions and conceptions of the moving body through bodily-based movement inquiries.

This thesis addresses research questions about ways of understanding human movement, of describing and representing human movement and of accessing the felt experience of the moving body in the emerging field of movement-based interaction design. The research questions were explored through a series of three distinct, yet related, projects, each one focusing on different aspects of designing for moving bodies in interactive, immersive environments. The first project analysed an existing interactive product, Sony Playstation2© Eyetoy™, as a prototype of future movement-based interactive, immersive environments. The second project involved the design and development of a specific interactive, immersive artwork, Bystander. The third project worked with trained dancers and physical performers in a constructed design situation.

The contributions of this research are first and foremost the *design methodology of Moving and Making Strange*: a design approach to movement-based interaction that prioritises the lived experience of movement by both designers and users and values the creative potential of the experiential, moving body. It consists of methods and tools for exploring, experiencing, describing, representing and generating movement that enable designers to shift between the multiple perspectives of the mover, the observer and the machine. It makes particular contributions as follows:

- Laban movement analysis and Labanotation as a design tool.
- Moving-Sensing schema: Suchman's analytic framework adapted as a design tool.
- Extension of existing human-centred design tools to explicitly represent moving bodies, in the form of movement-oriented personas and movement-oriented scenarios.
- Patterns of watching: a catalogue of audience behaviour in terms of movements and stillness in relation to engagement with a specific interactive, immersive artwork.
- New methods for generating, enacting and experiencing movement, sourced from dance and movement improvisation practices.

Chapter 1

Introduction

> In short, there is a richly subtle and complex nonverbal world that is there from the beginning of all of our lives, a dynamic world that is neither mediated by language nor a stepping stone to language, but that is literally significant in and of itself and remains literally significant in and of itself, a dynamic world articulating intercorporeal intentions that, although clearly affective in origin, are enmeshed in "agentivity," in expectations, in consequential relationships, and thereby in the phenomenon of thinking in movement.
>
> Maxine Sheets-Johnstone (1999a, p.504)

> Any technology designed for use in human activities incorporates assumptions about how it will be used. These assumptions, whether explicitly represented in the design process or not, are essential resources that designers exploit to shape their developing designs into specific products. Here, my interest is in the ways that assumptions about human activities are represented in the practices of information and communications technology (ICT) design, where those assumptions come from and how they shape the options for future use of the technology. This interest stems from the insight that our ability to think about any design problem, and the quality of our thinking, depend to a large extent on the appropriateness of the representational resources that we can use in our thinking.
>
> Lucy Suchman (1994b, p.1)

This chapter introduces the research questions and describes the background and the context for this research. It presents an overview of the theoretical foundations and research design. It concludes with a summary of the results presented in the body of this thesis.

This thesis is concerned with designing *for*, and *from*, the experiential, moving body in the field of interaction design. The research in this thesis springs from a commitment to designing *movement-based* interaction from a lived experience of movement. Movement-based interaction is an emerging area of interaction design, where interactions with computing technologies are based on the moving body as the source of input (e.g., Feijs, Kyffin, and Young, 2007; Larssen, Robertson, Loke, and Edwards, 2007b). The advent of motion-sensing technologies has enabled new kinds of interaction paradigms with a renewed focus on the active, moving body. This in turn has called for new approaches, methods and tools for designing these forms of interaction. One line of investigation, common to the fields of interaction design and human-computer interaction (HCI), is to look to other disciplines such as philosophy, psychology and anthropology as a source of potential approaches, methods and tools. This thesis explores ways of understanding, experiencing, describing and representing the experiential, moving body in the design of movement-based interaction, sourced from other disciplines and fields including dance, somatics, movement analysis, interaction analysis, anthropology and phenomenology. The specific domain of interest for this thesis is the moving body in interactive, immersive environments (or spaces) built on video-based, motion-sensing technologies. This kind of interactive system enables free body movement, without the use of physical or tangible input devices.

Within the context of movement-based interaction design, the research questions explored in this thesis are:

1. What understandings of human movement are relevant?
2. How and in what ways can the experiential nature of the moving body be accessed and understood?
3. How and in what ways can the moving body be described and represented?

These questions are framed with reference to the traditional task of human-computer interaction (Preece, Rogers, Sharp, Benyon, Holland, and

Carey, 1994), which is concerned with designing the input-processing-output loop in the following way:

- The design of input that people can perform and the computer can comprehend;
- The design of suitable feedback to the user on what the computer is doing in response to the input; and
- The design of output by the computer that people can comprehend.

The focus of this thesis is primarily on the *input* part of the input-processing-output loop; the relationship between people moving and the machine sensing and interpreting those movements. When the moving body becomes the primary input to interactive systems, it becomes part of the design material in a more significant way. An intimate knowledge of the design materials is fundamental to good design and for movement-based interaction design, the design materials include the moving body as well as software, hardware, input and output devices, motion sensors and so on. What knowledge and skills of the moving body do designers require in this emerging area of movement-based interaction design? This thesis advocates designers cultivating a bodily awareness of the forms, processes and qualities of movement being considered for design. It stems from a phenomenologically-inspired inquiry into the moving body, where we investigate our own experiences of movement, together with the experiences of others. The felt aspects of movement and the movement itself are inseparable in the lived experience of movement. In this way, designers can access the potential experiences of users in future movement-based interactive, immersive environments and design for both the external, functional aspects of movement and the internal, felt qualities of movement.

On the other side of the input process is the machine and its interpretation of the input of movement. In the design of movement-based interaction, some forms of bridging representations are required that enable the mapping between the movements performed by people and the sensing and interpretation of those movements by the machine. This thesis explores how designers can traverse between experiential understandings of the moving body and design representations of human movement to enable the design and evaluation of movement-based interactive technologies.

If we wish to design for vitality and aliveness, for pleasure in moving, then it is important to recognise that these qualities derive in part from the felt, kinaesthetic experience of the moving body. We need to be cognizant of the experiential effects of possible movement patterns used for interaction. *TGarden* (Wei, 2002), *whisper* (Schiphorst and Andersen, 2004) and *Body-Bug* (Moen, 2005, 2007) are three very different interactive systems reliant in different ways on improvised movement and kinaesthetic experience. The attendance by users of these systems to the felt experience of the movements used in interaction is crucial for ongoing interaction and for pleasurable engagement. Machine algorithms do not necessarily recognise 'felt experience' as such. The machine sensing and interpretation of the input data provides in turn new conditions for engagement. However the conditions for satisfying user engagement rely to some extent on the innate relationship between doing, sensing and feeling in the process of human movement, in the intertwining of human action and perception, as well as the contexts for movement provided by the design of the system.

1.1 Background

The field of interaction design is characterised by research and design approaches that focus on the human experience and practices of people using computing technologies in their work and everyday life (Preece, Rogers, and Sharp, 2002). Human-centred design approaches, in particular, employ methods aimed at acquiring understandings and insights into the practices of potential users of technology, prior to designing new technologies and future devices, products and systems. Ethnographically-inspired and phenomenologically-inspired approaches to design both value first-hand, first-person perspectives and experiential data.

Well established tools for representing users, their activities and contexts of use include personas and scenarios. Scenarios have typically been used for envisioning and simulating future use situations, allowing reflection-in-action and the continuous presence of the users during the design process (e.g., Kyng, 1995; Bødker, 1998, 2000; Carroll, 2000a,b; Rosson and Carroll, 2002). More recently, scenarios have been used for exploring situations where the setting is less well-defined and contextual information and awareness are desired such as in mobile and ubiquitous computing (Howard, Carroll, Murphy, Peck, and Vetere, 2002; Pedell and Vetere, 2005). However, there is still a lack of research explicitly dealing with describing and representing moving bodies.

New methods for designing for, and from, real and imagined situations of use are emerging that view enactment and physical role-playing as pivotal to exploring the design space (Ehn and Sjögren, 1992; Burns, Dishman, Verplank, and Lassiter, 1994; Sato and Salvador, 1999; Brandt and Grunnet, 2000; Buchenau and Suri, 2000; Howard et al., 2002; Iacucci, Iacucci, and Kuutti, 2002; Kuutti, Iacucci, and Iacucci, 2002; Carroll and Tobin, 2003; Laurel, 2003; Oulasvirta, Kurvinen, and Kankainen, 2003; Strömberg, Pirttilä, and Ikonen, 2004; Svanæs and Seland, 2004). Inspiration for these methods has come predominantly from theatrical performance practices. Researchers claim that the use of these methods increases designers' empathy with users and facilitates the generation, exploration and evaluation of design concepts in situations of use.

The development and availability of sensor technologies in the last decade has resulted in new fields of computing such as mobile and ubiquitous computing, tangible computing, interactive art and interactive product design. Motion sensors, in particular, enable input and sensing of the dynamic, qualitative characteristics of movement. Researchers and designers working in these fields have begun to draw on approaches to design involving the use of physical movements by designers to gain a bodily understanding of gestures and movements and to communicate design ideas and findings (Buur, Jensen, and Djajadiningrat, 2004; Donovan and Brereton, 2004; Jensen, Buur, and Djajadiningrat, 2005; Klooster and Overbeeke, 2005; Hummels, Overbeeke, and Klooster, 2007). A small number of researchers is also working with the moving body, by drawing on understandings and techniques from dance and somatics, to inspire design concepts and to reflect aspects of the kinaesthetic experience of movement in the actual interaction afforded by the interactive system (Schiphorst and Andersen, 2004; Kjölberg, 2004; Klooster and Overbeeke, 2005; Moen, 2005, 2007; Jacucci, 2006; Hummels et al., 2007; Jensen, 2007; Larssen, Robertson, and Edwards, 2007a).

1.2 Theoretical foundations

This research is inspired by philosophies of phenomenology and pragmatism as both offer perspectives for design research that privilege and look to *lived experience* as the continual source and verification of human knowledge and action as we encounter ourselves, others and the world. Ihde (1998) describes the emergence of three styles of philosophy in the mid-twentieth century, namely pragmatism, phenomenology and positivism. All three styles were concerned with praxis, but adopted quite different epistemological definitions and methods. Of the three, pragmatism and phenomenology looked to lived experience for understandings of phenomena and practice. Positivism turned to science and its experimental method based on hypothetical-deductive reasoning as the source of empirically founded knowledge. For a thesis such as this one, positioned in *design research* and committed to research that values the lived experience, the practices and the agency of potential users of technology, phenomenology and pragmatism supply theoretical principles and tools to support the particular methodologies developed and utilised here. Phenomenology provides a philosophical foundation for the central focus on the lived, moving body, as described in Chapter 3. I use the phenomenological philosophers, Maurice Merleau-Ponty and Maxine Sheets-Johnstone, and their advocacy of the central role of movement in perception and cognition, as a foundation for my theoretical approach to this research.

Pragmatism has been useful here for issues of methodological validity in design research. I draw on the criterion of 'workability' as defined by the pragmatic philosophers, Rosenthal and Bourgeois (1977). In the case of design research, workability can be offered as a criterion for the validity of design artefacts, including representations of movement. An explication of this is given in Chapter 4.

The research methodology is distinguished by the attendance to both the lived experience of the potential users of interactive technologies and the community of practitioners that informs the research, as well as to the experiential understandings gained from direct experience by the researcher. There are well-established research doctrines and practices that value experiential understandings by the researcher, particularly in the humanities. Strauss (1987) in *Qualitative Analysis for Social Scientists*, acknowledges the value of experiential data derived from personal experiences of the researcher in understanding phenomena. The dance anthropologist, Sally Ann Ness (2004) advocates the shift from an observational stance to an experiential investigation of the moving body by the researcher in anthropological investigations into dance in different cultures.

Sheets-Johnstone (1999a) provides a Husserlian-derived practical, philosophical method for accessing and elucidating experiences of movement. She draws parallels with the introspective methods of the scientist, von Helmholtz, for acquiring understandings of how movement is entwined in perceptual phenomena. We become 'laboratories unto ourselves' (Sheets-Johnstone, 1999a, quoting von Helmholtz). It is this notion of using our own bodies to acquire understandings of phenomena and practices that I embrace in this thesis. Sheets-Johnstone (1999a) provides a very clear articulation of the phenomenological attitude, which underpins the method of *free variation* for accessing the structures of experience.

> The phenomenological method is one of description; yet, as is evident, it is at the same time more than that, for in aiming toward a description of the phenomenon, it reflects backwards toward an elucidation of the structures of consciousness. It bypasses all question of the subject's objectivity or the object's subjectivity by elucidating the immediate world of lived experience, the world as it is immediately and directly known through a pre-reflective consciousness. This initial and direct knowledge constitutes the foundation upon which all future knowledge is built. (Sheets-Johnstone, 1999a, p.13)

In phenomenology as practiced by Sheets-Johnstone, the aim is to identify the essential characteristics of movement phenomena through the application of free variation. But in design work we can work with the same technique in a different way. Through free variation, we can open up the possibilities for movement and the corresponding forms of felt experience.

An understanding of the phenomenological attitude is helpful for this research in clarifying the nature of phenomenological analyses as conducted by philosophers and of phenomenologically-inspired approaches and methods used by technology designers. For Sheets-Johnstone, phenomenological work necessarily includes first-hand experiential data. Her own work draws on three sources: observations of phenomena of interest, first-hand experiential data and the use of scientific findings as phenomenological clues. Technology designers using phenomenologically-inspired approaches and methods value first-hand, first-person perspectives in understanding technology use and practice (as discussed in section 2.1). It is this same perspective that I follow in this thesis, by drawing on participants' experiences and practices of the moving body and urging designers to understand movement phenomena through their own felt, bodily experiences and inquiries.

My own understandings in this emerging research field of movement-based interaction design are informed and envigorated by movement practices that cultivate an awareness and sensitivity of the internal and external relations of the moving body in space and time. These include Ashtanga yoga and alternative dance forms incorporating movement practices of Body-Mind-Centering (Cohen, 1993) and the Bodyweather system of Butoh. I have a personal commitment to experiential and bodily knowing as a valid form of knowledge. Things are known and felt in the body which are not easily articulated through verbal and visual forms, but which can be explored, articulated or communicated through movement and touch. Polanyi (1983) distinguishes this form of knowledge as *tacit* knowing. He describes it for the case of visual perception, where we attend *from* internal bodily processes *to* the qualities of things outside. Movement practices like the ones I engage in provide a subjective, self-reflexive means of approaching research into movement-based interaction design, grounded in one's own body. The pragmatist philosopher, Richard Shusterman (2000) makes a similar case for the co-development and intertwining of bodily and mental awareness in his proposed discipline of *somaesthetics*. I also acknowledge the influence of my formal training in electrical engineering and computer science and my current teaching position in software design subjects for the past eight years. All these diverse backgrounds put me in an opportune position to successfully negotiate the disparate worlds of the experiential, moving body and the machine, as they come together in the design of movement-based interactive technologies.

1.3 Research design

The research questions were explored through a series of three distinct, yet related, projects. Each project focused on different situations of design and different conceptions of movement in order to gain an adequate understanding of a proposed design approach to movement-based interaction that prioritises the lived experience of movement. The overall aim of the three projects was to identify and trial methods and tools for understanding, describing, representing, experiencing and generating movement in the design of movement-based interaction. Two lines of investigation of potential design tools conducted throughout the three projects included Laban movement analysis and its companion movement notation system, Labanotation (see section 3.4 for background) and the adaptation of the analytic framework of Lucy Suchman (1987) (see section 2.3 for background).

The first project comprised an analysis of an existing movement-based interactive product, Sony Playstation2© Eyetoy^{TM} (hereafter referred to as Eyetoy), to examine the movements of players interacting with the Eyetoy games. The focus in the Eyetoy project was on an individual, moving body. The Eyetoy games were treated as a prototype of future movement-based interactive, immersive systems that could be interrogated about the kinds of movements that worked or not within these systems.

The second project, Bystander enabled a shift from a focus on an individual, moving body to many bodies. Different conceptions of movement arise and different aspects of movement become relevant when dealing with multiple bodies in interactive, immersive environments. Bystander is an interactive, immersive artwork built on video-based, motion-sensing technology. The research work in Bystander was concerned with the extension of traditional human-centred design approaches, methods, tools and techniques to the design of novel interactive, immersive environments available for public use in gallery and museum settings. The emphasis for this thesis was on constructing design representations to explicitly address moving bodies in social contexts and on the subsequent use of these representations for design reflection-in-action through physical immersion and enactment of movement in the prototype environment.

The third project, Falling Into Dance, continued the work done in the first two projects, by validating and extending their findings. One of the primary motivations was to extend the range and kinds of movement to be sensed, from everyday movement (in Bystander) and limited range of arm gestures (in Eyetoy) to more complex, heightened and choreographed forms of movement. Two studies were conducted with trained dancers and physical performers. A movement study of the act of falling was conducted with skilled movers. Falling was chosen for the purposes of 'making strange', as it is a movement pattern that we all know in some way and yet is not an established part of the movement lexicon for gestural input to interactive technologies. This notion of 'making strange' became instrumental to the development of the design methodology of Moving and Making Strange, arising from the results of the third project. It is covered in detail in Chapter 9. The second study involved working with dance and movement improvisation practitioners to find ways of generating and devising movement for use in the design process.

A detailed description of the rationale for the research methods and of the evolution and composition of the research is given in Chapter 4.

1.4 Contributions of the research

The primary contribution of the thesis is the design methodology of Moving and Making Strange. The contributions of the research in relation to the design methodology are summarised in Figure 1.1. Each of these contributions

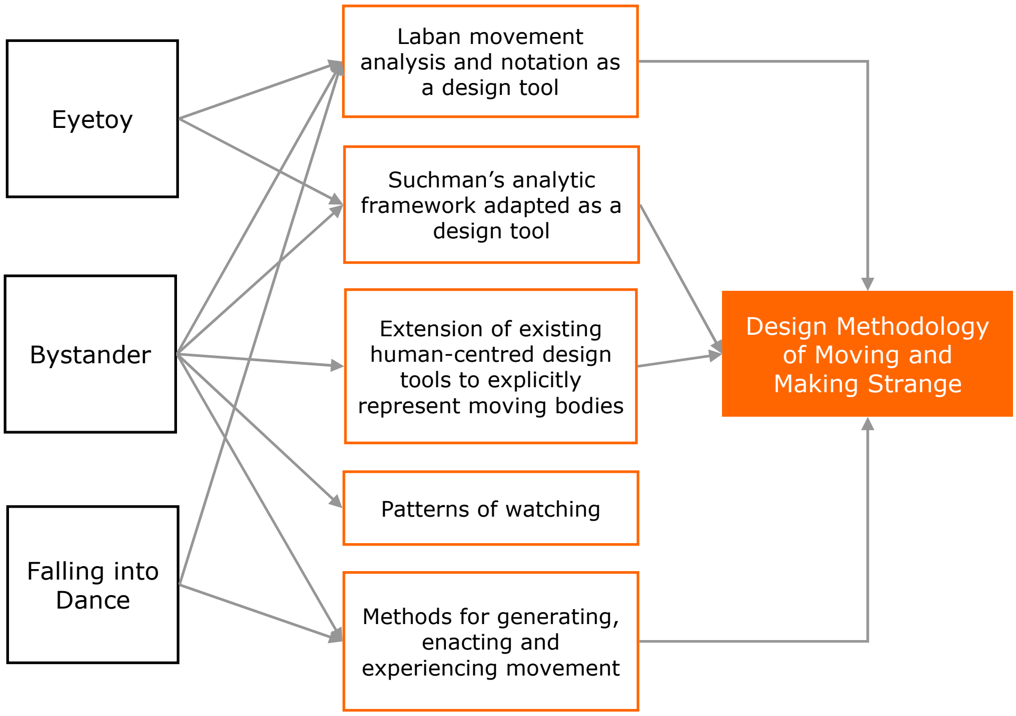

Figure 1.1 Diagram of thesis contributions

is briefly described in the following sections.

1.4.1 Design methodology of Moving and Making Strange

The design methodology of Moving and Making Strange is a design approach to movement-based interaction design that prioritises the lived experience of movement by both designers and users and values the creative potential of the experiential, moving body. It contains a range of methods and tools for exploring, experiencing, describing, representing and generating the moving body that enables designers to shift between the multiple perspectives of the mover, the observer and the machine. The methodology is underpinned by the notion of *making strange*. By *making strange*, I mean ways of unsettling habitual perceptions and conceptions of the moving body to arrive at fresh appreciations and perspectives for design that are anchored in the sensing, feeling and moving body. This notion of "making the familiar strange" is described by the phenomenologist, Sheets-Johnstone (1999a, p.143), as a way of reacquainting ourselves with familiar or habitual movements by varying our normal movement patterns and processes. Making strange or *defamiliarising* is a basic strategy in artistic expression (Danto, 1981) and in ethnography (Marcus and Fischer, 1986), as exemplified by Clifford Geertz and Harold Garfinkel. Geertz (1973) describes anthropology's preoccupation with the exotic as a device for making the familiar strange. The breaching experiments of Garfinkel (1967) were designed to disturb familiar ways of perceiving everyday life. A more detailed account of the application of the strategy of making strange in artistic, ethnographic and design practices and the relevance to the proposed design methodology is given in Chapter 9. An early version of the methodology was first published in Loke and Robertson (2007).

1.4.2 Laban movement analysis and Labanotation as a design tool

The continued application of Laban's system of movement analysis and notation in this research confirmed the usefulness of the system for describing and visually representing relevant aspects of movement to be treated as input to motion-sensing technologies, in particular Labanotation floor plans and Effort-Shape analysis. This thesis makes the following contributions of Laban movement analysis and Labanotation as a design tool in movement-based interaction design (Loke, Larssen, and Robertson, 2005a; Loke, Larssen, Robertson, and Edwards, 2007).

- Labanotation floor plans were used to visually represent the spatial trajectories of users and could easily be extended to represent the social interaction of moving bodies. This representation was termed the *spatial movement schema*.

- The Effort-Shape analysis was useful for describing the dynamic, temporal qualities of human movements and could act as a bridging representation between the movements of people and the sensing of those movements by a computer.

- Laban movement analysis provides a language and vocabulary that translates readily to the field of interaction design. Both the functional and expressive aspects of movement can be described. Laban movement analysis is beneficial for developing movement observation skills and sensitivity and awareness to movement and the kinaesthetic aspects of movement.

1.4.3 Suchman's analytic framework adapted as a design tool

This thesis contributes Suchman's analytic framework adapted as a design tool (Loke et al., 2007), renamed the Moving-Sensing schema. The framework provided a way of organising and structuring the representation of the interaction between user(s) and machine that enabled a clear focus on the relationship between the movements and actions of the user(s) and the sensing and interpretation of the user(s)'s actions by the machine. It assisted with the identification of alignments and slippages between the mutual interpretation of the interaction between human and machine, in the manner of the original framework. The description of the user's movements within the framework ensured that the movements could be understood in the context of interaction, from both the perspective of the user and the perspective of the machine.

1.4.4 Extension of existing design tools to explicitly represent moving bodies

The extension of existing human-centred design tools for representing users, their activities and contexts of use was a major focus of this thesis. This thesis contributes the following design tools for representing human movement as part of human-computer interaction, for interactive, immersive spaces built on video-based, motion-sensing technologies (Robertson, Mansfield, and Loke, 2004; Loke and Robertson, 2005; Loke, Robertson, and Mansfield, 2005b; Robertson, Mansfield, and Loke, 2006; Loke and Robertson, 2008b).

- *movement-oriented personas* and *movement-oriented scenarios*: traditional personas and scenarios were extended to represent moving bodies in social contexts.
- *user activity script*: combination of movement-oriented scenarios and spatial movement schemas for use in enactment and evaluation.

1.4.5 Patterns of watching

A catalogue of the *patterns of watching* was derived from the analysis of actual visitor activity (in terms of their movements and stillness) to the Bystander installation in a public gallery. These patterns of watching contribute to the existing literature on understandings of audience behaviour in interactive, immersive environments and gallery/museum settings.

1.4.6 New methods for generating, enacting and experiencing movement

This thesis contributes methods for generating, enacting and experiencing movement, drawn from dance and movement improvisation practices (Loke and Robertson, 2008a). The methods include movement improvisation scoring techniques, working with imagery and qualities of movement and working with kinetic variations of speed, scale and direction. These methods access the creative potential of the moving body and develop a designer's ability and sensibility to work with the moving body as a design material. The movement improvisation scoring techniques can also be used for enactment in, and evaluation of, interactive, immersive spaces.

1.5 Thesis structure

The thesis is organised into the following chapters:

Chapter 2 reviews the literature on interaction design and human-computer interaction relevant to this thesis. In particular, it covers phenomenologically-inspired approaches to interaction design, ethnographically-inspired approaches to interaction design, interaction analysis and Suchman's analytic framework, design representations and ways of seeing and methods and techniques for working with the moving body.

Chapter 3 reviews the literature on understandings of the moving body drawn from philosophy, dance, somatics, social science, anthropology and computer vision. It introduces and defines the theoretical foundations of this thesis with regard to the central role of movement in perception and action. Five conceptions of movement are presented to organise the understandings of movement from other disciplines. Ways of analysing and describing movement are reviewed, with a particular focus on the Laban system of movement analysis and notation.

Chapter 4 describes the evolution and composition of the research methodology and the research methods employed in the three projects.

Chapter 5 presents Project I: Eyetoy. The activities, analysis, results and findings are described in detail.

Chapter 6 presents Project II: Bystander. The activities, analysis, results and findings are described in detail.

Chapter 7 presents Project III: Falling into Dance. The activities, analysis, results and findings are described in detail.

Chapter 8 contains a reflection on the use of two potential design tools—firstly, Suchman's analytic framework adapted as a design tool in the projects Eyetoy and Bystander. And secondly, Laban movement analysis and Labanotation as a design tool in the projects Eyetoy, Bystander and Falling into Dance.

Chapter 9 presents the design methodology of Moving and Making Strange, a proposed design approach to movement-based interaction.

Chapter 10 briefly summarises the thesis and its conclusions and offers suggestions for future work.

Chapter 2

Interaction Design

> We encounter the deep questions of design when we recognize that in designing tools we are designing ways of being.
>
> Winograd and Flores (1986, p.xi preface)

This chapter provides the necessary background for a thesis contributing to the field of interaction design. It covers phenomenologically-inspired and ethnographically-inspired approaches to interaction design, with a focus on embodied actions and felt experience. It introduces interaction analysis and Suchman's analytic framework. It discusses design representations and ways of seeing, including visual representations, conceptual design frameworks, personas and scenarios, and how these currently support the representation of the moving body. It concludes with a survey of methods and techniques employed by other researchers for working with the moving body in design.

2.1 Phenomenologically-inspired approaches to interaction design

> For the phenomenologist, any quest for knowledge about a phenomenon begins with the direct intuition of the phenomenon, apart from any prejudice, expectation, or reflection; hence, this direct intuition is pre-reflective. The phenomenologist's attitude toward the phenomenon is neither objective nor subjective, but rather an attitude of being present to the phenomenon, fully and wholly, to intuit it as it appears, without preshaping it in any way by prior intentions or beliefs. He is thus led to describe the 'lived experience' of the phenomenon, the essential relationship between consciousness and its world.
> (Sheets-Johnstone, 1999a, p.12)

The philosophy of phenomenology concerns itself with the phenomena of experience, of direct lived experience, and claims that these phenomena are central to questions of ontology and epistemology. Phenomenologically-inspired approaches to interaction design are characterised by the prioritising of lived experience, the valuing of experiential data and the use of first-person perspectives, accounts and methods for understanding practices and the relations to technology design and use.

There is a growing attention in the literature to felt experience and sensing, feeling and acting bodies as relevant to the design of interactive computing technologies, most recently theorised, for example, in the work of McCarthy and Wright (2005), Jacucci, Jacucci, Wagner, and Psik (2005), Klemmer, Hartmann, and Takayama (2006) and Schiphorst (2007). McCarthy and Wright (2005) call for putting 'felt-life' at the centre of human-computer interaction. The performance perspective of Jacucci et al. (2005) emphasises experiences with technology where awareness, felt-life and reflection are central to the interaction. They draw on theatrical performance practices to assist with their approach. Klemmer et al. (2006) propose five themes for interaction design: thinking through doing, performance, visibility, risk and thick practice, informed by theories of embodiment from psychology, sociology and philosophy. Schiphorst (2007) considers technology as experience and proposes a framework from the field of somatics (the body as experienced) for understanding and accessing the body in everyday life through attentional strategies that can then be applied in design.

The recognition that all human actions (including cognition) are embodied actions, is fundamental to recent trends in interaction design. An increasing number of researchers have contributed phenomenologically-motivated theoretical perspectives on the relations between embodied actions and technology design and use (e.g., Robertson, 1996, 1997a, 2002; Dourish, 2001; Svanaes, 2001; Larssen, Robertson, and Edwards, 2005).

Robertson (1997b) established a theoretical framework that acknowledges the centrality of *experience of the actual body* to the design of systems to support people working over distance. Actual bodies imply acting and perceiving embodied subjects, in which "perception and action, are fundamentally inseparable in lived cognition" (Varela, Thompson, and Rosch, 1991, p.172–173). Her conceptualisation of actual bodies is informed by the work of Merleau-Ponty, Foucault, feminist epistemology, situated cognition and action and distributed cognition. She continues to re-articulate the phenomenology of Merleau-Ponty to the study of technology design and use. In Robertson (1996, 1997a), she applied Merleau-Ponty's notion of the *reversibility* of perception to a field study of cooperative design to develop a taxonomy of *embodied actions* that serve communicative functions in cooperative work. The taxonomy also serves as a bridging structure between the field study of cooperative work and the design of technology that might support that work over distance. In later work, Robertson (2002) again used Merleau-Ponty's notion of the reversibility of perception to stress the importance of the public availability of actions and artefacts for maintaining awareness in distributed activities.

Dourish (2001) emphasised the role of embodiment in the design of interaction when he described embodied interaction as an approach that hinges on the relationship between action and meaning as part of a larger system. Interaction design undertaken from this perspective "turns our attention away from the artefacts themselves and toward the ways in which people engage with them in different settings" (Dourish, 2001, p.184).

Svanaes (2001) promoted the application of the phenomenology of Merleau-Ponty to the design of context-aware technology, as its first-person focus on the lived body and its relation to the environment enabled understanding of such systems from the user's perspective. His analysis recognised that context must always be understood from the perspective of those whose context it is.

Larssen et al. (2005) explored multiple perspectives on movement in HCI through a comparison of biomechanics and phenomenology, laying the ground for the conceptions of movement amenable to the field of interaction design, contributed by this thesis. I elaborate this further in section 3.2, *Conceptions of movement*, as a theme running through the thesis.

Robertson (1996, 1997a) and Larssen et al. (2005) are notable for paying explicit attention to bodily actions and movement phenomena from a phenomenologically-motivated theoretical perspective. This is an area that I expand on in my thesis, by bringing together the work of two phenomenologists concerned with the centrality of movement in perception and cognition, Maxine Sheets-Johnstone and Maurice Merleau-Ponty (see section 3.1). Phenomenologically-inspired approaches to movement-based interaction motivate the research into methods and techniques for working directly with the moving body. The work of other researchers in this area is covered in section 2.5. My particular contributions to this area, one of the major foci of my thesis, are described in detail in Chapter 9.

2.2 Ethnographically-inspired approaches to interaction design

A number of researchers have applied approaches from ethnography and ethnomethodology to the study and understanding of work practices and the relations between technology design and use (e.g., Suchman, 1987, 1994a, 1995, 2007; Suchman and Trigg, 1991; Luff, Heath, and Greatbatch, 1992; Jordan, 1994; Harper and Sellen, 1995; Robertson, 1997a). These approaches involve a close scrutiny and detailed analysis of the interactional characteristics of practitioners involved in a variety of work tasks and activities. The bodily practices and embodied actions of the practitioners often come into stronger focus in these kinds of analyses.

Research and design approaches for gesture- or movement-based technology use are emerging that are grounded in studies of work practice and everyday life (e.g., Buur et al., 2004; Brereton, Bidwell, Donovan, Campbell, and Buur, 2003; Jensen et al., 2005; Cederman-Haysom and Brereton, 2006). In particular, the research approach of Buur, Djajadiningrat and Jensen in tangible interaction design stems from an interest in building tangible user interfaces that respect and build bodily skill (Jensen et al., 2005). They conducted ethnographic fieldwork studying the work practices of brewery operators, with a focus on physical actions and bodily skill. From these studies of practice, they developed a set of design methods for capturing the characteristics and qualities of skilled physical practice, thus enabling designers to develop a feel for physical actions.

Ethnography is a research approach that implicitly and often explicitly demands that you make strange. This is because it is always interested in understanding what the 'natives' take for granted. Bell, Blythe, and Sengers (2005) work with *defamiliarising narratives*, constructed from ethnographic data on a range of cultures, to provide alternative viewpoints for helping them rethink assumptions built into domestic technologies. It is a form of *defamiliarisation* or *making strange* based on "cross-cultural juxtaposition" (Marcus and Fischer, 1986).

The shift to public or non-work settings brings different challenges to the study of human activity and interaction for use in technology design. Alternative techniques are emerging that seek partial, fragmentary data on the use—current and future—of technology in work and everyday life.

One pioneering and influential technique is *cultural probes*, devised by Gaver, Dunne, and Pacenti (1999). The cultural probes are a collection of materials such as postcards, maps, a disposable camera, a photo album and a media diary, designed to provoke inspirational responses from the community of participants. The probes collect fragmentary data over time. It is "inspirational data", intended to stimulate the imagination of the designers rather than define a set of problems. Their approach employs the basic strategy of defamiliarisation by prompting participants to reflect on their everyday lives through the use of the probes. Gaver et al. (1999) approach research into new technologies from the tradition of artist-designers, where they concentrate on aesthetic control, the cultural implications of their designs and *ways to open new spaces for design*. The design methodology presented in this thesis operates from a similar premise of finding new ways to approach the design of movement-based interactive technologies, with an emphasis on working creatively with the experiential, moving body to generate and evaluate design proposals.

More attention is being paid to mobile and movement characteristics in studies of practice in non-traditional settings. Hagen, Robertson, Kan, and Sadler (2005) provide a review of the current state of emerging research methods for understanding mobile technology use. An important source of understanding how people move and conduct themselves in museums and galleries comes from researchers in interaction and conversation analysis (Lehn, Heath, and Hindmarsh, 2001; Heath, Luff, Lehn, Hindmarsh, and Cleverly, 2002; Hindmarsh, Heath, Lehn, and Cleverly, 2005) and museum visitor studies (Fernández and Benlloch, 2000). They have shown that people's experience and perception of an exhibit is fundamentally shaped by and through social interaction with others in the same space.

An understanding of the practices of users of technology goes hand in hand with a reflexive understanding of the practices of design. The participatory design tradition is renowned for its understanding of the design process as a process of mutual learning between professional designers and skilled users within the application domain and as a process where future or alternative technology and work organisation are envisioned and experienced rather than described (Ehn and Sjögren, 1992). Schön (1983) is influential for his insightful analysis of the practice of design. His notions of reflection-in-action and design as a reflective conversation with the materials of the situation continue to have relevance in design research and this thesis. In Chapter 6, I discuss the experiential design methods of enactment and immersion as possible categories of reflection-in-action that involve an active, moving body and coming-to-know (Larssen et al., 2007a) through sensorial, bodily experience. The *felt* presence, positioning and motion of other people in the Bystander prototype exhibit in relation to the physical and digital properties of the interactive space were important factors for understanding and evaluating the design as part of reflection-in-action.

2.3 Interaction analysis and Suchman's analytic framework

> The starting premise is that interpreting the significance of action is an essentially collaborative achievement. Rather than depend on reliable recognition of intent, mutual intelligibility turns on the availability of communicative resources to detect, remedy and at times even exploit the inevitable uncertainties of action's significance. (Suchman, 2007, p.86)

Suchman's (1987; 2007) pioneering work on human-machine interaction revealed the flaws in the then prevailing view of human action in cognitive science and artificial intelligence as one based on a planning model of human action. Instead she proposed an alternative view of understanding human action as *situated*. Situated action refers to "actions taken in the context of particular, concrete circumstances." (Suchman, 2007, p.26). She describes the relation between plans and situated actions:

> As commonsense constructs plans are a constituent of practical action, but they are constituent as an artifact of our *reasoning about* action, not as the generative *mechanism of* action. Our imagined projections and our retrospective reconstructions are the principal means by which we catch hold of situated action and reason about it, whereas situated action itself, in contrast, is essentially transparent to us as actors. (Suchman, 2007, p.60)

She exposes the inherent difficulties in attempting to predetermine the intention of a person's action from their observable behaviour and to then specify this in a plan to be implemented as a computer program.

Her study involved the observation and analysis of novice users attempting to use a large and relatively complex photocopier, that came with a machine called an expert help system. The purpose of the machine was to instruct the user of the photocopier in its operation. Suchman applied conversation analysis techniques from the field of ethnomethodology to the study of human-machine interaction in this instance. Suchman describes her interest in this study as,

> My central concern in the investigation is a new manifestation of an old problem in the study of mutual intelligibility; namely, the relation between observable behavior and the processes, not available to direct observation, that make behavior meaningful. [...] In either case [psychological or social studies], the problem of meaningful action turns on the observation that behavior is inherently subject to indefinitely many ascriptions of meaning or intent, while meaning or intent are expressible through an indefinite number of possible behaviors. (Suchman, 2007, p.30)

As part of the analysis, she devised an *analytic framework*, which focused on the resources available to user and machine for shared understanding in the interaction. Figure 2.1 illustrates the analytic framework. It is composed of four columns, of which the two left-hand columns describe the user actions (e.g., physical actions and talk) in terms of actions available or not to the machine and the two right-hand columns describe the machine effects and design rationale. It is organised so that the two central columns represent the mutually available, human-machine "interface". The outer columns are then the respective interpretations of the user and the design. This organisation enabled comparison and contrast of the user and machine points of view and identified the points of confusion, as well as the points of intersection or "shared understanding".

The framework was important for showing that the coherence of the user's actions was largely unavailable to the system. Only a partial trace of the user's actions was accessible to the machine. It also exposed the radical asymmetries in relative access of user and machine to contingencies of the unfolding situation. The description of the users' talk as part of their activity

The User		The Machine	
Actions not available to the machine	Actions available to the machine	Effects available to the user	Design rationale

Figure 2.1 Suchman's analytic framework

in figuring out how to use the photocopier revealed the flexible and contingent nature of human activity, in contrast to the prescribed and procedural character of the machine.

Douglas (1995) applied Suchman's analytic framework as part of her research into using conversation analysis and constructive interaction as design methods that provide contextualised information about user expectations and intentions. Episodes of user testing are videotaped for later analysis by developers. The users work in pairs following the technique of constructive interaction, where each participant "must inform the other in an explicit verbal record about problems, causes, and solutions" (Douglas, 1995, p.187). The videotapes are then analysed by developers using conversation analysis techniques and Suchman's analytic framework. Findings are then fed back into an iterative design process.

One of the key insights from Suchman's work is that assumptions about user behaviour become embedded in computer programs and influence in crucial ways the agency of potential users of interactive machines. The adaptation of Suchman's analytic framework as a design tool in this thesis enabled my focus on the conceptions designers have of users and the corresponding interpretations of user behaviour made by the machine. Used in this way, questions could be asked about the relations between user behaviour and machine behaviour and the different options available to designers. This thesis pays particular attention to conceptions of movement that form part of the design of the interactivity between users and interactive systems that utilise human movement as direct input. The specific adaptations of the framework are described in Chapter 5 (Project I, Eyetoy) and Chapter 6 (Project II, Bystander). A reflection on the use of the framework in both projects is given in Chapter 8, prior to its inclusion in the design methodology of Moving and

Making Strange, presented in Chapter 9.

2.4 Design representations and ways of seeing

> In the very broadest sense, designing is the process by which things are made. In a sense only slightly less broad, designers make representations of things to be built. They shape materials to function in some context through a web of deliberate moves and discovered consequences, often unintended. Materials resist the imposition of form and it is a rare move that has only its intended consequences. (Schön, 1990, p.110)

This section provides a certain trajectory through the literature on representations in interaction design and related fields, such as participatory design. It illustrates the roles and forms of representation in design, with a view to addressing the unique requirements of representing the moving body.

Representations are a crucial part of the design process. Each form of representation focuses on certain aspects of the design space, whilst throwing others into relief. As Bødker (1998) recognised, representations are situated within the specific practices of design and thus each design project uses and produces whatever representations are most appropriate. Her notion that design representations cross boundaries between design and use activities is fundamental to the production of representations in this research. Representations can function to promote shared understanding or as *boundary objects* (Star, 1990) which allow for multiple interpretations. The same theme of design representations offering multiple interpretations is discussed by Schön (1992) when he mentions the ambiguity of prototypes which are subject to multiple readings.

Bødker echoes Schön's (1983) notion of design as a reflective conversation with the materials of a situation, when she states that "design representations do not "stand for" existing phenomena that may be inspected alongside, but for designed phenomena, the conception of which is developing in design"

(Bødker, 1998, p.119). Schön talks of *design moves*, where the designer is engaged in a process of seeing-moving-seeing. He illustrates this concept through the example of an architect working in some visual medium, in this case, drawing:

> the designer sees what is "there" in some representation of a site, draws in relation to it, and sees what he or she has drawn, thereby informing further designing. (Schön, 1992, p.133)

Representations are intimately bound with *ways of seeing*. The works of Schön, Goodwin, Latour, Suchman and Haraway, among others, all emphasise the situated, malleable and constructed nature of seeing. Schön succinctly describes the relation between representations and ways of seeing when he states, "Stories and visual images may function like prototypes, each a source of a different way of seeing the situation." (Schön, 1990, p.134). Latour (1986) and Goodwin (1994) both speak of cultures or professions designating "what it is to see and what there is to see" (Latour, 1986, p.9). Suchman (1995, p.63) draws out the importance of one's own positioning "in relation to what we are seeing as much as any meaning inherent in the images themselves", when she analyses representations of work. The politics of positioning in relation to ways of seeing are at the heart of Haraway's arguments for situated and embodied knowledges, characterised by partial perspectives and partial connections (Haraway, 1991). Latour (1986) offers another perspective on representation and instruments of visualisation with what he terms *inscription devices*. Inscription devices work to *simplify* the messy confusion of reality and involve certain ways of seeing.

> In the debates around perception, what is always forgotten is this simple drift from watching confusing three-dimensional objects, to inspecting two-dimensional images which have been *made less confusing*. (Latour, 1986, p.15, original emphasis)

Design representations may take the form of sketches, drawings, diagrams, mock-ups, prototypes, video, scenarios, storyboards, formal notations and formal models. This is not an exhaustive nor comprehensive list; instead, it illustrates the forms of representation commonly found in practices of interaction design and related software design disciplines, such as software engineering (Pressman, 1997; Sommerville, 2001). Anything that can stand in place of some aspect of the real thing can function as a design representation. A small subset of these representational forms, pertinent to this thesis, will be discussed in some detail, including visual representation and visual communication practices, conceptual design frameworks and scenarios.

Visual representations are graphic renderings of phenomena of interest. They organise perception and are part of visual communication practices. Conceptual design frameworks offer different ways of framing and understanding the interactions between people and interactive machines. Personas and scenarios are an established and common technique for representing users, their activities and the context of use. Each of these representational forms is discussed next and specifically, in terms of how they support the representation of different aspects of movement.

2.4.1 Visual representations and visual communication practices

The moving body is in one sense a visual medium—it can be seen by others. We can use our bodies to convey or represent ideas, qualities, forms and other meaningful aspects of the design situation. Methods for doing this are the subject of section 2.5. The moving body has a dynamic, temporal character which does not lend itself easily to static representation on paper or in digital form. Tufte (1997) points out the challenges of representing motion on paper or in static forms:

> Sequences of still images suffer the obvious (though no less important for being so) loss of the experience of the passage of time, the loss of the rates and rhythms of actual motion. (Tufte, 1997, p.109).

"the fixity of images on paper, despite clever techniques for showing motion, greatly limits representations of the quick rhythms of magic" (ibid.). Yet this same *fixity* allows designers to reason about, critique and hold onto movement-related design concepts and understandings. In movement-based interaction design, we also need representations of movement that enable reasoning about and linking to machine input, processing and output.

In HCI, the moving body is commonly captured on video and still images are extracted from the video to represent selected postures and sequences of movement. Høysniemi and Hämäläinen (2004) experimented with various visual representations including images sequences of moving bodies extracted from video data, but abandoned Labanotation in their design of a movement-based interactive game for children. They found the image sequences easier to analyse with all the frames visible side by side. This enabled comparison and grouping of the children's movements and measurement of the frequency of steps and the different phases in the movement cycle. Buur et al. (2004) use *video action walls* to map qualities of human actions. Short video clips of physical action vignettes are clustered together and annotated with descriptive text. This technique preserves the dynamic character of movement and enables grouping of like qualities.

In Henderson's study of design engineers and their visual communication practices, visual knowledge and kinaesthetic knowledge are highlighted as two important types of nonverbal, *tacit* knowledge[1]. The use of sketches and drawings throughout the design process works to access and make explicit in some ways the tacit knowledge of various participants. The sketches and drawings "stand for or point to more complex stocks of tacit knowledge" (Henderson, 1991, p.451).

> Cognition is distributed, as it were, as various forms of nonverbal knowledge are elicited and captured to some degree through interaction with sketches and drawings. The visual representations help coordinate distributed cognition since they allow for the manipulation of tacit knowledge between individuals. (Henderson, 1991, p.450)

Henderson recasts Latour's (1986) concept of *inscription devices* as *conscription devices* in engineering design, where engineering sketches and draw-

[1] *Tacit knowing* was defined by Polanyi (1983) as a primary knowing mediated by the body prior to our ability to verbally articulate such knowing.

ings enlist and organise group participation. They serve as both a group thinking and communication tool and an individual thinking tool:

> Sketches are the real heart of visual communication. They are probably the most important carriers of visual knowledge because they serve both as an interactive communication tool and as an individual thinking tool. (Henderson, 1991, p.459)

Visual communication practices using the moving body and using representations of the moving body are still emerging and need to be developed for movement-based interaction. We need ways and language to invoke and talk about movement and qualities of movement. We also need representations that capture aspects of movement for use in reasoning about movement for input and interaction with interactive technologies and representations that facilitate re-generation of the performance and experience of movement. A growing body of researchers is addressing these very needs, as surveyed in section 2.5. This thesis focuses on representations of human movement external to the computer and representations that can serve as a bridge between human and machine perspectives. Movement notations are considered as a likely bridging representation and are discussed in section 3.3.2. Digital representations of human movement internal to the computer are covered briefly in section 3.3.3, but are outside the immediate scope of interest.

2.4.2 Conceptual design frameworks

Schön (1983) talks about framing and re-framing the design space, to generate new ways of seeing the design situation. The design process can then be considered a *frame experiment*:

> Beginning with one way of framing the problem, derived from a particular generative metaphor, we invent and implement solutions whose unanticipated effects make us aware of the selective attention or mistaken assumptions built into our initial frame. We become aware of values we did not know we held until we violated them. (Schön, 1990, p.137)

A number of conceptual design frameworks exist which offer different perspectives and ways of framing the interaction between people and interactive computing technologies. Each of these frameworks will be briefly discussed in terms of what they offer to the design of movement-based interaction.

The *Expected, Sensed and Desired* framework was developed by Benford, Schnädelbach, Koleva, Anastasi, Greenhalgh, Rodden, Green, Ghali, Pridmore, Gaver, Boucher, Walker, Pennington, Schmidt, Gellersen, and Steed (2005) to assist in the design of moveable, physical interfaces, such as mobile devices or interactive furniture. It focuses on the often complex relationship between physical form and sensing technologies. Key aspects of this framework are that *expected*, *sensed* and *desired* movements of interfaces only partially overlap and that mismatches between the categories can reveal potential problems, as well as opportunities to be exploited, in design solutions. This framework can be adapted to focus explicitly on the movements of users instead of devices. See Loke et al. (2007) for an application of the adapted framework to the analysis of movements of people interacting with Eyetoy games. In brief, the analysis clarified the relationship between the user, the technology (the form of the interface and devices) and the game application. It also suggested areas of potential redesign, such as pausing the game by stepping outside the camera's frame of view. But also, perhaps more interestingly, the framework reveals the ways in which the user can subvert this relationship, through an examination of the non-sensed, less expected or less desired movements.

Bellotti, Back, Edwards, Grinter, Henderson, and Lopes (2002) developed a framework, *Making Sense of Sensing Systems*, for the design of sensor-based systems, based on a model of human-computer interaction as human-human interaction. They focus on what happens when technology moves into the environment around us and the challenges this poses to the interaction between people and computers. Their framework is informed by understandings of human-human interaction derived from the social sciences; human-computer interaction is viewed as communication between the user and technology and the concern is how to achieve joint accomplishment in realising the interaction (Bellotti et al., 2002, p.416). The framework is composed of a set of five issues that Bellotti et al. suggested could be posed as questions that system users must be able to answer to accomplish some action. See again Loke et al. (2007) for an application of the framework to movement-based interactions with Eyetoy. The use of this framework enabled us to focus on the input and output mechanisms of the Eyetoy interface. Since the Eyetoy operates with a GUI-like display, some of the challenges that Bellotti et al. set out to tackle are solved in conventional GUI ways.

The *Stop Making Sense* framework by Rogers and Muller (2003) aims to inspire the design of sensor-based interactions by exploiting the unique characteristics of sensors as imprecise, unpredictable and discrete/continuous. It contains five concepts that are relevant to the design of the user experience, where reflection, exploration and discovery are valued. These concepts were transformed into a set of questions, after the style of Bellotti et al. (2002). They applied the framework to the design of a children's game, *The Hunting of the Snark*. A set of sensor-based interactions was developed to support various physical activities in the game and included sensing placement of objects, sensing location to detect virtual objects, sensing real-time gestures and sensing body movements.

Eriksson, Hansen, and Lykke-Olesen (2007) present a framework for describing and analysing camera tracking applications ranging from interactive spaces to mobile devices. It contains three concepts of *space*, *relations* and *feedback*. Despite the fact that the applications demonstrated within this framework utilise movement as input in various forms, the actual framework concepts do not employ a vocabulary for describing movement beyond basic tracking of bodies and body parts, shape, position and orientation.

Bongers and van der Veer (2007) present the *Multimodal Interaction Space* framework, for describing interaction styles starting from the physical level. It consists of three dimensions: *Levels*, *Modes* and *Modalities*. Their intention with the framework is to create interactive spaces and devices that offer rich and diverse forms of interaction, based on the three dimensions in the framework. Physical movement is an essential part of multimodal interaction, yet the framework offers little guidance for working with movement and its felt experience.

Hornecker (2005) (see also Hornecker and Buur (2006)) propose four themes in their *Tangible Interaction Framework* for the design of collaboratively used tangible interaction systems. The four themes are *tangible manipulation*, *spatial interaction*, *embodied facilitation* and *expressive representation*. They recognised that any technology offers structure that implicitly directs user behaviour by making some actions easier, whilst constraining others. In tangible interaction systems, structure is as much in the physical actions that users perform as it is in the software itself. Tangible interaction implicitly involves movements of the body, where the movement is constrained and enabled by a physical object. This in itself creates a context for movement; however, the focus of this thesis is on immersive contexts for movement that are not necessarily dependent on physical, tangible objects.

All of these frameworks treat movement in very general terms; some not at all. There is still a need for more nuanced and specific ways of describing and analysing *movement* in the interaction. Other disciplines such as dance and anthropology offer understandings, approaches, language and notation for describing and analysing movement in its richness and complexity. Some of these are covered in sections 3.2, 3.3 and 3.4. The trial, application and adoption of Laban movement analysis and description forms part of the work of this thesis and is presented in Chapters 5, 6 and 7.

2.4.3 Personas and scenarios

Well-established tools for representing users, their activities and contexts of use include personas and scenarios. Scenarios are stories or narratives in textual and/or visual form or as Bødker (2000, p.72) describes, "scenarios are selective scripts or stories that stage user actions with a future artefact." Scenarios have traditionally been used in the design of task and work-oriented technology as a means of representing users, their activities and the context of use in work situations. They have typically been used for envisioning and simulating future use situations, allowing reflection-in-action and the continuous presence of the users during the design process (Kyng, 1995; Jacobson, 1995; Bødker, 1998, 2000; Carroll, 2000a,b). More recently, scenarios have been used for exploring situations where the setting is less well-defined and contextual information and awareness are desired such as in mobile and ubiquitous computing (Howard et al., 2002; Pedell and Vetere, 2005) and in audience experience of interactive art (Khut and Muller, 2005).

Grudin and Pruitt (2002) (see also Pruitt and Grudin (2003)) argue that most scenario-based design focuses predominantly on the context of use and actually pays little attention to the users themselves. They claim that scenarios can be much more effective when built on personas, especially when the personas are based on data collected from real people. Cooper (1999, p.124) defined personas as "hypothetical archetypes of actual users". The use of personas has been extended by others through drawing on techniques from creative writing and film (e.g., Blythe, 2004; Djajadiningrat, Gaver, and Fres, 2000; Nielsen, 2002). Djajadiningrat et al. (2000) employ the technique of *extreme characters*, fictional users with exaggerated emotional attitudes, for use in the envisionment of innovative interactive products.

Scenarios serve different purposes at different stages of the design process. Kyng (1995) describes three types of scenarios employed in cooperative design work: use, exploration and explanation scenarios. *Use* scenarios indicate how computer support and/or changes in work organisation may improve upon work situations. They describe future possibilities and "set the stage for how end users in these workshops use mockups and prototypes." (Kyng, 1995). *Exploration* (or requirement) scenarios supply the use-details and focus on whether current technical capabilities meet the requirements of the scenarios. They are more abstract in the sense that they do not contain external references to specific organisations and work situations. *Explanation* scenarios explain new possibilities for support using terms related to work situation descriptions and use scenarios. They record some of the hypothesising involved in developing specific aspects of a system or tool. In the scenario-based design approach of Rosson and Carroll (2002), scenarios serve as a central representation throughout the development cycle, first describing the goals and concerns of current use in *problem* scenarios highlighting typical and critical situations of use, then undergoing successive transformations and refinements into *activity* scenarios, *information* scenarios and *interaction* scenarios. Bødker (2000) suggests *plus* and *minus* scenarios for evaluation of future solutions through caricatures that dramatise the positive and negative aspects respectively.

Scenarios can be used for generating performance. Scenario enactment and its various uses are covered in more detail in section 2.5.3. This research extends the tools of personas and scenarios to focus specifically on moving bodies in social contexts.

2.4.4 Summary—Design representations and ways of seeing

Design representations play a crucial role in the design process. Particularly as they imply certain ways of seeing the design situation. They function as design tools so designers can think about aspects of the design. The representation of the moving body presents new challenges to designers of movement-based interaction, where the temporal nature of the body-in-motion and the felt experience of movement are not easily transferred to traditional, static forms of representation. Video documentation attempts to alleviate the first challenge of representing the flow of movement in time, but not the second of representing the felt experience of movement.

Scenarios are promising as a means of describing and re-enacting the activity and movements of people, thus evoking patterns of movement and the felt experience of movement. One of the contributions of my thesis is the production and use of *movement-oriented* scenarios, based on *movement-oriented* personas (see Chapter 6). These two design representations of moving bodies address the lack of research in interaction design explicitly dealing with describing and representing moving bodies.

A range of conceptual design frameworks exists for exploring and evaluating the interactions of people with various kinds of interactive devices and spaces built on sensor-based technologies. The applications envisaged by the authors of the frameworks generally promote or sense physical movements and spatial interactions of users. However, the frameworks themselves treat movement in very general terms, some not at all. Designers working in movement-based interaction need more nuanced and specific ways of describing and analysing movement in the interaction. The combined use of Suchman's analytic framework and the Laban system of movement analysis and description offers a solution to this issue and is described in Chapter 5 and Chapter 8.

2.5 Methods and techniques for working with the moving body

Researchers in human-computer interaction, interaction design and related fields have developed a variety of different approaches to designing for, and from, the moving body. Common to their approaches is a shared commitment to grounding understandings of their design domain in their own experiences as sensing, feeling and moving beings and to designing interactive systems from experiences and explorations of movement, rather than from a technological starting point.

These approaches include the use of physical movement by designers to gain a bodily understanding of gestures and movements and to communicate design ideas and findings, the use of the moving body as design material, together with developing a design sensibility for working with movement and the use of enactment and role-playing for generating, exploring and evaluating design concepts in situations of use. Inspiration for these approaches and methods has come predominantly from dance and theatrical performance practices.

2.5.1 Bodily understanding

This section describes approaches and methods for gaining bodily understanding of movement ideas and the body-in-motion and for communicating ideas and understandings with the moving body.

The notion of *experiential bodily knowing* is put forward by Larssen et al. (2007a) as "a designer's (sens)ability to reason about movement and responses to movement as part of the process of designing movement enabled interaction with technology". In their study, this experiential bodily knowing is acquired through the learning of bodily skill in a movement practice such as pilates, yoga or Capoeira, where knowing is constructed through experiences of the body over time. This kind of knowing is *in-the-body*. They distinguish three dimensions of experiential bodily knowing: continua of knowing, the distinction between bodily knowing and understanding and the recognition of knowing in self and others. They claim that "developing greater sensibilities for recognising one's own movement experiences" (Larssen et al., 2007a) leads to an increased understanding of how others might experience movement and thus provide a more informed basis for designing.

Several researchers work with a design strategy of 'actions before product' (Buur et al., 2004; Donovan and Brereton, 2004; Jensen et al., 2005; Klooster and Overbeeke, 2005; Hummels et al., 2007). The emphasis is on understanding and exploring physical actions prior to designing "interface mechanisms that afford such actions" (Buur et al., 2004, p.186). Designers working in this way need to develop a sensitivity towards actions, physicality and qualities of movement. The *hands-only scenarios* method of Jensen et al. (2005) and Buur et al. (2004) involves the performance of a string of hand actions drawn from observations of particular work practices in order to elicit the qualities of movement in the actions and to gain a bodily understanding of the movements. One interesting finding from their work with design students in developing this method, is that re-enactment of movement without the original objects and context can become an empty gesture. In order to retain the qualities and details of the movement, they found that handling the original objects and synchronising the performance of a string of actions *amongst a group of students*, encouraged precision and retained the qualities of the movement. When working solely with movement, as is the case in my thesis, the question arises as to whether or not this is a concern. A related concern is the production of meaningful movement and the resources required to facilitate it. As the findings from my thesis suggest, the ability to generate meaningful movement is dependent to some extent on the context of action and the constraints for performance. This discussion is taken up in Chapters 5, 7 and 9.

As part of ongoing research into the design of gestural input devices for dental practitioners, Donovan and Brereton (2004) devised a gestural design game called "Meaning in movement". Participants begin with a set of three words that describe aspects of dentistry. They then choreograph a sequence of movements that reflect the words. The aim of the game is to explore and reflect upon movement qualities through the use of gesture, prior to designing specific instrument manipulations.

One method Brandt and Grunnet (2000) devised for gaining a bodily understanding of a work task (for a refrigeration technician) consists of breaking down the work task into a sequence of physical actions. The designers then perform these actions, holding each physical action like a statue or "frozen image". The acting out by designers provides a means of testing if everyone in the design team has a similar perception, from a bodily perspective, of the users and the users' work. This could be described as a shared bodily understanding.

2.5.2 The moving body as a design material and design sensibility

A small but growing number of researchers is conducting interdisciplinary work in the areas of dance (and related performance practices) and HCI (Schiphorst and Andersen, 2004; Kjölberg, 2004; Klooster and Overbeeke, 2005; Moen, 2005, 2007; Jacucci, 2006; Hummels et al., 2007; Jensen, 2007; Loke and Robertson, 2007). Dance is an artform and practice which deals exclusively with the moving body. Dance, in all its forms and traditions, offers diverse ways of understanding the body in motion and a vast range of approaches and methods for working creatively with the moving body. The focus for many of these researchers is on how to bring aspects of dance and movement practices into design practices, particularly ways of working with the moving body as a design material and design sensibility.

The approach of Schiphorst and Andersen (2004) is exemplary for attendance to bodily experience and awareness as a starting point for design. They utilise first-person methodologies from performance practices (e.g., dance, theatre) and somatics to create gestural protocols for interaction with a wearable computing public art installation called *whisper*. In the early design phase of *whisper*, workshop participants generated movement vocabularies by negotiating permission and control of their own physiological data. The series of workshops drew on performance techniques such as improvisation, props, phantom partners, prosthetic devices, ritual space and placebo objects. One particular technique that resonates with my thesis is the focus on what they term *somatic attributes* such as breath, stillness and slow motion movement. Working with somatic attributes can heighten awareness of bodily processes and sensations and refine one's ability to articulate and control the felt experience of movement.

Researchers such as Hummels et al. (2007) advocate designers cultivating movement and kinaesthetic sensibilities and abilities to support the design of rich, expressive movement-based interaction. Larssen et al. (2007a) espouse similar commitments to developing the sensing, feeling and moving abilities of the designer or what they refer to as 'design (sens)ability'.

An example of a contemporary approach to interaction design that values aesthetic experience and more specifically, *kinaesthetic* experience is provided by Moen (2007, 2005). Moen uses people's experiences of modern dance to inform the design of a movement interaction prototype, *BodyBug*. The prototype was intended to "encourage and trigger movements and provide a possibility to sense one's (kinaesthetic) body and to move in new ways" (Moen, 2005, p.123). Moen drew on a field study of participants attending a course in improvisation and composition based on modern dance, to generate a set of movement-based design criteria corresponding to aspects of movement. For example, the movement aspect of *movement impulses* has corresponding design criteria of "create movement that trigger[s] movement; use the kinesthetic sense; no specified 'correct' or 'incorrect' use, no 'punishments' are given." (Moen, 2007, p.254). I share a similar concern with Moen (2007, p.258) for the design of future technologies, that will "influence people's movement patterns and movement habits" and thus, their ways of being in the world and the quality of their existence.

Klooster and Overbeeke (2005) introduce their *Choreography of Inter-*

action framework for the design of interactive products. The framework is based on three concepts of *Physical Involvement*, *Dynamic Quality* and *Expressed Meaning*. In their design approach, creative exploration of the movements of the user in interaction with the future product precedes the design of the physical form of the product. The final form of the product arises out of the choreography of interaction, out of the interplay between the three concepts, as the material expression of the choreography of interaction. The concept, or what they term 'pivot', of Dynamic Quality connects meaning and physicality (that is, the other two pivots of Expressed Meaning and Physical Involvement). They use three dimensions for Dynamic Quality derived from Laban's system of movement analysis—(1) Spatiality, (2) course of Time and (3) play of Forces.

The *Metaphor Lab* of Jensen (2007) consists of three design activities aimed at transferring movement qualities to the design of new interaction modalities in tangible interaction design. The first activity involves acting out movements portrayed in the *Video Action Wall* tool, to get a feel for the movement and to facilitate description of the movement qualities using Laban's Effort-Shape description. In the second activity, metaphors are created to describe the movement qualities. In the third activity, the metaphors act as the basis for designing interactive sculptures, with the aim of preserving and communicating the movement qualities through the form of physical interaction.

The masked performance techniques of Jacques Lecoq are applied by Jacucci (2006) to the field of interaction design. He reconceptualises the use of props and mock-ups in user-centred design work as 'incomplete forms' that can function as masks. Concepts for design such as neutrality, expressivity and incompleteness can be explored through performance exercises of movement based on 'neutral', 'characterised' and 'larval' masks. Jacucci (2006, p.1042) suggests masks as tools for design inquiry,

> Masks permit them [performers] to distance themselves from their own personality and even from the role of the characters they play. Ultimately, these distancing effects can articulate the inquiry by transforming the act of 'seeing' in order to make it more conscious.

Mask work enables exploration and deconstruction of movement, where the interpretation of movement is biased by the presence of the mask. Explorations with neutral masks, for example, involve experiencing movements through awakenings, journeys, encounters and farewells. These techniques complement the emerging set of methods and techniques for exploring and experiencing movement and its qualities in my proposed design methodology.

2.5.3 Enactment and physical role-playing

New methods for designing for, and from, real and imagined situations of use are emerging that view enactment and physical role-playing as key to exploring the design space. Enactment and role-playing provide ways for designers to observe users in envisioned situations of use or to directly experience the envisioned situation of use themselves. Scenario enactment extends conventional verbal 'walk-throughs' of textual vignettes by bringing the scenario to life through performance and making visible or felt, factors that are often tacit or difficult to verbalise (Carroll and Tobin, 2003). Researchers have explored techniques and devices from theatrical performance traditions to improve the process and outcomes of scenario enactment including the use of dramatisation, improvisation, role-playing and props (Ehn and Sjögren, 1992; Burns et al., 1994; Sato and Salvador, 1999; Brandt and Grunnet, 2000; Iacucci and Kuutti, 2002; Iacucci et al., 2002; Kuutti et al., 2002; Carroll and Tobin, 2003; Laurel, 2003; Mackay, 2004; Strömberg et al., 2004; Svanæs and Seland, 2004; Newell, Carmichael, Morgan, and Dickinson, 2006; Ehn, Binder, Eriksen, Jacucci, Kuutti, Linde, Michelis, Niedenthal, Petterson, Rumpfhuber, and Wagner, 2007). Some approaches advocate users acting out scenarios of future use, with designers observing and interjecting (Howard et al., 2002; Iacucci and Kuutti, 2002; Kuutti et al., 2002; Carroll and Tobin, 2003; Strömberg et al., 2004; Svanæs and Seland, 2004; Newell et al., 2006), whilst others advocate designers acting out scenarios of future use (Buchenau and Suri, 2000), with users acting as directors with expert knowledge (Brandt and Grunnet, 2000).

Ehn and Sjögren (1992) published one of the earliest examples of scenarios as scripts for action. Working within the participatory design tradition, they advocate design-by-doing and design-by-playing as engaging and meaningful ways for users to participate in the design process. Their scripts for action involve the use of games and dramatic play metaphors. Another pioneering method for acting out and physical role-playing is *bodystorming* which originated with Burns et al. (1994) and their *informance* (informative performance) design practice. They define bodystorming as the use of performance and improvisation methods for "reenacting everyday people's performances" and "living with data in embodied ways" (Burns, Dishman, Johnson, and Verplank, 1995). The key aspects of their method include designers role-playing as users, utilising simple prototypes as props and acting out performance scripts describing event sequences rather than detailed dialogue and interactions. The nature of the scripts opened up space for imagination and improvisation in character building and possible interactions with proposed design concepts. The performances also provided a common platform for discussion amongst a varied group of peers and clients.

The *Experience Prototyping* approach of Buchenau and Suri (2000) includes role-playing, improvisation and bodystorming for exploring and evaluating design ideas and prioritises designers experiencing real and imagined activities, artefacts and contexts of use *themselves*. They point out the "vividness of this owned experience [by designers] creates subjective, lasting memories which influence and guide the designers' choices and decisions" (Buchenau and Suri, 2000). They do raise, however, an interesting risk in role-playing where one can get caught up in *having* the experience, instead of *understanding* the experience. To remedy this they advocate a balance between active and passive ways of realising experience. Bodystorming has been applied by Oulasvirta et al. (2003) to the design of ubiquitous computing where they claim it enables a more accurate understanding of contextual factors such as the physical, social, interactional and psychological that are not readily observable.

Sato and Salvador (1999, p.35) present a comprehensive set of theatre techniques, under the banner of *Focus Troupes*, for "creating quick, intense, immersive, and engaging focus group sessions" aimed at new product concept generation and evaluation. They classify which theatre techniques are most effective when actors are used to play out roles and scripts or when an audience of potential users does the acting or improvising. They also distinguish between situations when a product concept does, or does not, exist. Some examples of theatre techniques include acting out an everyday situation and providing fairy-tale props, acting out what goes on inside a product, adding objects to the situation and using the same script but changing the attitude or emotion.

Drama is explored by Brandt and Grunnet (2000) and Newell et al. (2006) as a way of staging meetings between designers and users within a participatory or user-centred design tradition. They draw on techniques from theatre to dramatise and act out scenarios, with the aim of evoking the future use of interactive products and creating empathy with users and contexts of use. Augusto Boal's Forum Theatre is a form of interventionary, political theatre where the audience is given agency over and encouraged to actively participate in the unfolding performance. Brandt and Grunnet (2000) use it with designers acting out scenarios of future use and users acting as directors with expert knowledge. Newell et al. (2006) use it to generate dialogue between designers and older, disabled users as they found traditional user-centred methods failed to adequately solicit requirements that genuinely reflected the needs of older people. Brandt and Grunnet (2000) also worked with two other techiques: Johnstone's theatre improvisation techniques and Stanislavski's acting techniques. Johnstone's theatre improvisation techniques work from the premise that improvising from well-defined restrictions assists the creative process. Brandt and Grunnet (2000) apply this principle in design work by providing guidelines for improvising use situations. Stanislavsky's "magic if" technique is used to speculate on a range of situations for character development and to build empathy with the character. Brandt and Grunnet (2000) use it to build empathy with users by speculating on what they might do in a variety of situations.

In a similar vein, Carroll and Tobin (2003) have crafted an envisionment process for future technology design aimed at simulating users immersed in possible futures. It incorporates aspects of participatory design, Forum Theatre, Postdesign and Futures studies. Their envisionment process is chiefly concerned with the development and performance of *contextual scenarios* using endowed props where users, actors, designers and researchers can choose to participate constructively in different ways, such as observing, interjecting, envisioning or acting (Howard et al., 2002). Contextual scenarios take the form of mini-stage directions focusing on the context of use and are used to seed theatrical performances. They use actors trained in theatre improvisation as surrogate users to act out the contextual scenarios. The researchers are able to direct the scenarios on-the-fly by introducing constraints during the performance, enabling exploration of the impact of different contextual variables on the developing design ideas.

Strömberg et al. (2004) also work with Johnstone's improvisation techniques in exploring early concept definitions for ubiquitous computing. They developed the *interactive scenario* method to increase the participation of potential users in the early stages of concept design. It involves scenario role-playing and improvisation techniques for exploring physical interactions with ubiquitous computing technologies. They report that intensive work is required to prepare and reflect on an interactive scenario session. However, it is beneficial for revealing issues related to a user's spatial and physical interaction with futuristic interfaces, that may not be so readily apparent through less active and less embodied methods.

Iacucci et al. (2002) present three roles of performance, primarily in early concept design, including *exploring* design ideas, *communicating* scenarios and *testing* scenarios and concepts with mock-ups and improvisational role-playing. They identify three concepts useful for a deeper understanding of the roles of performance. The concepts include the *creation of a fictional space*, the *role of imagination* and *interactional creativity*. They present a specific method embracing these concepts called *Situated and Participative Enactment of Scenarios* (SPES) in Kuutti et al. (2002) and Iacucci and Kuutti (2002). In SPES, the designer follows a participant user in their daily activities. The user is supplied with a *magic thing*, a simple mock-up of a future device, intended to provoke ideas for new services or product features out of new situations. The designer and user together invent and act out new scenarios of use as interesting situations arise. This method aims to generate ideas for design out of a creative, performative process. This general approach is echoed by design researchers working with movement as a design material (see section 2.5.2 above) and resonates with the principle of *making strange*, defined in my proposed design methodology (see Chapter 9).

Brenda Laurel (2003) presents *design improvisation* as a way of stimulating creativity and opening up new design spaces. Design improvisation is based on elements of theatrical improvisational techniques, theatre games and performance ethnography. In Laurel's (2003, p.54) words, "the designer uses empathy to perform design solutions that are drawn from deep identification with real, individual people in specific situated contexts in the real world."

Svanæs and Seland (2004) developed a one-day workshop format involving role-playing and lo-fi (low fidelity) prototyping for end users to contribute to the design of mobile systems. Central to their approach is putting the users centre stage and learning about potential design ideas by "observing them acting out and designing their present and future life worlds" (Svanæs and Seland, 2004, p.486).

The collaborative work of Ehn et al. (2007) has brought together many of these performance-oriented techniques to create inspirational learning environments for design and architecture students. Their advocacy of *performative interactions* in design work is resonant with my research approach, which emphasises embodied experience and attention to the interrelations between body movements, spatial interactions and system behaviour.

It should be noted that the use of scenario enactment in this thesis was primarily for design reflection on a specific system, unlike much other research which is concerned with envisionment of possible future uses of technology. Enactment and physical role-playing rely on the moving body, but the methods surveyed above do not have an explicit focus on movement *per se*.

2.5.4 Summary—Methods and techniques for working with the moving body

Performance-based techniques for enactment and role-playing offer improved means of exploring and generating design ideas and concepts, communicating design ideas between designers and users, testing and evaluating design proposals and creating empathy with users and contexts of use. Most of the approaches surveyed above in section 2.5.3 however, *do not* pay close attention to the moving body and the felt experience of movement, unlike the researchers working directly with the moving body, surveyed in the first two sections.

The felt aspects of movement and the movement itself are inseparable in the lived experience of movement. It is this twin attendance to the felt experience of movement and the visually observable aspects of movement that characterises the emerging approach to movement-based interaction design surveyed here. The researchers surveyed in section 2.5.1 recognise and promote the value of understanding and articulating these dual aspects of movement. They have developed specific methods for acquiring bodily understandings of movement and for communicating about movement through movement.

Working with the moving body as a design material inherently requires an intimate understanding of the moving body. For the researchers surveyed in section 2.5.2, the body-in-motion and its felt experience are the generative source and medium for exploration of dynamic, qualitative concepts for design and the ultimate test of successful engagement with interactive systems, products and spaces. Methods and techniques for facilitating the use of the moving body as a design material and sensibility are still emerging. The disciplines of dance, physical performance, somatics and eastern movement practices, such as Tai Chi and Chi Gong, offer abundant, not yet fully tapped, sources for these methods and techniques. Schiphorst (2007) has already done significant research in this area of drawing on first-person methodologies from somatic and performance practices and has mapped out the terrain for future research.

What is lacking in the literature, however, is a range of specific techniques and exercises for accessing and directing attention to different aspects of movement and for acquiring movement skills for working with parameters of space, time, etc. Exercises for working solo or together facilitate different kinds of knowledge and skill. In the literature, these kinds of techniques and exercises are often referred to in a blanket statement as 'physical warm-up'. It is these very techniques and exercises that designers need to practice with their own bodies in order to work productively and creatively with the moving body as a design material and design sensibility. The methods for investigating movement in my proposed design methodology are intended to serve this purpose.

2.6 Summary—Interaction Design

Phenomenologically- and ethnographically-inspired approaches to interaction design both value the lived experience of people. These approaches to design utilise methods for improving understandings of human experience, phenomena and practices prior to designing new technologies. The work of my thesis seeks to contribute to these approaches, by identifying and developing methods for accessing and understanding the lived experience of movement.

Design representations such as visual representations, conceptual design frameworks, personas and scenarios were examined for their potential to support the representation of human movement, with a view to utilising or extending existing forms of representation. We need representations that capture aspects of movement for use in reasoning about movement for input and interaction with interactive technologies and representations that facilitate re-generation of the performance and felt experience of movement. This thesis focuses on representations of human movement external to the computer and representations that can serve as a bridge between human and machine perspectives.

Suchman's analytic framework enables the analysis of the interactions between humans and machine in terms of the resources available, or not, to both user and machine. It assists with the identification of breakdowns or misalignments in the interaction. In this thesis I explore the potential of adapting Suchman's framework as a design tool for the analysis and design of the interaction between moving bodies and movement-based interactive technologies.

Researchers working with enactment and physical role-playing in design have typically drawn on methods and techniques from theatre and improvisation practices, but their focus has not necessarily been explicitly on movement. Researchers working with the moving body as a design material and design sensibility are drawing on methods and attentional strategies from dance and somatics. The actual techniques for developing these movement-based skills are often glossed over in the published literature. My thesis seeks to contribute to these approaches, by identifying and developing methods and tools for exploring and evaluating design concepts, prototypes and systems with a specific focus on the moving body.

Chapter 3

The Moving Body

> To separate myself into a mind and a body would be to perform a radical surgery upon myself such that a vibrant kinetic reality is reduced to faint and impotent pulp, or excised altogether. (Sheets-Johnstone, 1999a, p.487)

The moving body is essential to how we experience the world. It, along with our primary senses of sight, sound and touch, constitute our perception of external things and ourselves. The moving body is simultaneously involved in acting and perceiving. The central role of movement in perception and cognition[1], as argued by phenomenologists, Maurice-Merleau Ponty and Maxine Sheets-Johnstone among others, is presented as a theoretical foundation for this thesis. A range of different understandings of the moving body, gleaned from various disciplines including anthropology, dance, physiotherapy and somatics, is presented in order to contribute to a greater understanding of movement in the discourse and practice of interaction design. Ways of analysing and describing movement are discussed, including systems of movement analysis where movement is viewed in the frames of social and spatial interaction, movement notations and algorithmic analysis of motion by computers.

[1]In this thesis, perception is regarded as active perception and as a cognitive activity. I use the terms, perception and cognition, as separate terms when I need to highlight/emphasise perception particularly amongst the full range of human cognitive activities.

3.1 The central role of movement

> Movement is, on the contrary, first and foremost the natural mode of being a body—a ready and perpetual kinetic susceptibility and effusion, as it were, of animate life. (Sheets-Johnstone, 1999a, p.494)

The central role of movement in perception and cognition is outlined, from the perspectives of two philosophers working in the phenomenological tradition, Maurice Merleau-Ponty and Maxine Sheets-Johnstone, as a foundation for my theoretical approach to this research. Their work supports the primary thrust of my thesis, that of designing for, and from, the experiential, moving body, beginning with an experience of movement.

Merleau-Ponty (1962) is important for his insights into the phenomenology of perception, in particular the central role that *movement* plays in perception. The body is conceptualised as an integrating function, the site of perception, a dynamic field of potentials for action. For Merleau-Ponty, perception is always active, embodied and generative of meaning (Robertson, 1997b). The philosophical notion of intentionality underlies Merleau-Ponty's analysis of perception. Perception is always directed 'towards something'. His assertion that "to move one's body is to aim at things through it" (Merleau-Ponty, 1962, p.160–161) suggests the *instrumentality* of the moving body in acts of perception, particularly perception of the external world, as suggested in this quote:

> Our bodily experience of movement is not a particular case of knowledge; it provides us with a way of access to the world and the object, with a 'praktognosia', which has to be recognized as original and perhaps as primary. (Merleau-Ponty, 1962, p.162)

He talks of a *body-image*, a total sense of one's posture in the intersensory world, defined in relation to the *value* of existing or possible tasks. Lingis (1994) interprets the work of Merleau-Ponty in his book, *Foreign Bodies*, as being primarily concerned with the exposition of a *competent* body, destined for the world. He explains the workings of the body-image, or postural schema, in this quote:

> The perception of intersensorial things is done by the postural schema which integrates the body's powers and converges its sensory surfaces. It is the postural schema that makes the body's mass into force and power. The postural schema that advances unto things and takes hold of them is not a momentary invention, but a dynamic diagram for operations which maintains itself and varies itself. The postural schema is the locus of perceptual competence. A movement perceives an object, aims at an objective. Perceptual competence is motor competence. (Lingis, 1994, p.20)

Lingis chides Merleau-Ponty for not giving sufficient weight to the other spaces we inhabit, the "unpracticable spaces", the world of the imagination, dreams and death, "the private theatres of delirious apparitions" (Lingis, 1994, p.21). Our immersion in these other spaces also shapes our experiences of our own bodies and provides imperatives for creativity and action.

What is missing from Merleau-Ponty's *Phenomenology of Perception* is the notion of *kinesthesis* as the organ of perception of *self*-movement. Kinesthesis, kinaesthesia or the kinaesthetic sense[2], comes from the Greek, kines=to move + theses=feeling. It enables us to know and be aware of internal sensations of body movement. It provides the felt, qualitative dynamic of our own body in movement. Sheets-Johnstone's phenomenological accounts of the moving body emphasise and explicate the kinaesthetic sense as vital to our perception of self-movement. Sheets-Johnstone draws heavily on the work of Husserl with regard to animate forms, movement and kinaethesia and extends his work to consider more rigorously the phenomenon of *thinking in movement*. Where Husserl considered movement only with respect to external perception, Sheets-Johnstone extends the analysis to include the actual perceptual experience of self-movement in the phenomenon of kinaesthesia. She brings together contemporary findings from studies of infancy, impro-

[2]Note that the kinaesthetic sense is often used interchangeably with proprioception in the fields of dance and somatics. This is in contrast to the usage of the terms in other fields, where a narrower definition of kinaesthesia refers to the sense of muscular effort and proprioception to our sense of balance. Gendlin (1992), a philosopher and psychotherapist, notable for his work on the 'felt sense', defines kinaesthesia as a sense of movement and proprioception as a sense of muscular effort. In this thesis, I adopt the definition of kinaesthesia as the felt sense of motion and tension, after Sheets-Johnstone.

vised dance, paleoanthropology and evolutionary biology to form a case for moving as a way of knowing and how thinking in movement is foundational to the lives of animate forms.

Sheets-Johnstone points out our common apprenticeship in learning to move our own bodies as infants, this being the basis for our fundamental knowledge of the world. We learn to move ourselves,

> not by *looking* and *seeing* what we're moving; we do so by attending to our bodily feelings of movement, which include a bodily felt sense of the direction of our movement, its speed, its range, its tension, and so on. Our bodily feelings of movement have a certain dynamic. We feel, for example, the swiftness or slowness of our movement, its constrictedness or openness, its tensional tightness or looseness, and more. In short, we perceive the *qualia* of our own movement; our bodily feelings of movement have a certain *qualitative character*. (Sheets-Johnstone, 1999a, p.56, original emphasis)

Accessing this original experience of learning to move is difficult for an adult body. However, she proposes the practical phenomenological method of 'free variation' for 'making the familiar strange', as a means of bringing to awareness the felt, qualitative character of one's movement. This notion of making the familiar strange, directly informed my design methodology of Moving and Making Strange, the primary contribution of the thesis, and will be discussed in Chapter 9.

3.2 Understandings of the moving body

This section provides a range of different understandings of movement, drawn from other disciplines such as anthropology, dance, somatics and physiotherapy, that contribute to a greater understanding of movement in the discourse and practice of interaction design. It proffers a set of five conceptions of movement that may be useful for thinking through the possible functions, meanings and interpretations of the moving body in the design of movement-based interaction. These various conceptions of movement are not mutually exclusive categories, rather they offer different perspectives and approaches to understanding the moving body and for rethinking assumptions about movement that may be built into interactive technologies. The five conceptions of movement I present here provide an emphasis on the experiential, expressive, perceptual and social character of movement, to support the shift in design perspective inherent in my proposed design methodology. The literature is organised and presented according to the five conceptions of movement given below.

- Movement as anatomical, mechanical function
- Movement as expression and transformation
- Movement as perception
- Movement as felt, kinaesthetic experience
- Movement as a communicative act

3.2.1 Movement as anatomical, mechanical function

A starting point for understanding human movement is the physical structure, functioning and movement potential of the human body. The movement potentials of individual people vary according to their particular anatomy, physiology, training and bodily skills. We can focus on the anatomical, physiological and biomechanical characteristics and constraints of the moving body and treat the body as a musculoskeletal system composed of bones, joints, muscles, tendons and ligaments that can be subjected to measurement (Gray, 1995; Alcamo, 1997; Trew and Everett, 2001) and analysed as a biomechanical system of structures and forces (Hall, 1999; Trew and Everett, 2001). This view is useful for interaction design as the human body provides both constraints and resources in the determination of possible movement profiles for physical interaction with technology.

3.2.2 Movement as expression and transformation

The realm of dance goes beyond a functional, instrumental view of movement and sees the body as an expressive force that can move through space and time (Sheets-Johnstone, 1966; Laban, 1971; Bartenieff and Lewis, 1980; Fraleigh, 1987, 1999; Blom and Chaplin, 1988). In dance the focus is on the aesthetic, expressive and transformative qualities of movement. Sondra Horton Fraleigh (1987, p.49) provides a definition of dance as "human movement created and expressed for an aesthetic purpose", where aesthetic means 'affectively vital' and implies receptivity by an audience.

> When dance is valued as art, it engages us in the vital qualities of its medium—the vital qualities of the lived body. On a primal level, dance expresses and is experienced through the vital body—through movement, not words. Thus it does not necessarily express (or represent) literal emotions or feelings, although it can. It is, however, necessarily rooted in human feeling and founded in kinesthetic sensitivity and intelligence. (Fraleigh, 1987, p.47)

Exploring the moving body in dance is a deeper inquiry into the possibilities of expressive movement that is of a heightened form compared to the everyday. In dance the expressive element is not necessarily self-expression, but a more universal "extension of the expressive condition of the human body" (Fraleigh, 1987, p.28). The consciousness and imagination that one brings to the moving body yields possibilities of transformative experience.

> But a dance does not necessarily call for interpretation in words; it exists as a site for a wordless (yet poetic) communion. The power for communion resides in the human body, which exhibits an expressive condition in its motion and in its stillness. We are drawn to dance because it transports us beyond the literal word and into the body's poetry. (Fraleigh, 1987, p.74)

The dancer and ethnographer, Sally Ann Ness (1992) describes the transformative nature of learning and acquiring a new dance, a new choreography.

The mastery of a choreographed movement involves a neuromuscular repatterning that fundamentally reconstitutes our sense of self and brings new insights into who we are.

Dance works with the moving body as a creative medium, shifting between the literal and the abstract. Blom and Chaplin (1988, p.25) define *abstracting* as eliminating the particulars "that tie us to everyday behaviors and responses" and that "makes the resultant movement closer to the universal experience that claims us all." Examples of abstracting include translating concrete images to movement, creating movement metaphors for symbols and verbal instructions and manipulating a motif designed from a gesture. "At higher levels of abstraction, the medium itself becomes more pronounced and active, creating its own sense and syntax, its own magic." (Blom and Chaplin, 1988, p.27).

Butoh, a Japanese dance form, also known as "dance of darkness", works with the primal, organic body, exploring states of being through transformative imagery in the body and through a meditative, disruptive relation to time. It also unmasks the culturally mannered body.

> Butoh is most of all a process of finding expression, a primal body utterance. Its cathartic field is composed of gestural images rising to form out of the subconscious in whatever sublime or awkward manner they take. (Fraleigh, 1999, p.34)

Understanding the moving body as a creative and expressive medium can provide designers with new insights into the potential uses and experience of human movement with interactive technologies. In order to design for new kinds of movement-based interactions, designers can also draw on the creative potential of the moving body within their own design practices.

3.2.3 Movement as perception

A detailed account of the role of movement in perception, as argued by Merleau-Ponty and Sheets-Johnstone, was given previously in section 3.1. Gibson (1986) proposes a complementary view in his ecological approach to visual perception. He radically re-conceptualises vision as a *perceptual* *system* composed of a *moveable* eye-head-brain-body complex, in contrast to the then orthodox theory of the retinal image. He describes the centrality of movement in the act of visual perception, where locomotion, head-turning, eyeball movements and tiny, continuous adjustments to the lens, retina and related optical anatomy work in the service of perceiving and exploring the environment. Perception of self and of environment go hand-in-hand.

In the field of somatics[3], an integrative approach to the moving body known as Body-Mind Centering (BMC), developed by Bonnie Bainbridge Cohen (1993), views movement as instrumental to how we perceive the world. It is through the sensing and feeling aspects of movement that we develop through life and participate in life with others. BMC works with direct experience of evolutionary movement patterns that form the basis of growth and perception (Cohen, 1993; Hartley, 1995). Moshe Feldenkrais (1972) and Thomas Hanna (1988) promote the cultivation of sensory awareness through movement for integrating physical and mental development.

Keleman (1985), in *Emotional Anatomy*, views the body as a fluid expression of our emotional state and history. He describes anatomy as "a kinetic morphology, the shapes of human process extended over time. It is a pattern of feeling, a state of tissue." (Keleman, 1985, p.58). He conceives of the patterns of expansion and contraction at all levels of the human organism from cell outwards as organising basic perception and cognition.

In relation to interaction design, an awareness of the interplay and intertwining between body and mind, action and perception broadens the significance of movements selected for interaction and the forms of bodily engagement enabled by particular technology design decisions. The types of movement and the forms of bodily engagement that are encouraged or allowed for interaction have a corresponding impact on the kinds of experiences we might have in computer-mediated environments.

[3]soma: the study of the experienced body as opposed to the objectified body, coined by Thomas Hanna (1988)

3.2.4 Movement as felt, kinaesthetic experience

The kinasthetic sense is recognised as crucial to the experience, performance and training of the body in dance and movement improvisation. As discussed in section 3.1, Sheets-Johnstone (1999a) explicates the primary role of the kinaesthetic sense in our perception of self-movement. Kinaesthetic awareness is defined by Blom and Chaplin (1988) as contributing to the experiential body of knowledge in the practice of dance or movement improvisation. They describe kinaesthetic awareness as a primary perception and self-awareness of the body in motion. The body's proprioceptive system judges "spatial parameters, distances, sizes; monitors the positions of the parts of the body; and stores information about laterality, gravity, verticality, balance, tensions, movement dynamics" (Blom and Chaplin, 1988, p.18). The awareness of the experience of movement grows through repetition and experience. Paying attention to and experimenting with different combinations of movement parameters through movement improvisation, leads to increased sensitivity to felt sensations and to increased ability to produce and direct movement with greater subtlety and range.

Sheets-Johnstone describes four primary qualitative structures that are present in all movement and define a spatio-temporal-energic dynamic. These are identified as tensional, linear, amplitudinal (areal) and projectional qualities. In *The Primacy of Movement*, she states, "These qualitative aspects of movement are of course separable only reflectively, that is, analytically, after the fact; experientially, they are all of a piece in the global qualitatively felt dynamic phenomenon of self-movement." (Sheets-Johnstone, 1999a, p.143).

She defines each qualitative structure as follows:

- tensional quality—our felt effort in moving
- linear quality—felt linear contour of our moving body and the linear paths we describe in the process of moving
- amplitudinal quality—felt expansiveness or contractiveness of our moving body and the spatial extensiveness or constrictedness of our movement

- projectional quality—the manner in which we release force or energy, e.g., in a sustained, explosive or punctuated manner

In another work, she proposes that the intimate relation between emotion and movement is grounded in the congruency of their qualitative dynamics, where affective feelings and tactile-kinaesthetic feelings are experientially intertwined (Sheets-Johnstone, 1999b). Her example of the emotion, *fear* illustrates the resonance between the dynamics of fear and the associated kinetic dynamic: “its felt urgency, clutchedness, stops and starts, desire for escape” (Sheets-Johnstone, 1999b, p.270).

Sheets-Johnstone’s four qualitative structures of movement are reminiscent of the Effort-Shape description in the Laban system of movement analysis, although a direct mapping is not easily made or necessarily warranted between the two systems. Laban (1971) also speaks of psychosomatic experience in his description of movement sensations as significant in expressive movement. The Laban system is described in detail in section 3.4.

In movement-based interaction design, designers need ways of developing understandings of the moving body based on an attendance to the felt experience of movement. As outlined above, there are a range of ways of attending to and describing the felt experience of movement that can provide designers with a language and skill in articulating the felt, kinaesthetic aspects of movement.

3.2.5 Movement as a communicative act

The discipline of anthropology treats the moving body as invested with communicative significance. Farnell (1999) presents a contemporary overview of anthropology’s current inquiry into human movement that now conceptualises body movement as dynamically embodied action in semantically rich spaces. The production and negotiation of meaning between people occurs through bodily movements that have specific meaning arising from the local context and situation. Reed (1998) provides a review of dance and studies of human movement, focusing on the relations between body, movement and culture and the meanings in patterned and structured movement systems.

Adrienne Kaeppler and Drid Williams both drew inspiration from various schools of linguistic analysis to develop their respective systems of understanding and analysing human movement. Kaeppler (1978) applied the concepts of kinemes[4] and their combinations into morphokines (analogous to phonemes and morphemes in linguistics) to the analysis of dance structure. Williams (1991, 1995) created a human semiotics of action called *semasiology*, in which human movement is considered as *action signs* rather than behaviour. "The action is thus described as a socially and semantically-laden action that is part of a prescribed social set of actions that are rule-governed and language-based." (Williams, 1991, p.182). Movements become action signs when they are employed as signs and symbols to some person(s).

Goodwin (2000) proposes a view of action that is built through the visible, public deployment of multiple semiotic fields that mutually elaborate each other. *Semiotic field* refers to the way signs are deployed within an encompassing medium. He focuses on semiotic fields for spoken language, gesture, posture and bodily orientation. He describes a *participation framework* which is built and sustained through the visible embodied actions of the participants.

Ness (1992) introduces a category of *choreographic phenomena* for identifying and describing patterned body movements from an anthropological perspective. Dance and other structured movement systems often involve conventionalised patterns of movement with particular relationships to space and time. Williams (1991) speaks of the syntax and grammar of dance idioms. These movement idioms usually take place in a structured space that has semantic significance. Williams (1991, p.280, original emphasis) states that "the space *internal to* a rite of a Mass can be shown to be different from the space *internal to* a football game." The priest performs a pattern of codified movement that has specific meaning for the ritual of the mass. Ritual movements tend to emphasise the rhythmic and symbolic aspects of movement. In comparison, the football player tends to perform a series of set moves but in a much more improvised fashion according to the contingent

[4]Kaeppler's usage of the term *kineme* is different from that of Birdwhistell—see section 3.3.1.

action of the game.

In relation to my research, interactive, immersive environments delineate spaces for the development and practice of structured movement systems. The meaning arising from these systems needs to be considered in the design of these environments. Do movement idioms emerge out of these environments or do they need to be explicitly designed?

Gesture

The complex relationship between gesture and spoken language is dissected in a range of ways by McNeill (1992), Kendon (1997) and Roth (2002). McNeill (1992) presents a taxonomy of gestures, where gestures are conceived as spontaneous creations of individual speakers and reveal the imagery of language. Categories of gesture include imagistic—iconic and metaphoric—and non-imagistic—deictic and beats.

Kendon (1997), in his review of gesture, focuses on the communicative and semiotic aspects of gesture, ignoring what he sees as less communicatively intentional forms of body movement such as posture shifts, self-touchings and incidental object manipulations. He examines how gesture and speech are inextricably linked as part of a single process, where gesture is often used to reinforce or specify linguistic expression. Kendon (1997, p.118) describes gesture as “useful both for conspicuous display and for inconspicuous communication, for communicating at a distance and when noise levels are high.” His observations of work-setting gesture systems suggested that they exhibit a limited character—the form of the gestures and their meaning have emerged out of the particularities of the work setting and are generally not used outside that setting.

Roth (2002) has explored the relationship between gesture and spoken language, positing that the emergence of discourse is supported and preceded by gesture. His studies on the development of scientific language by school children indicate that their initial explorations through object manipulation (ergotic movements) and sensing of materials (epistemic movements) evolve into iconic gestures (symbolic movements) that then support the emergence of discourse where abstract concepts can be discussed.

Gestures also play a larger role in human activity than just one of communication. An alternative view of gesture as a form of embodied knowing in the hand is offered by Goodwin (1997). He describes this in his study of chemists learning to discriminate the colours of black in the preparation of a fibre.

> The gestures performed here reveal a way of knowing that flows in the opposite direction, from the hand as a sensory actor alive to the ad hoc sensations it encounters as it works with external materials, to theories about how those sensations are relevant to the accomplishment of the activities in progress. The gesture points not to some hidden image lodged within the speaker's brain, but instead to the hand as an agent of experience in its own right encountering specific phenomena in the world it is working within." (Goodwin, 1997, p.18)

Brereton et al. (2003) also view gesture as having a broader definition than purely communicative. They generated a set of Gesture Themes from an analysis of a range of work practices. The purpose of the Gesture Themes is to identify typical roles that gestures play in activity, prior to designing new gesture-based tools. The five Gesture Themes are (1) Commanding Gestures, (2) Preparatory Gestures, (3) Gestures as Placeholders, (4) Shared Tools, Shared Workspace and (5) Mirroring Gestures.

An understanding of movement as gesture in the broadest sense reveals the multiple roles of gesture in human activity. Movements of the body can play a gestural role in interaction with machines, as well as other people. The discrimination of movements for use in gestural input to interactive systems continues to challenge designers, particularly for interactive, immersive spaces involving multiple users. Wei (2002) addresses this issue by proposing gesture as embodied, a-linguistic experience in his work with responsive media spaces, for example *TGarden*. Here gesture is seen as a subjectifying act of creation, rather than intersubjective signification. The *TGarden* provides a space for the performance of gesture by multiple participants "that can be improvised continuously relative to an open, dense topology of gesture." (Wei, 2002, p.471)

3.2.6 Summary—Understandings of the moving body

The conceptions of movement presented above illustrate the many and varied understandings and conceptualisations of the moving body that I consider most pertinent to the field of movement-based interaction design. When human movement is the direct input to interactive systems and spaces, the moving body must be considered from a manifold of perspectives—the potential for movement as dictated by the anatomy of the body, the felt experience of movement, the sensing and feeling aspects of movement in perception and cognition, the expressive and choreographic aspects of movement, the temporal and spatial patterning and the meaning, intent and communicative power in movement. In this way, designers can assess the implications of their design choices for the quality of the lived experience of active, moving users.

3.3 Analysing and describing movement

This section discusses the literature on describing and analysing movement in space and time, from the social sciences, dance and the computer vision community. Each different system of analysis is founded on its own conceptualisation of the body in motion. These differing conceptualisations give rise to different forms of representing movement. Existing forms of representing human movement are examined, particularly the use of movement/dance notations. One particular system of movement analysis and notation used extensively in this thesis, Laban movement analysis and Labanotation, is described in detail in section 3.4.

3.3.1 People analysing and describing movement

Several systems have been developed for analysing and describing human movement. They each exhibit different foci on the body in motion, from a focus on the changing patterns of motion in the body to a focus on the moving body embedded in social and spatial interaction. A questioning of the relationship between movement and meaning underlies the different ways of analysing and describing movement.

Analysing movement as social interaction

Anthropologists such as Birdwhistell, Hall and Goffman are renowned for their work on analysing human movement as non-verbal communication. Birdwhistell (1970) developed his theory of human movement known as kinesics. Inspired by structural linguistics and its units of phonemes and morphemes[5] of spoken language, kinesics is an attempt to analyse visible bodily motion into movement units known as *kinemes* that represent the smallest communicative element. The types of body motion found to be used for non-verbal communication include hand, leg and torso movements, posture and weight shifts, gaze shifts, head nods and facial expressions. Daly (1988, p.45), however, suggests that kinesics is not useful for analysing the through-time phenomenon of movement, as "Its roots in the unit-and-structure technique of structural linguistics tends to impose on movement an inappropriately static framework."

Hall's proxemics is a theory of spatial interaction that recognises how culture influences our perception and use of space for communication. Hall (1968) contends that people experience space differently according to the culturally influenced patterning of the senses and selective attention and inattention to specific aspects of the environment. He also includes in his analysis the influences of the various senses, emotions and relationships between people. He distinguishes four categories of intimate, personal, social-consultive and public space.

Goffman (1959) proposed an elaborate theory of social interaction using a theatrical and dramaturgical metaphor, where each interactor performs a role in a routine that is contingently fostered by those involved. To quote Goffman (1959, p.30),

[5]Phoneme—A phonological unit of language that cannot be analysed into smaller linear units and that in any particular language is realized in non-contrastive variants; phonetic elements of a given word. Morpheme—significant elements of a word, be they root, suffix, prefix, inflection or aught else; A minimal and indivisible morphological unit that cannot be analysed into smaller units. Oxford English Dictionary http://dictionary.oed.com

> While in the presence of others, the individual typically infuses his activity with signs which dramatically highlight and portray confirmatory facts that might otherwise remain unapparent or obscure. For if the individual's activity is to become significant to others, he must mobilize his activity so that it will express *during the interaction* what he wishes to convey.

The views of spatial and social interaction, by Hall and Goffman respectively, are potentially useful for observing and describing people moving and interacting in immersive environments, as they provide frames for analysing the movements of people in relation to each other and their environment. More recently researchers in interaction and conversation analysis (Lehn et al., 2001; Heath et al., 2002; Hindmarsh et al., 2005) and museum visitor studies (Fernández and Benlloch, 2000) have contributed to theories of social and spatial interaction concerned with the perception and experience of interactive artworks or museum exhibits. They have shown that people's experience and perception of an exhibit is fundamentally shaped by and through social interaction with others in the same space. The aspects of social interaction included how visitors collaborate and coordinate activity, have sensitivity to others' presence and orientation, encourage or discourage participation, continually monitor the environment and maintain peripheral awareness of and align their activities to the conduct and performance of others, be they companions or strangers. These aspects of social interaction were relevant to the second project, Bystander, as it involved multiple visitors inhabiting the immersive environment of an interactive artwork.

The psychotherapist, Scheflen (1974) contributed significant insights into understanding nonverbal communication and the relationship between movement and meaning. He asserted that behaviour can have many simultaneously different and sometimes contradictory kinds of meanings. He outlined four types of meaning: (1) denotative references, (2) the meaning derived from the immediate context of the interaction or transaction, (3) the cultural origins and personality of the speaker and (4) meta-acts that comment on and qualify one's own behaviour. Daly (1988), in her review of movement analysis, outlines three principles for understanding the relation between

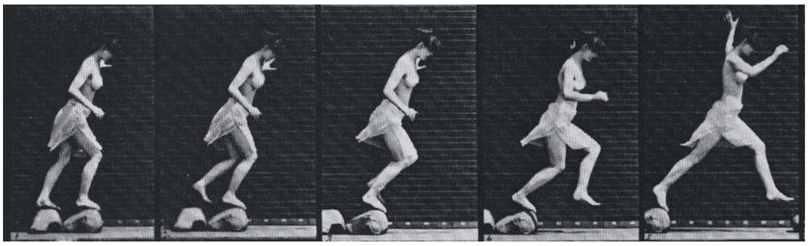

Figure 3.1 Frame by frame motion analysis by Muybridge, first published in 1887

meaning and movement: (1) behaviour is a patterned system, (2) all behaviour in an interaction is seen as functioning in its structure and therefore as contributing to meaning as well and (3) meaning is created by the relationships between behaviour and its many layers of context. She points out that the question of the meaning in movement "involves not just the phenomenon itself but also the observer as active meaning-maker." (Daly, 1988, p.45).

Analysing movement using images and video

An early form of movement analysis developed by Muybridge in 1887 involved the use of sequences of photographic stills. He created a large archive of photographic documentation of what he called human locomotion—sequences of split-second images of people performing actions ranging from stooping for a cup to dancing and dressing (Muybridge, 1984). Figure 3.1 depicts a woman jumping over stepping stones. His work was the forerunner for contemporary methods of movement analysis dominated by use of the video camera (Farnell, 1999).

Jacob Buur and fellow researchers have developed a range of techniques for working with video as a design material in participatory design (Buur and Soendergaard, 2000; Buur, Binder, and Brandt, 2000; Brereton et al., 2003; Buur et al., 2004; Jensen et al., 2005). Not all the techniques focus explicitly on movement, but they all provide means of retaining links to the dynamic, temporal nature of human action and movement. The *Video Card Game* technique involves turning video into tangible arguments, by representing significant sequences of video data (from field studies, situated interviews, user workshops, usability evaluations) with keyframes on a physical card (Buur and Soendergaard, 2000). The technique aims to encourage designers and developers to make the use of video data an integral part of design work, by appropriating the artefacts and finding relevance in and ownership of them. It is a form of collaborative video editing suitable for novice video analysers.

In Buur et al. (2000), they construct a series of video artefacts from the raw video footage of work practice: video portraits, small thematic videos and type scenarios. The *video portraits* are an attempt to capture the "landscape, the places and the kind of awareness that seemed to be associated with being there." (Buur et al., 2000). The raw footage is analysed for themes and short fragments of interesting footage are assembled into *small thematic videos*. The final kind of video artefact is the *type scenario*. It is a small episodic video that provides a story of practice, encapsulating the issues pertinent to the design work. The scenarios provide "a recognisable and negotiable ground for explorations" of how things might be different (Buur et al., 2000).

The *Video Action Wall* technique involves construction of a mosaic of looped video clips of user actions (Buur et al., 2004). The idea is then to group actions according to perceived qualities of action, by moving the video clips around and positioning like clips closer together. It enables comparison of and conveys temporal, dynamic aspects of physical actions—that is, qualities of movement. Buur et al. (2004) point out the difficulties design students encountered with identifying and naming the *qualities* of the actions, rather than the actions themselves. In the work of Jensen et al. (2005), they found that the use of metaphoric and poetic expressions for describing the movement aspects of physical actions enabled designers to grasp more readily the distinctive character and quality of the movements and physical actions.

Jordan and Henderson (1995, p.39) define the practice of Interaction Analysis in their survey of the field as,

> an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment. It investigates human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying

> routine practices and problems and the resources for their solution. Its roots lie in ethnography (especially participant observation), sociolinguistics, ethnomethodology, conversation analysis, kinesics, proxemics, and ethology.

The viewing, editing and transcribing of video data is crucial to the practice of Interaction Analysis. Video recordings enable the close examination of "the temporal organization of moment-to-moment, real-time interaction." (Jordan and Henderson, 1995, p.23). They identify a set of ways of looking at video data defined as *analytic foci*—these include the structure of events (beginnings and endings, segmentation), the temporal organisation of activity (the macro level, rhythm and periodicity), turn-taking, participation structures, trouble and repair, the spatial organisation of human activity and artefacts and documents. Depending on the analytic foci of interest, more or less description of the bodily movements of people will be made in relation to temporal, spatial, social and artefactual characteristics of the interactions.

Kirk, Crabtree, and Rodden (2005) conducted an analysis of the nature and role of gestural action in the performance of a remote collaborative physical task. Their focus is on the bodily practices that participants engage in to mediate interaction and highlight objects for perception, as part of cooperative activity. They approach the analysis of the video data with a concern to understand the 'stroke of gestural phrases'. That is, to describe "particular patterns of gestural phrase and the business or work that they do" (Kirk et al., 2005). They identified a corpus of *gestural phrases* that promote awareness in a mixed reality ecology, where virtual and physical objects are integrated into the same shared workspace.

The analysis of human movement can be undertaken from many different perspectives. The approaches surveyed above focus on movement in its social and cultural contexts, the meanings in patterns of movement and the temporal and spatial qualities of active, moving bodies. The movements of the body can be understood in relation to the body itself as well as in relation to the wider social and cultural contexts. Designers of movement-based interaction need to be able to understand and analyse the moving body from these multiple perspectives, in order to appreciate the implications of design choices made in relation to the movements of people as direct input to interactive systems.

3.3.2 Movement notations

Movement notation is the translation of four-dimensional (three dimensions of space plus time) movements into signs written on two-dimensional paper. Each system of movement notation assumes an underlying system of analysing movement, a way of conceptualising the body-in-motion. Anne Hutchinson Guest is one of the leading scholars on the history and contemporary practice of dance notation. She provides an in-depth discussion of the historical development of notation styles from the eighteenth century onwards, covering twenty-two different styles of notation (Guest, 1984, 1989). Feuillet is credited with publishing the first dance notation system in 1700. An illustration of a score by Feuillet is presented in Figure 3.2. Contemporary notation systems for documenting dance choreography include Labanotation, Benesh and Eshkol-Wachmann. Labanotation and its system of movement analysis are presented in detail in section 3.4.

Benesh was devised for recording ballet scores and uses a visual representation of the body derived from a stick figure. What is innovative about the Benesh system is the drawing not of the stick figure itself, but the plotting of the position and movements of key points in the body (the extremities and centre joints of the limbs). A matrix of five horizontal lines is used to represent the human figure, with the top line representing the head and the bottom line representing the foot. The symbols are drawn on a music-like staff. A picture of the Benesh staff is given in Figure 3.3. The principle of notating in the Benesh system is one of simplicity; it relies on the comprehension of the language of a particular dance style. A step-hop-hop pattern of movement is illustrated in Figure 3.4 using the Benesh system.

The Eshkol-Wachmann system is based on a mathematical and logical approach to movement. The movements of the body are taken to be circular in nature, as dictated by the structure of the joints of the body. This is illustrated for the conical movements of the limb in Figure 3.5. Movement is

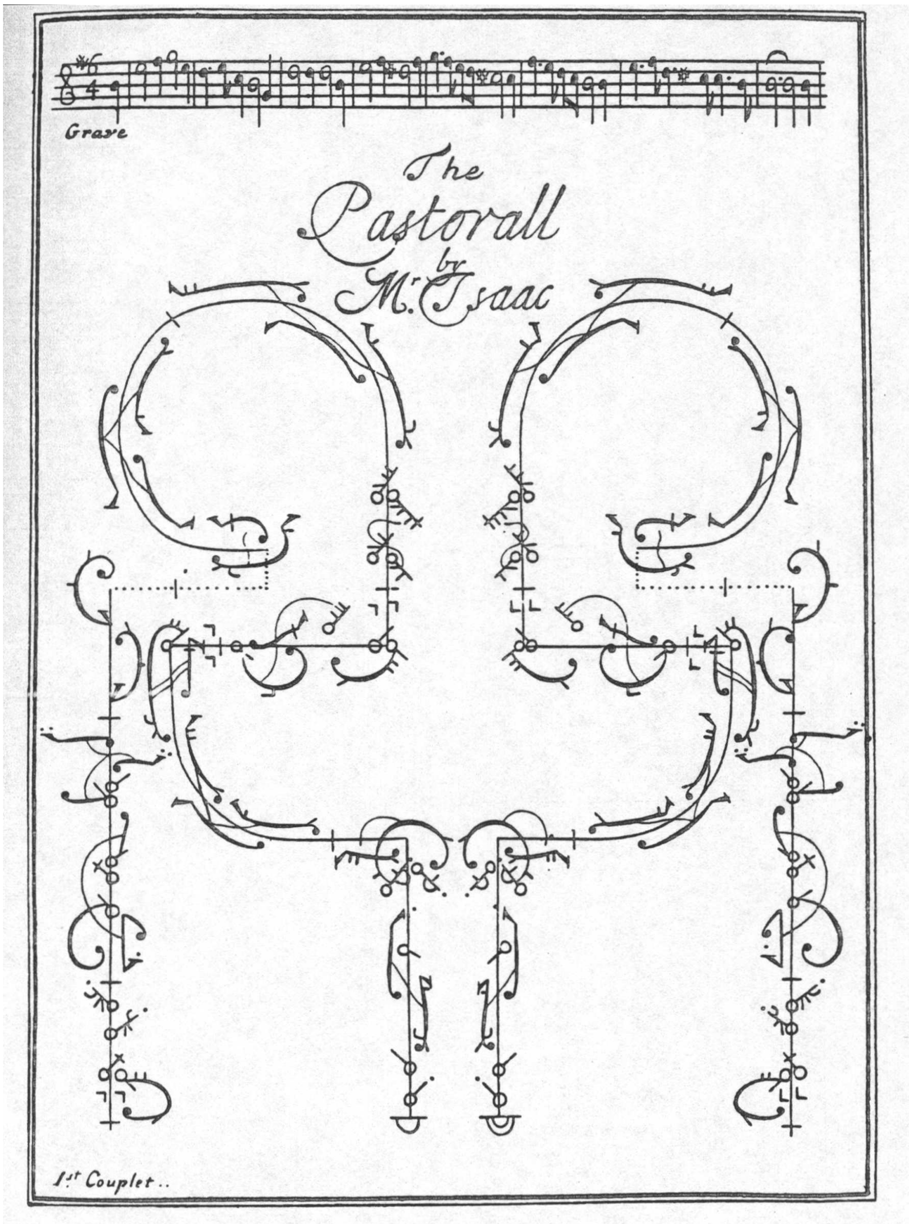

Figure 3.2 An example of a dance notated in the Feuillet system of movement notation, 1700. The spatial arrangements or floor plans are overlaid with notational symbols for moving bodies. Reproduced from the original publication by Guest, 1984.

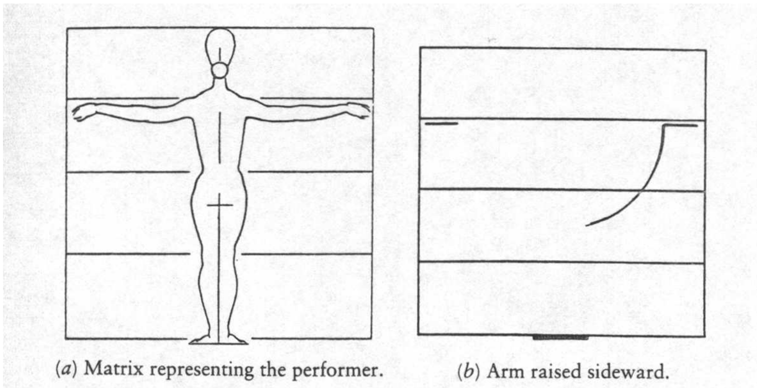

Figure 3.3 The Benesh staff. Reproduced from the original publication by Guest, 1984.

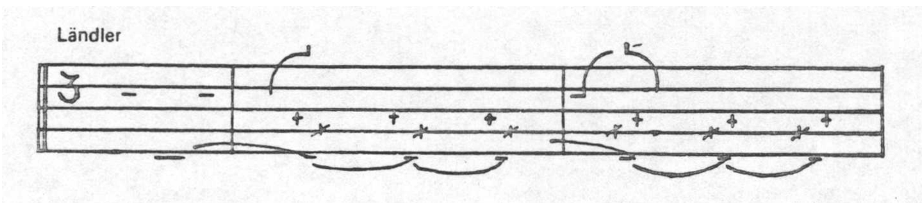

Figure 3.4 A step-hop-hop pattern of movement notated using the Benesh system. Reproduced from the original publication by Guest, 1984.

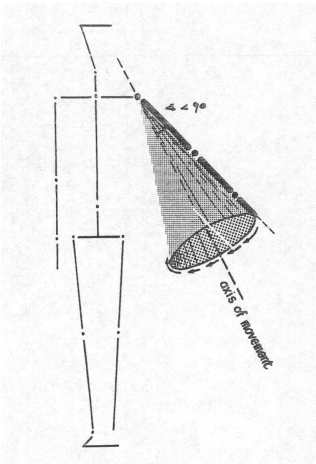

Figure 3.5 A depiction of the axis of conical movement in the Eshkol-Wachmann system. Reproduced from the original publication by Guest, 1984.

described using a system of coordinates to indicate the transition from one point to another, to indicate the character of the path, the sense and amount of movement and the statement of the position of the axis of the limb and axis of the movement. The Eshkol-Wachmann system is concerned only with the changes which take place in the body's configuration. Human expression or motivation is absent from the notation. It has also been applied to the analysis of animal movements. A score for the dance piece, *Diminishing Series* is presented in Figure 3.6.

Guest outlines a comprehensive set of requirements and criteria desirable in a system of movement notation (Guest, 1984, p.189–197). The criteria include universality, comprehensiveness, movement analysis, versatility in movement description, flexibility in application, logicality, visuality, legibility and practicality. The system of movement notation must be able to describe characteristics and components of movement such as the body, space, basic actions, weight, design, degree, relationship to the environment, timing, initiation of movement, dynamics, stage location, group indications, interpretation specified and technical indications.

The process of notating movement is contingent upon the needs of the analysis or documentation of movement—what is to be made visible and what is tacit or left out—and the skills of the notator. "Two notators often describe

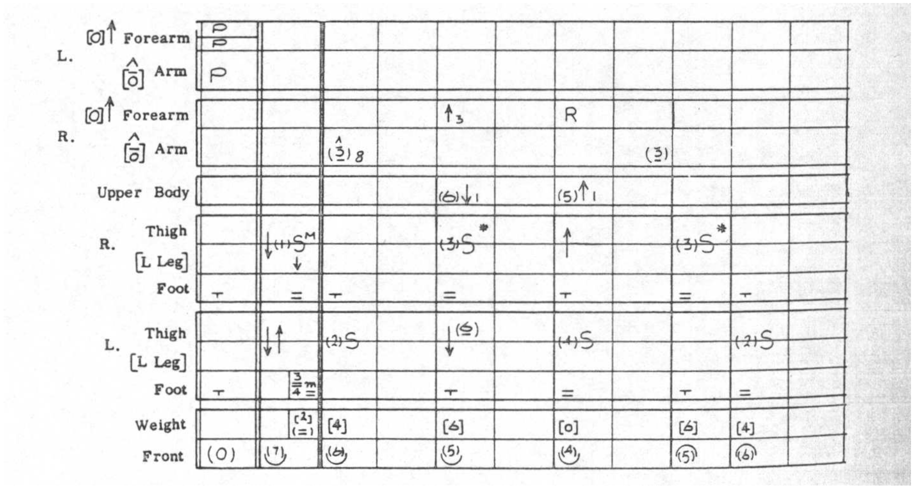

Figure 3.6 A score for the dance piece, *Diminishing Series*, notated using the Eshkol-Wachmann system. The score is read from left to right. Reproduced from the original publication by Guest, 1984.

the same movement differently. What they 'see' in the movement and how they choose to describe it is a direct result of their movement education." (Guest, 1984, p.3).

Bartenieff, Hackney, Jones, van Zile, and Wolz (1984) present their experiences of using Laban movement analysis and notation as a research tool in studying dance. They describe their methodological approach as well as the results of their analysis and notation work. They developed and worked with a range of different representations during their analysis of a particular dance form. These representations included a choreographic outline, summary images, notated scores (for example, Labanotation, Effort-Shape notation, Space Harmony notation) and integrated scores. The *choreographic outline* represents delineations of the major phrases and the outstanding features of each phrase. It is presented as a table composed of distinct sections of the dance. Each section of movement is described firstly as a subjective description of what is happening and secondly as a summary image. A *summary image* expresses the overall feeling or most striking feature of the movement section. *Integrated scores* combine the choreographic outline with the various types of notated scores. An example of an integrated score is given in Figure 3.7. They found that a tension exists between the descriptive and interpretative styles of individual researchers and the need for a common vocabulary and language for describing observations of movement.

The choice of movement notation for use in movement-based interaction design will reflect the particular needs of the design situation and the aspects of the moving body considered relevant to the design. An overview of Labanotation is given in section 3.4.2, prior to the exploration of the suitability of Labanotation as a design tool in this thesis.

3.3.3 Algorithmic analysis of movement

Research endeavours and design approaches and solutions directed to the use of human movement with technology over the past thirty years have grappled with the technical challenges posed by treating the moving body as input, especially in the area of visual analysis and digital representation of the moving body (Badler and Smoliar, 1979; Gavrila, 1997; Pavlovic, Sharma, and Huang, 1997; Aggarwal and Cai, 1999; Pinhanez, 1999; Camurri, Hashimoto, Ricchetti, Ricci, Suzuki, Trocca, and Volpe, 2000; Camurri, Lagerlof, and Volpe, 2003a; Camurri, Mazzarino, and Volpe, 2003b; Davis and Horaud, 2003; Wang, Hu, and Tan, 2003; Hachimura, Takashina, and Yoshimura, 2005; Sminchisescu, Kanaujia, and Metaxas, 2006). There is a substantial body of work in the area of computer recognition and characterisation of human movement, which relies largely on biometric data and mathematical, statistical models of human movement. *Computer vision* uses video data as input and is concerned with the visual analysis of human movement. It is rooted in algorithmic and computational approaches to the visual analysis of human movement. It aims to recognise human motion at three distinct levels—body parts or gestures, tracking of the whole body and human activities. Recent work has shifted from recognition of low-level motion data to recognition of action, with a focus on the context of human actions (Pinhanez, 1999; Sminchisescu et al., 2006), and recognition of the expressive character of movement (Camurri et al., 2000, 2003a,b; Hachimura et al., 2005).

A host of sensing technologies, besides video-based computer vision, are now available for sensing and recognising human movement, such as data

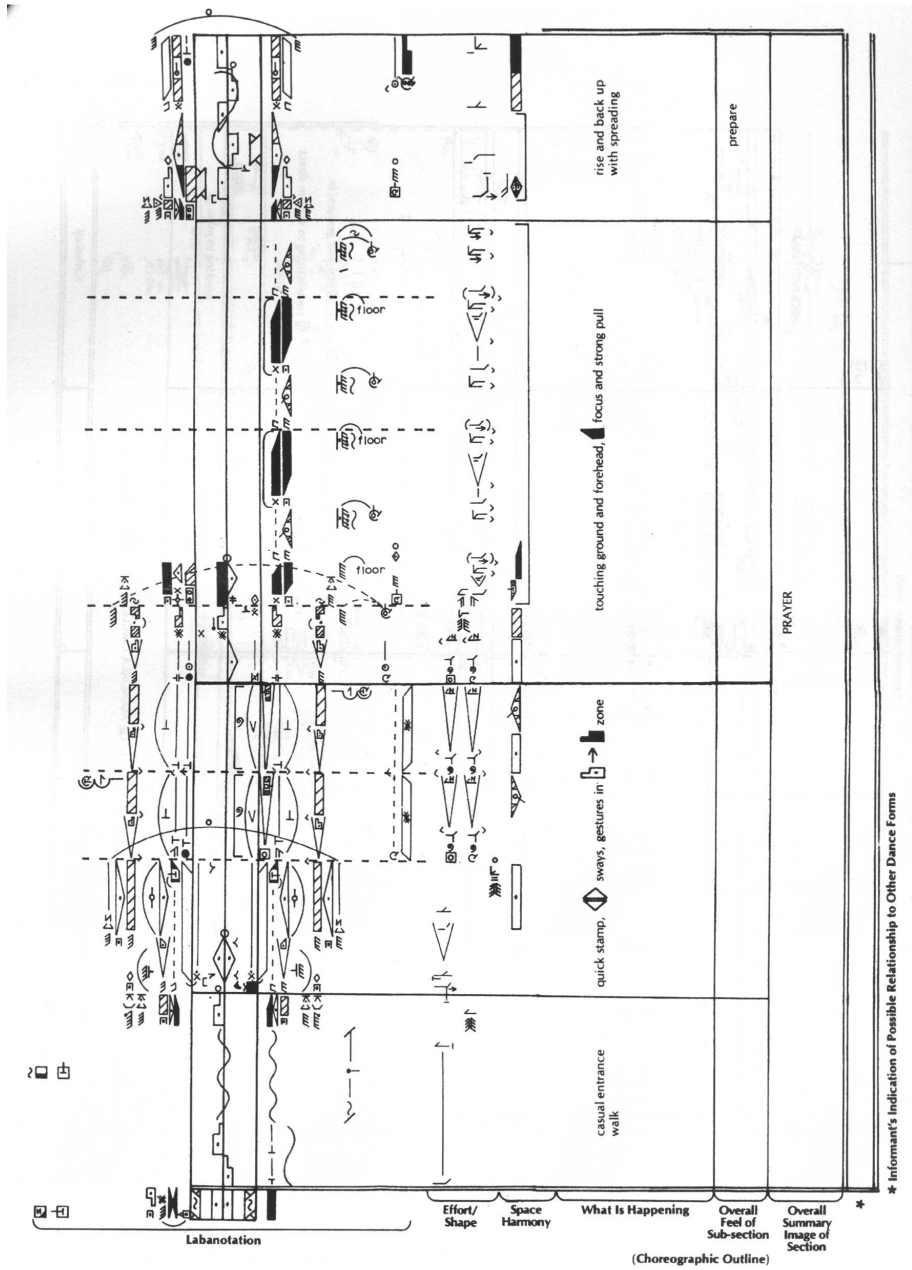

Figure 3.7 An example of an integrated score documenting the movement analysis of a dance from South West India called Cholkettu. Reproduced from the original publication by Bartenieff et al., 1984.

gloves, infra-red sensing, touch or pressure sensitive devices and more recently in the area of ubiquitous computing, the use of mobile phones or radio frequency identification (RFID) tags for detecting movement (Bellotti et al., 2002; Michahelles and Schiele, 2003; Rogers and Muller, 2003). The choice of sensor technologies provides constraints on the characteristics of movement that can be sensed and used for interaction.

The research surveyed here has a strong technical focus on devising computational models and algorithmic solutions for recognising, tracking and interpreting human motion. What it lacks though is connection to the lived experience of movement—the prime focus of my thesis. I propose ways of working directly with the experiential, moving body and design methods and tools for linking the human perspective and the machine perspective of the moving body.

3.3.4 Summary—Analysing and describing movement

Approaches to analysing human movement as non-verbal communication, drawn from the social sciences, include Birdwhistell's kinesics, Hall's proxemics, Goffman's theory of social interaction based on a theatrical metaphor and Scheflen's identification of four types of meaning related to behaviour. With these systems of analysis, the moving body is embedded in social and spatial interaction. Dance and movement notations focus on the changing patterns of motion in the body and between bodies, in relation to parameters of space and time. Different systems of movement notations have their own ways of conceptualising the body-in-motion. The same holds for computerised motion analysis and tracking systems—each has different ways of conceptualising and digitally representing the moving body.

A range of techniques for analysing video data, drawn from the practices of participatory design and interaction analysis, enables a close focus on the moving body. My research draws inspiration and guidance from the work of these researchers and seeks to contribute to ways of working with movement analysis and video data.

3.4 Laban movement analysis and Labanotation

> [Movement] has to be experienced and comprehended as an entirety. The urgent advice is given:- *invent short movement sequences, or mime scenes, in which the movements described can be recognised.* This is a means of training not only observation but also movement imagination, and of finding the immediate connection with the practical application of bodily exertion in terms of artistic expression. (Laban, 1971, p.27, original emphasis)

One of the strands of investigation in this research has been the suitability of Laban's system of movement analysis and notation to this area of movement-based interaction design. Traditionally Laban movement analysis (LMA) and Labanotation have been used in dance and movement observation for observing and recording both natural and choreographed movement and for exploring movement. They continue to be used in fields traditionally associated with the physical body, such as dance choreography (Guest, 1984), physical therapy (Bartenieff and Lewis, 1980) and drama (Newlove, 1993), and have also been applied in anthropology (Lewis, 1995; Farnell, 1999). Since the late 1970's, Laban movement theory has been applied to various fields of computing, such as human-computer interaction, computer animation and artificial intelligence (see section 3.4.3).

LMA is a system and language for observing, describing and analysing all forms of human movement. It was originally developed by Rudolf Laban (1971) in the 1920's and extended primarily by Knust (see Guest, 1984), Hutchinson (1977), Lamb and Watson (1979) and Bartenieff and Lewis (1980). It offers a vocabulary for describing the structural and physical characteristics of the moving body, the use of space and the dynamic, qualitative and expressive aspects of movement. Labanotation is the companion system of recording movement using symbolic notation, originally developed as kinetography by Laban (1971) and further developed by Hutchinson (1977) and others at the Dance Notation Bureau, New York. Unlike most other notation systems, Labanotation (and LMA) includes a thorough analysis of the dynamics of movement (Guest, 1984).

3.4.1 Laban movement analysis

There are three essential forms of analysis and description—*Motif*, *Effort-Shape* and *Structural*—which focus on the movement characteristics of an individual body.

Motif is the simplest form of description and describes the salient feature of a movement or its motivation. It is a shorthand way of depicting just the essential aspects of the movement within a specific context. For example, it might describe just the steps taken in ballroom dancing or walking without representing any other aspects of the movement.

Effort-Shape describes the more qualitative and expressive aspects of movement and the inner attitude of the mover. It is concerned with "the changing patterns which occur in the ebb and flow of energy within the body" (Hutchinson, 1977, p.12). For example, in dance choreography this form of description conveys the aesthetic, emotional and expressive qualities of the dance. *Effort* (or the energy content) of a movement is described in motion factors of Weight, Space, Time and Flow; together with how a person engages with or resists each factor. Each factor is represented by two polarities: Weight (Light/Strong), Space (Direct/Indirect), Time (Sudden/Sustained) and Flow (Bound/Free). There are eight basic Effort actions derived from the motion factors of Weight, Space and Time. A diagram of the basic Effort actions is illustrated as an Effort cube, otherwise known as The Dynamosphere (Newlove, 1993), in Figure 3.8. For example, a *Glide* is Light in Weight, Direct in Space and Sustained (i.e., slow) in Time (see top, back, left corner of cube in Figure 3.8). A specific example of a movement with an Effort of *Glide* is ironing a delicate fabric. This type of Effort exhibits a delicacy in relation to Weight. In contrast, ironing out the creases with a firm pressure has an Effort of *Press*, which is strong in relation to the dimension of Weight (see bottom, back, left corner of cube in Figure 3.8).

Laban (1971) defines an Effort element in terms of two components: measurable, objective aspects of Resistance, Speed, Direction and Control; and

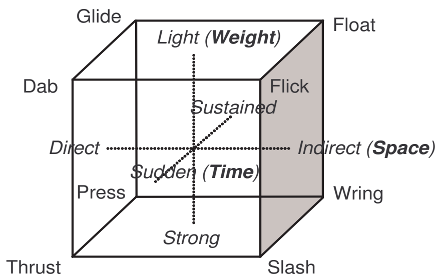

Figure 3.8 Effort Cube

personal and classifiable aspects of Levity, Duration, Expansion and Fluency. The second component relates to the *movement sensation*, that is, qualities of psychosomatic experience. Laban (1971, p.81) describes the significance of movement sensations as,

> While in functional actions the movement sensation is an accompanying factor only, this becomes more prominent in expressive situations where psychosomatic experience is of utmost importance.

A table relating the Measurable and Classifiable Aspects of Effort elements for motion factors of Weight, Time, Space and Flow, is reproduced from his book, *The Mastery of Movement*, in Figure 3.9.

For example, for a Floating effort action, the movement sensation is 'suspended'. In such a movement, the psychosomatic experience of Levity is *light*, as if buoyed aloft, of Duration is *long*, as if existing in everlasting time, and of Expansion is *pliant*, as if crumpled in space.

Shape describes the spatial shaping of form—growing, shrinking or carving patterns in space. It describes the expressiveness inherent in the form of a movement in terms of Shape Flow, Directional Movement and Shaping. The spatial intent of a movement determines the particular spatial shape that is produced as the movement unfolds. For example, the action of pulling a fishing net out of the water has a spatial intent that is directed along a radial line from the centre of the body to the periphery where the hands hold the net. The related spatial shape of the body is one that expands and contracts

Motion factors	**Effort element**: *fighting*	**Effort element**: *yielding*	**Measurable Aspects** (objective function)	**Classifiable Aspects** (movement sensation)
Weight	firm	gentle	Resistance: strong (or lesser degrees to weak)	Levity: light (or lesser degrees to heavy)
Time	sudden	sustained	Speed: quick (or lesser degrees to slow)	Duration: long (or lesser degrees to short)
Space	direct	flexible	Direction: straight (or lesser degrees to wavy)	Expansion: pliant (or lesser degrees to threadlike)
Flow	bound	free	Control: stopping (or lesser degrees to releasing)	Fluency: fluid (or lesser degrees to pausing)

Figure 3.9 Measurable and Classifiable Aspects of Effort elements. Reproduced from *The Mastery of Movement*, Laban (1971)

along the path dictated by the spatial intent as the person repeatedly pulls the net in towards the body (Bartenieff and Lewis, 1980).

The spatial shaping of the body can be analysed in terms of what forms the body makes and the relation of the body to itself and its environment. Shape analysis provides a set of descriptors for dynamic, fluctuating shape characteristics, classified into categories of Shape Form and Shape Quality (other categories exist but have not been used in this research). Shape Form describes the static shapes that the body takes, for example, pin-like, wall-like, ball-like or screw-like. Laban (1971, p.70) defines these four terms in relation to the organisation of parts of the body as (a) spine and its pin-like extension, (b) right-left symmetry of body and its wall-like surface, (c) limbs, together with their respective trunk regions curling and circling in ball-like shapes and (d) shoulder-girdle and pelvis twisted against one another in screw-like fashion.

Shape Quality describes the way the body is changing toward some point in space, for example, opening or closing, indicating the degree of extension or contraction in the body. More specific terms include Rising and Sinking (along the vertical axis of the body), Spreading and Enclosing (along the horizontal axis), and Advancing and Retreating (along the sagittal axis).

Shape analysis was developed primarily by Lamb and Watson (1979). They describe the shaping process as,

> The actual process of variation, which results in a succession of differently sculpted positions, can be described as a sculpturing, or shaping process. If we wish to become more aware of the shape of a person's posture pattern, as he dresses himself, or greets friends at a party, or elbows his way around a store, for example, it helps to imagine that all his joints are emitting vapour trails as though they contained jet engines. (Lamb and Watson, 1979, p.49–50)

They suggest that "effort and shape are the two processes from which movement is created." (Lamb and Watson, 1979, p.81).

Structural provides the fullest and most specific description of movement in clearly defined and measurable terms: the body and its parts, space (direction, level, distance, degree of motion), time (metre and duration) and dynamics (quality or texture, e.g. strong, heavy, elastic, accented, emphasised). The *motivation* for the movement can come from various sources: directional destination, motion, anatomical change, visual design, relationship, centre of weight and balance, dynamics and rhythmic pattern. The *Structural* description is mostly concerned with directional destination as the motivation for movement; that is, where is the body going, where is the movement aimed in space. It forms the basis of the Labanotation.

3.4.2 Labanotation

Labanotation is a movement notation based on LMA, designed for notating movements of an individual body and for group choreography. The notation of movements of an individual body is recorded on a vertical *body staff*. The notation symbols represent change; that is, movement. Labanotation is the only movement notation system that combines the four dimensions of movement (three dimensions of space plus time) into a single symbol. The staff is divided into columns for different body parts—support (typically the legs and the feet), leg gestures, body, arms and head. Movements are understood as either steps or gestures. A step is a movement that involves

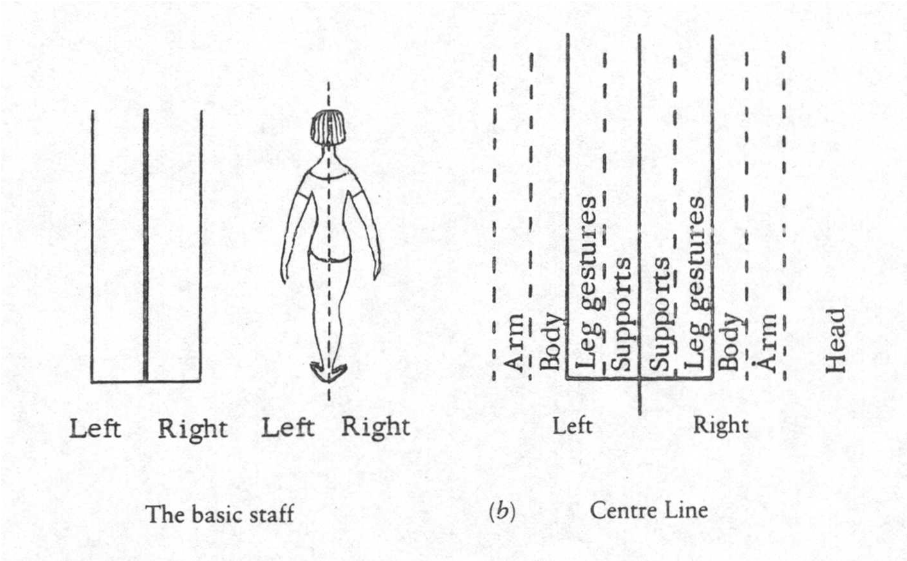

Figure 3.10 The Laban staff. Reproduced from the original publication by Guest, 1984.

a transfer of weight. A gesture is a movement of a part of the body that does not involve a transfer of weight. A diagram of the Laban staff is given in Figure 3.10. An understanding of the model of the body and principles of movement used in Labanotation is required. This model is based on the mechanics of the skeleton and the different degrees of freedom of the various joints and limbs. For example, the arm is connected to the body at the shoulder with a ball and socket joint. This type of joint dictates the available paths of movement of the arm. For arm gestures, the spatial directions and levels originate at the base of the limb, namely the shoulder. The free end, the hand, is at the extremity of the limb. For the arms, a spatial level of High is above the shoulder, Middle is at shoulder height and Low is below the shoulder. The symbols on the body staff below the double line represent the starting position of the body. Any movement is then described as a change from this starting position. Symbols for direction and level of movement in relation to the body are illustrated in Figure 3.11.

The Structural form of Labanotation is read from the bottom to top, with time in the vertical axis. Time can be split into measures (rows in the

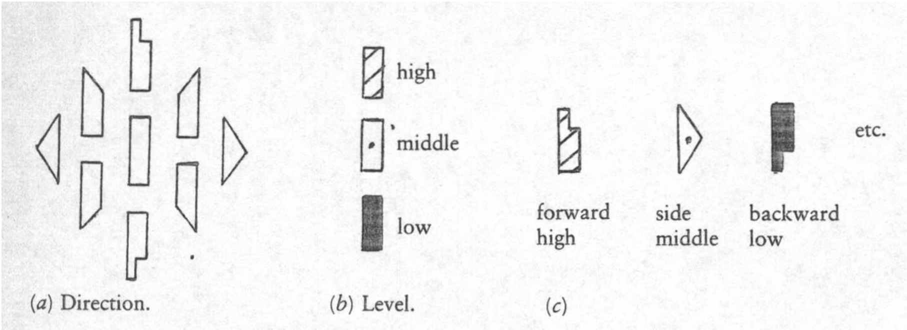

Figure 3.11 Symbols for direction and level of movement in the Laban system. Reproduced from the original publication by Guest, 1984.

diagram), just as in musical scores. The vertical staff represents the body, the centreline being the centreline of the body; the right hand columns represent the right side of the body and likewise for the left. The columns are used for the main parts of the body, such as S—Support, and A—Arm; for example, movements of the arms are written in the 'A' column. Symbols for indicating direction and level of movement in space can be combined and placed in the columns associated with the major body parts. Timing and duration of movement are indicated by the position and length of the symbol. No symbol in a column implies no movement. A wide range of symbols is available to give more detailed information; for example, the degree of contraction of the hand. An example of a notated score for a dance, Balanchine's *Serenade* is given in Figure 3.12.

For group choreography, *floor plans* are used to represent the overall arrangement of moving bodies in space and time. The spatial layout, configuration and trajectories of individual and multiple people can be shown. An example of a floor plan is given in Figure 3.13. This part of the notation is often used in conjunction with the body staff to document both the macro and micro levels of detail of moving bodies in space and time. It was particularly useful in this thesis as it can so easily be extended to represent the social aspects of human activity.

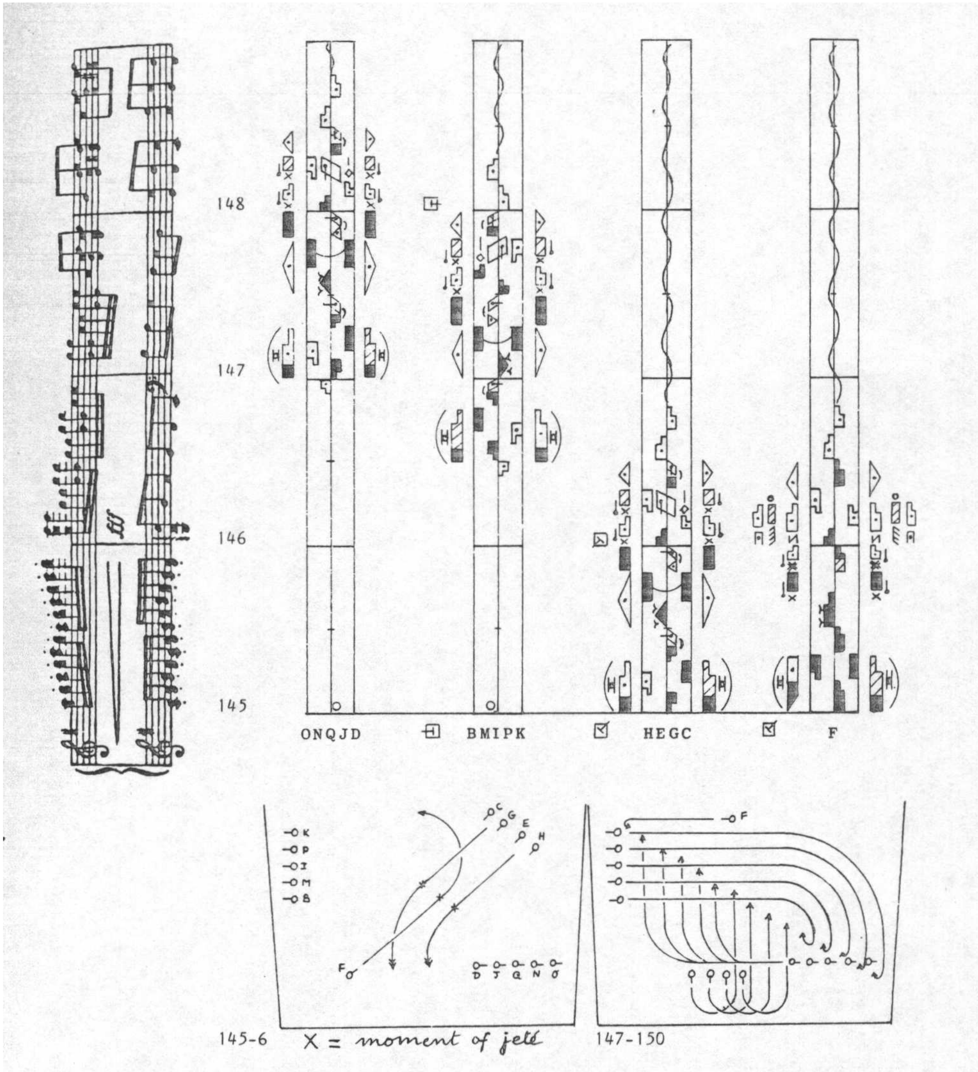

Figure 3.12 An example of a Laban-notated score for a dance, Balanchine's *Serenade*. It includes the Structural description and floor plans and an indication of the timing of the movements with the music. Reproduced from the original publication by Guest, 1984.

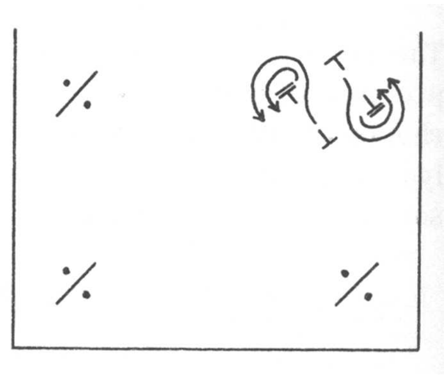

Figure 3.13 An example of a floor plan illustrating the paths of movement for a group of four people in the upper right hand quadrant. Repeat signs indicate that all four groups do the same thing. Reproduced from the original publication by Hutchinson, 1977.

3.4.3 Applications in computing fields

Other researchers in human-computer interaction, computer animation and artificial intelligence have used Labanotation and Laban's theory of movement for *simulation* and *recognition* of movement. Some of the most extensive and early work on simulating movement as part of computer animation, using Labanotation, was done by Badler and Smoliar (1979). They derived a set of "primitive movement concepts" from the model of the body used in Labanotation, to create a realistic computer animation of a human body in movement. This early work has been continued with the development of the EMOTE model—a 3D character animation system that incorporates other elements of Laban's theory such as Effort-Shape parameters in order to produce simulated movement that is more natural and expressive (Badler, Costa, Zhao, and Chi, 2000; Chi, Costa, Zhao, and Badler, 2000). Further examples include animation systems for visualising dance choreography from written notation scores, such as LabanDancer (Calvert, Wilke, Ryman, and Fox, 2005), and for creating virtual avatars (Deray, 2001).

Aspects of Laban's theory are also being used in attempts to extract expressive and emotive qualities from human movement, as part of computerised motion recognition systems. One prime example is *EyesWeb*, a system that recognises gesture and affect from dance movement (Camurri et al., 2000, 2003a). EyesWeb processes the in-coming video stream using algorithms based on Effort-Shape parameters (Camurri et al., 2000). The EyesWeb expressive gesture processing library offers modules for motion, space and trajectory analysis (Camurri et al., 2003b). Researchers in robot-human communication are also investigating the quantification of LMA in order to extract characteristic features of human movement (Hachimura et al., 2005). The use of LMA and Labanotation in this thesis to describe and represent the spatial shaping of the body and spatial trajectories fits well with motion recognition systems like EyesWeb. Schiphorst, Lovell, and Jaffe (2002) have developed a gestural semantics of caress in which qualitative attributes of gesture are expressed as a function of tactility. The implementation of qualitative semantics is based upon Laban's Effort-Shape analysis.

LMA is being used in the conceptual phases of the design of interactive products. Fagerberg, Stahl, and Hook (2003) applied Effort-Shape analysis to the design of gestures for affective input to mobile phones. Jensen (2007) explored using Laban movement qualities first experienced in the body to then inspire the design of objects exhibiting the same qualities. Jensen et al. (2005) and Buur et al. (2004) describe qualities of human actions in terminology from Laban's Effort description. Similar to the approach of these researchers, my thesis investigates the usefulness of LMA and Labanotation as a system and language for describing, representing and reasoning about movement for the design of movement-based interaction. I am also interested in the potential for representations of movement based on LMA to bridge the two perspectives of the moving body, from the lived experience of the human and from the machine.

3.5 Summary—The Moving Body

Understandings of the moving body drawn from other disciplines such as anthropology, dance, phenomenology, physiotherapy and somatics provide designers of movement-based interaction with resources for conceptualising and articulating different aspects of the moving body for potential interaction with technology. Attendance to the felt experience of movement as well as the functional aspects of movement opens up spaces for design of new realms of experience enabled by movement-based interactive technologies and is the motivation for the research into design methods and tools presented in this thesis.

Designers working in this emerging area of movement-based interaction design need ways of analysing, describing and representing human movement. There are many existing systems of movement analysis and notation, drawn from the social sciences, interaction analysis and dance, which can be employed by designers for this purpose. The various systems enable interpretations of movement as functional, expressive and qualitative through to the semantic. Dance and movement notations focus on the changing patterns of motion in the body and between bodies, in relation to parameters of space and time. Movement can be interpreted in the sociocultural frame of patterns of social and spatial interaction between people and the patterns of meaning in structured movement systems. These multiple and different frames of analysis and interpretation enable designers to make deeply informed choices about the kinds of movement performed for interaction and the interactive treatment of those movements.

This thesis examines in detail one specific movement notation, Labanotation as a potential design tool for representing movement and acting as a bridging representation between the movements of people and the interpretation by the machine of those movements as input. It is the only notation system that deals with the dynamic, qualitative aspects of movement, as well as the structural and functional. The Laban system of movement analysis is also explored as a tool for designers to develop bodily understandings of movement based in the terminology of the system and to observe the moving bodies of potential users of interactive technologies.

Chapter 4

Research Methodology

In this chapter, the evolution and composition of the research methodology is described, including a rationale for the choice of research methods.

The research methodology is characterised by an open-ended investigation underpinned by principles of reflective practice (Schön, 1983) and an open and receptive stance to the data and phenomena (van Manen, 1997). In the spirit of reflective practice described by Schön (1983), the research work proceeds with a first move to answering the research questions. The results of this first move are then critically reflected upon in the light of the original research questions to determine the next move. An iterative cycle of action, reflection and revision or refinement drives the research work towards completion. Scrivener and Chapman (2004) outline a similar approach, characterised by reflective practice, recently developed for practice-based research in art and design, where a central component of the research is the making of a creative production.

A high-level schematic of the research design, presented in Figure 4.1, illustrates the role of reflective practice in the research methodology. Core research activities of literature review, data collection, data analysis and trialling of design methods/tools are interwoven with periods of reflection and subsequent revision or refinement of the various research activities and possibly the research questions themselves.

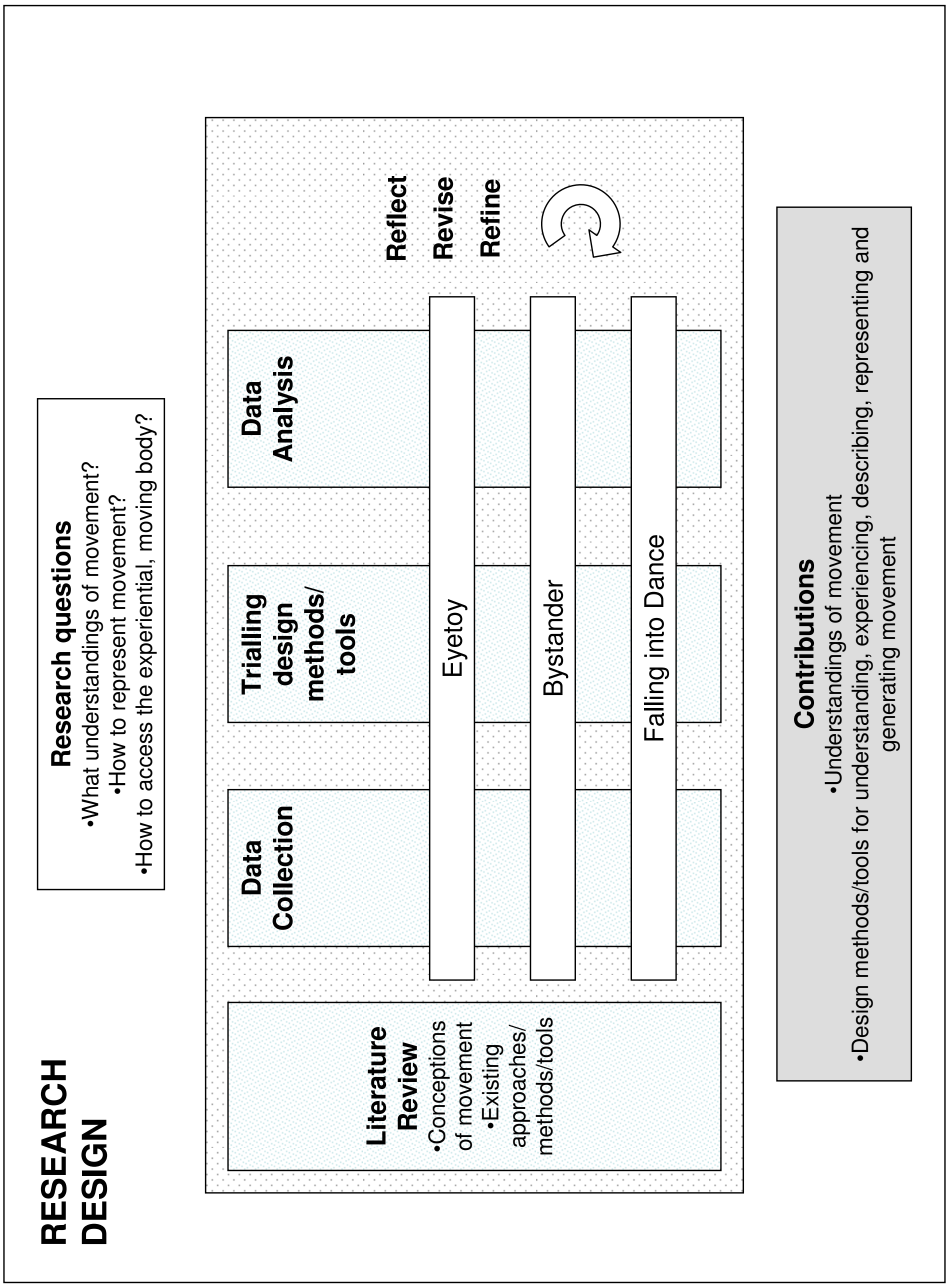

Figure 4.1 Diagram of research design

The research questions were explored through a series of three distinct, yet related, projects. In accordance with the principles of reflective practice, the objectives and structure of the second and third projects were devised in relation to the findings of the preceding projects. The third project, in particular, underwent significant revision during its conduct in order to generate appropriate data addressing the research questions.

The overall aim of the three projects was to identify and trial methods and tools for understanding, describing, representing, experiencing and generating movement in the design of movement-based interaction. Different conceptions of movement are dealt with in each project. A recurring thread of investigation throughout the three projects is the production and use of design representations of human movement. Two notable sources for potential design representations, drawn from other disciplines concerned with human movement and interaction analysis, were repeatedly trialled in each of the three projects as part of this investigation—Laban movement analysis and its companion movement notation system, Labanotation (see section 3.4) and the analytic framework of Suchman (1987, 2007) (see section 2.3). Labanotation was selected because it is the movement notation that has had the furthest reach into other disciplines, including anthropology, HCI and computer vision. It is also the only notation to include the dynamic, qualitative aspects of movement.

The research methodology is also characterised by a phenomenologically-inspired approach to research, where knowledge and theories are grounded in lived experience. The phenomena of interest are the actions and movements of people for potential interaction in interactive, immersive spaces. Research methods aimed at accessing various aspects of these phenomena have been utilised across the three projects. Ethnographically-inspired methods of interviews, passive/participant observation, videotaping and video analysis have been employed to access first-person, experiential understandings of people's movement and activity in different contexts and situations. Research methods drawn from user-centred and participatory design traditions have been utilised including collaborative design sessions with participants, videotaping and video analysis, enactment and the construction and trialling of

Project / Research Method	Eyetoy	Bystander	Falling into Dance
Interview	✔	✔	✔
Observation	✔	✔	✔
Videotaping activity	✔	✔	✔
Video analysis	✔	✔	✔
Construct/trial design method/tool/probe	✔	✔	✔
Enactment	✔	✔	✔
Collaborative design session		✔	✔

Figure 4.2 Summary of research methods used in each project

design methods/tools in real-world projects or constructed design situations. A summary of the research methods employed in each project is presented in Figure 4.2.

4.1 Issues of methodological validity

For this thesis, the question of methodological validity arose with regards to the design representations produced as part of the research. What was an adequate test of validation for a design representation?

The validation under question is not the same kind of validation usually associated with scientifically controlled experiments, where objectivity and repeatability are the criteria for verification of theory and facts (Crotty, 1998). I am drawing instead, on the criterion of 'workability' as defined by the pragmatic philosophers, Rosenthal and Bourgeois (1977). The test of truth for a pragmatist is workability, not coherence—in simple terms, does it stand up to the test of lived experience (or practice). A philosophic understanding or theory may have internal coherence but if it cannot be verified through actual lived experience, then it is not deemed workable and thus is rejected. In the case of design research, workability can be offered as a criterion for the validity of design artefacts, including representations of movement. This validity however, is provisional upon the particular design situation.

Validation of design representations (or other design artefacts) is defined for the purposes of this thesis as 'validation through continued use and through applicability to new design situations'. An artefact is deemed valid if, through its use, understandings of the design situation are clarified, elaborated, refined or reconfigured. This validation must be done anew for each specific design situation, as the particularities of that situation will determine the specific criteria for validation. Continued validation in different design situations could eventually make such a representation part of a designer's normal toolkit.

In this research, the design representations of movement produced have two key characteristics. Firstly, they will retain recognisable elements of the lived experience and embodied practice of movement from which they were generated so that they provide adequate means of re-enacting and regenerating the process and quality of movement in order to experience it again. Secondly, they are produced from the perspective of being able to think through possible translations or mappings from the execution of movement by people to the detection and interpretation of those movements by a computer system relying on video-based motion-sensing technology for input of such movements. That is, the representations need to map between people's movements and representations of those movements that a computer could recognise. Not all the representations of movement will have both characteristics, but across the set of representations these two characteristics will hold.

Each project is described in the following sections in terms of its objectives, activities and the research methods employed. Detailed descriptions of the activities and results of each project are provided in the chapters to follow.

4.2 Project I—Eyetoy

The first project consisted of an *analysis* of an existing movement-based interactive product, Sony Playstation2© Eyetoy™, to examine the movements of players in interaction with the Eyetoy games. Eyetoy is an example of a simple form of interactive space composed of a single projected display screen and a motion-sensing input camera. The player stands in front of the screen and uses body movements to interact with the game. The conception of movement in this system is that physical actions and gestures of the player map to physical actions in the game. It was used as a prototype of future systems that are based on human movement and computer vision. This project served as a preliminary exploration of some existing tools that could be adopted or adapted for understanding, analysing, describing and representing human movement treated as input to interactive, immersive spaces. The first tool is the Laban system of movement analysis (LMA) and its companion notation system, Labanotation. The second tool is Suchman's (1987) analytic framework for analysing the interaction between humans and machine.

4.2.1 Research methods

A table of the research methods employed in this project is given in Figure 4.3. This project was undertaken in conjunction with a fellow doctoral student, Astrid T. Larssen and my supervisor, Toni Robertson. Collection of empirical data of eight participants playing the Eyetoy games took place in a controlled laboratory setting. Each participant's game-play was filmed on digital videotape for later analysis. Observations and note taking were made during the session, to be correlated later with the video data analysis. Analysis of video data involved repeated viewings to determine the movements of the players in interaction with the game technology.

Suchman and Trigg (1991) highlight one of the primary advantages of working with video recordings in that it provides a "powerful corrective to our tendency to see in a scene what we expect to see". Video data also facilitates the collaborative interpretation of the material on the video tape

Research Method	Description
Interview	Interviews with participants post gameplay about their experience of playing. Questionnaire with usability related questions.
Observation	Observation and note-taking of participant's gameplay.
Videotaping activity	Video recordings of participants' gameplay from two angles.
Video analysis	Broad sweep of video data to identify basic set of actions and movements for participants. Detailed movement analysis and transcription using Laban movement analysis and Labanotation. Analysis of human-machine interaction using Suchman's analytic framework.
Construct/ trial design method/tool/probe	Trial of Suchman's analytic framework for analysing movement as input for interaction with machine.
Enactment	Re-enactment of players' movements to gain bodily understanding of movements used in gameplay and skill in using the Laban system of movement analysis.

Figure 4.3 Table of research methods for the Eyetoy project describing the instantiation of each method

by a group of researchers, designers and work practitioners who can bring multiple perspectives to the analysis. Repeated viewings are necessary to clarify and refine the joint understandings elicited from the video material.

We did not transcribe the entire video footage, instead focusing on samples of movement phrases that illustrated the participant's characteristic movement styles, in line with the method of selective transcription for Interaction Analysis described by Jordan and Henderson (1995).

> there is no ideal or complete transcript according to any abstract standard. Rather, the question must be: How adequate is this transcription for purposes of the analysis to be performed? (Jordan and Henderson, 1995, p.10)

Transcription of selected movements was done using Laban movement analysis and Labanotation to gain a more informed understanding of the movements used in interaction and to trial the applicability and usefulness of the Laban system to movement-based interaction design. This analysis required the researchers to acquire understandings of the movement analysis system through performing and analysing the movements with their own bodies, as well as honing visual observation skills.

The players' actions and movements were further analysed using Suchman's (1987) analytic framework for interaction analysis of human-machine interaction. This enabled the exploration of the relationships between bodily actions and the corresponding responses from technology from the perspective provided by this particular framework. A more detailed account of the process is provided in Chapter 5.

4.3 Project II—Bystander

This project provided a case study of the design of *Bystander*, an interactive, immersive environment built on motion-sensing technology, from conception through to production. *Bystander* is a form of interactive, immersive environment that presents complex data through visual imagery, text and sound and utilises human presence and movement as input. It was part of an Australian Research Council-Linkage grant[1] and involved a design and development process with a multi-disciplinary team of artists, designers and programmers over a two year period.

The conception of movement in this system is one where the patterns of motion and stillness of the visitors are interpreted as indicative of the level of audience engagement with the interactive artwork. Increased motion and physical activity is taken as a gauge of less attentive audience engagement. A quiet and physically still composure is interpreted as a highly attentive audience engagement. As we will see during the development of this project, this conception of movement is problematic for interactive, immersive artworks built on motion-sensing technologies.

The research work was concerned with the extension of traditional human-centred design approaches, methods, tools and techniques to this particular

[1]ARC LINKAGE PROJECT LP0349327 The BYSTANDER FIELD: immersive 'feedback' environments for exhibiting and dramatically interacting with semiotic, aesthetic and emotional patterns in archived imagery. Chief Investigators: Professor Ross Gibson, A/Prof Toni Robertson; Project participants: Dr Tim Mansfield (DSTC), Lian Loke (FIT), Kate Richards (project manager)

Research Method	Description
Interview	Interviews with participants post-enactment to discover their understanding and experience of the system and their experience of using personas and scenarios.
Observation	Participant observation in design process.
Videotaping activity	Video recordings of scenario enactments in prototype environment. Video recordings of interviews post-enactment. Video recordings of visitors to final exhibited work.
Video analysis	Analysis of video data to observe activity and movements of participant users for reflection and refinement of design tools. Analysis of video data to extract patterns of movement of visitors to final exhibited work.
Construct/ trial design method/tool/probe	Construction and refinement of moving personas, movement-oriented scenarios, movement schemas in Labanotation, user activity script for use in iterative design process. Adaptation of Suchman's analytic framework as a design tool for exploring the human-machine interactivity.
Enactment	Scenario enactment following user activity script in prototype environment.
Collaborative design session	Regular meetings with entire design team to exchanges ideas and present various design artefacts by different stakeholders.

Figure 4.4 Table of research methods for the Bystander project describing the instantiation of each method

genre of movement-based interactive systems. The emphasis for this thesis was on constructing design representations to explicitly address moving bodies, embedded in social interaction and the subsequent use of these representations for design reflection-in-action through physical immersion and enactment of movement in the prototype environment.

4.3.1 Research methods

My role was as a researcher and participant in the design process. I was part of the team of three technology designers investigating the use of human-centred design methods and tools in the creation of an interactive, immersive, artistic work. We worked on the project with the two artists/authors of the work and other professionals skilled in programming, exhibit design, digital sound composition and graphic design. A table of the research methods employed in this project is given in Figure 4.4. The development of the system involved iterative cycles of design activities with the creation, use and refinement of design representations of moving bodies. In particular, this involved the construction and refinement of moving personas, movement-oriented scenarios, movement schemas in Labanotation, the user activity script and the further adaptation of Suchman's (1987) analytic framework as a design tool for exploring the human-machine interactivity. Scenario enactment following the user activity script was conducted twice in the prototype environment to test the system with users and for the designers to experience the potentials for interaction offered by the system. Interviews were conducted with participants of the user testing post-enactment to discover their understanding and experience of the system as well as their experience of using personas and scenarios to guide the enactment. The interviews and the scenario enactments were videotaped for later analysis and feedback into the design process. The design representations of moving bodies and the results of the user testing were exchanged with the design team at regular meetings. The activity of actual visitors to the exhibited work was recorded on digital videotape for later analysis of the patterns of audience behaviour and movement. A more detailed account of the process is provided in Chapter 6.

4.4 Project III—Falling into Dance

The primary aim of the third project was to validate and extend the findings of the first two projects. A range of motivations existed for the kind of research activities undertaken in the third project. Firstly, to continue and extend the work done in the second project, Bystander, on constructing forms of representation for design that deal explicitly with the moving body or bodies. Secondly, to see how the methods and tools already used in the previous two projects can be applied to this new design situation and, if necessary, extend or augment the methods and tools. Thirdly, to extend the range and kinds of movement to be sensed, from everyday movement (in Bystander) and limited range of arm gestures (in Eyetoy) to more complex, heightened and choreographed forms of movement. More complex forms of movement were examined, such as the action of falling and choreographed phrases of movement. The action of falling is considered to be a complex movement that required significant investigation into its performance and a subject's experience of that performance, prior to designing for such an action. Falling is a movement that we all know in some way but do not necessarily practice. As such, it lends itself to making strange. The action of falling takes the body on a trajectory through a volume of space that is often traversed in all three planes simultaneously. The body assumes different postural positions through the trajectory, including standing, off-centre, contracted, spreading and extending and lying on the ground. This range of body postures in motion presents a complex form of input for a computer vision-based input device. Similarly, choreographed phrases of movement present complex forms of input if they are to be recognised as such.

I chose to work with trained dancers and physical performers for their expertise in using the moving body as a design material (Schön, 1987). I saw the practices of dance, movement and choreography as a rich source of potential methods and tools that could be reapplied in this field of movement-based interaction design. A series of studies was undertaken to trial and identify a range of methods and tools for working with the moving body, which start from the experience of the moving body. The first study was of skilled movers in the act of falling. The second study explored ways to choreograph movement.

The primary aim of this third project was achieved through a *constructed design situation*, using a hypothetical, future system as a vehicle for further exploring how movement could be understood, described, represented, experienced and enacted in the design of such movement-based interactive systems. Unlike the second project, Bystander, there was no readily available design project in which to situate this work. The creation of a constructed design situation enabled prolonged attention to, and visibility of, the design artefacts and their transformations throughout the project. It also meant that the design situation itself was open to modification and reshaping according to how well it was serving the aim of the project. In actuality, this is what happened. This third project was interlaced with periods of critical reflection on the unfolding research work as it was conducted. The activities

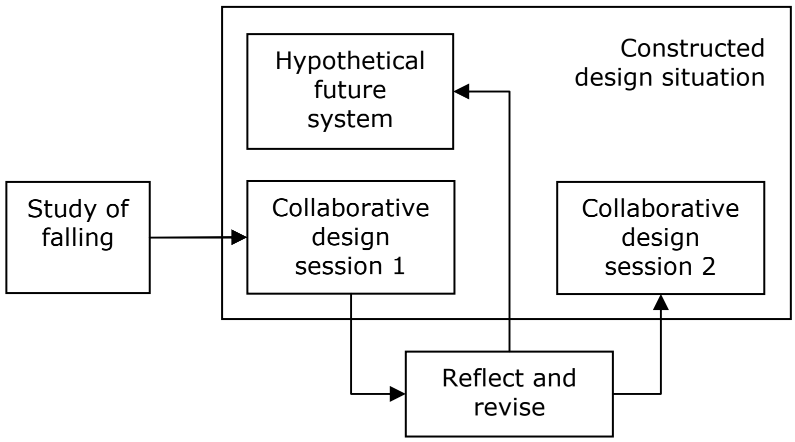

Figure 4.5 Diagram showing revision of Falling into Dance project

in the project underwent revision and were reformulated to better serve the primary aim of the project, as summarised in Figure 4.5 and described below.

The original vision for the constructed design situation of the third project revolved around the exploratory design of an interactive space that sensed the action of falling. The first activity involved a movement study of the act of falling with eight participants. The outcomes of this activity were an understanding and description of the act of falling as experienced by skilled movers. This data was then used as material in the following series of collaborative design activities undertaken with skilled movers. It is the second of these collaborative design activities that underwent significant revision after critically reflecting on how well the first collaborative design activity contributed to the aim of the project and the research questions. Along with a revision of the second collaborative design activity was a substantial change to the hypothetical future system. The research process governing the design and conduct of the second collaborative design activity was instrumental in generating new methods and tools that addressed the research questions of the thesis.

Research Method	Description
Interview	Interviews and physical demonstrations with participants to understand the act of falling by skilled movers.
Observation	Observation of physical demonstrations. Participant observation in study of choreographing movements.
Videotaping activity	Video recordings of physical demonstrations. Video recordings of collaborative design sessions.
Video analysis	Analysis of video data to generate a range of descriptions and representations of the falling body. Analysis of video data to generate a range of descriptions and representations of the choreographed moving body. Analysis of video data to identify methods for generating and devising movement from the practices of dance and movement improvisation practitioners.
Construct/ trial design method/tool/probe	Trialling forms of representing movement ideas and choreography and corresponding interactive treatment. Production of inspirational resource kit to inspire and constrain movement ideas and choreography contributed by the participants.
Enactment	Enactment of choreographed movements during collaborative design sessions to acquire a bodily understanding of the movements.
Collaborative design session	Working with dancers and movement improvisation practitioners on generating and choreographing movement for use in an interactive, immersive space.

Figure 4.6 Table of research methods for the Falling Into Dance project describing the instantiation of each method

4.4.1 Research methods

A table of the research methods employed in this project is given in Figure 4.6. In the first study, interviews and physical demonstrations were conducted with eight participants trained in dance and physical performance. These sessions were filmed on digital videotape for later analysis. As the researcher, I acquired first-hand experiential data on the act of falling through learning how to fall under the instruction of some of the participants. Data analysis of video footage was performed to determine the nature of the experience and process of the act of falling across the eight participants, from the first-person perspective of the participants. A range of descriptions and representations of the falling was also extracted from the video data for potential use in the design process.

In the second study, collaborative design sessions (or workshops) were conducted with dance and movement improvisation practitioners to find ways of generating and choreographing movement for use in movement-based interaction design. I took part as a participant observer in these sessions in order to acquire a bodily understanding of the movement ideas and choreography. A set of resources for inspiring and constraining the movements choreographed for interaction and a range of design representations of movement and corresponding interactive treatments for use in movement-based interaction design were trialled with the participants. These representations were created during, and refined after, the design sessions. The design sessions were filmed on digital videotape for later analysis. Data analysis of the design sessions was performed to identify and describe methods for generating and choreographing movements from the practices of dance and movement improvisation practitioners. A range of descriptions and representations of the choreographed moving body was also extracted from the video data for potential use in the design process.

In both studies, elements of Laban movement analysis and Labanotation were used to analyse and represent aspects of human movement that could be relevant to the design of interactive, immersive spaces built on video-based, motion-sensing technologies. In particular, Laban Effort-Shape analysis and Labanotation floor plans were utilised.

4.5 Summary—Research Methodology

Each of the three projects explored and contributed to understandings of movement and to the repertoire of methods and tools for designing movement-based interaction from a starting point in the experiential, moving body. The findings from all three projects are brought together in the major contribution to the thesis, the design methodology of Moving and Making Strange. The original genesis of the methodology resulted from the outcomes of the third project. The final form of the methodology is a synthesis of the outcomes of all three projects and is described in Chapter 9.

Chapter 5

Project I. Eyetoy

This project forms part of my investigation into an understanding of human movement for designing movement-based interaction with technology. The project serves as a starting point for developing an understanding of movement as input for interaction in order to inform interaction design. It comprises an analysis of movements produced by interaction with the Sony Playstation2© Eyetoy^{TM} games. The Eyetoy games are being used as a prototype of future systems that are based on human movement and computer vision. The games utilise free body movements performed by players as input and very basic computer vision to sense that input. The analysis was undertaken with the following objectives:

1. to understand movement as input for interaction
2. to find ways of describing and representing movement
3. to explore the use of Labanotation as a design tool in movement-based interaction design
4. to explore what perspectives are offered by Suchman's (1987) analytic framework for understanding and analysing movement-based human-computer interaction

These objectives were addressed by performing two key activities. The first activity involved analysis and transcription of the players' movements using an existing movement notation, Labanotation. The primary aim of this activity was to examine the ways in which this notation, for representing and recording human movement, might provide designers with a useful tool when designing interactions that involve the moving body as input; specifically, a design tool that might support their considerations of the forms of human movement and the possible interpretations of that movement by technology.

The second activity involved applying Suchman's (1987) analytic framework to the analysis of the players' movements in interaction with the Eyetoy games. The aim of this activity was to see what perspectives the framework offered to interaction design, particularly an understanding of human movement as input.

These two activities are described in detail and the results of the project are presented in the following sections. The Eyetoy games are introduced and the experimental setup is described in section 5.1. A rationale for the choice of research methods is given in Chapter 4. Preparatory data analysis is described in section 5.3, prior to discussing the results of the movement analysis using Labanotation in section 5.4 and the application of Suchman's analytic framework in section 5.5. A critique of Labanotation is presented in section 5.6. The chapter concludes with the findings from the project.

5.1 Introduction to Eyetoy

Eyetoy is a motion detection technology consisting of a video camera that plugs into a Playstation2 game console. The Eyetoy games can be played using movements of any part of the body, but tend to be played mainly with movements of the arms. Players interact with the game by moving their limbs to do things like selecting a character, reaching to a spot and striking at stationary or moving objects. The player has no direct physical contact with the technology; instead their movements are sensed by the Eyetoy camera. The input movements performed by players are generally in response to game-initiated events. They are performed as physical actions and simultaneously represent a corresponding physical action in the game's virtual space. Here the term *virtual space* is used to refer to the internal world of the game and *playground* to refer to the space of the physical world from which the player influences the virtual space, after Konzack (2002). In Eyetoy, these two spaces merge, as the player's body and movements are input to the virtual space and conversely, the playground is composed of a 3-dimensional physical space within which the player is located, that has a projection of the gamescape on one side of the space, directly opposite the player. A mirror video image of the player is inserted into the gamescape so the player can see themselves in the 2-dimensional virtual space. The Eyetoy camera functions best with balanced lighting. Errors in input can occur with suboptimal lighting conditions. During game-play, only certain areas of the screen are deemed active at any point in time depending on the game context. By active, we mean that the player's movements are able to be sensed by the camera and registered as input. The technology is constrained to detect movements in the lateral plane and does not register depth as movement in the sagittal plane. There is an optimal distance for motion recognition of the player, given by a certain calibrated distance from the camera. See Demming (2004) for a study that focuses more specifically on the usability of the games.

An examination of the available games was undertaken to identify the most suitable games for the study. A *suitable* game was taken to mean a game that was seen to elicit a range of movements while at the same time being fairly quick and easy to learn. Two of the twelve Eyetoy games, *Beat Freak* and *Kung Foo*, were selected for use in this project. Here follows a brief description of the two games.

Beat Freak (see Figure 5.1) requires the player to move their hand over a speaker in one of the four corners of the screen at the same time as a CD flies across the speaker. The CDs fly out from the centre of the screen and reach the centre of the speaker cone in time with the music. The active area for input in this game is the circular zone representing the cone of the speaker, which is positioned in each of the four corners of the screen. For a given event such as a CD flying out from the centre to the upper left corner, the target area becomes active for a specific time period in which the user's movement can be registered.

Figure 5.1 Beat Freak

Figure 5.2 Kung Foo

In *Kung Foo* (see Figure 5.2) the player has to move their limbs to strike Wonton's (the bad guy) henchmen. This prevents the henchmen from reaching the middle of the screen, which otherwise causes the 'loss of a life' for the player. The henchmen appear randomly from pagodas positioned at the sides of the screen. Extra points are gained by breaking wooden boards and hitting Wonton himself. The active area for input is the area corresponding to any of the moving henchmen, Wonton or the stationary wooden boards.

5.2 Experimental setup

The experimental setup is described here to set the scene for the analysis to follow. Eight participants, four female and four male, were recruited to play the two games. Before playing, data on demographics and previous experience with the games were collected. The participants were warmed-up with a series of yoga stretches to minimise the likelihood of injury. The participants were introduced to each game by using the game's Help feature. They then played each game twice on the *easy* level and once on the *medium* level. The participants were filmed from two angles. One view captured a projection of the participant's mirror image in the gamescape; the other view captured from front-on the participant's full body whilst playing. See Figure 5.3 for a diagram of the experimental setup. After playing, the participants were interviewed about their experience with the game and given a questionnaire with usability related questions.

5.3 Initial data analysis

Three of the eight participants were initially selected for analysis on the basis of variation between their movement styles. The actions and movements were identified from these three and then compared against the remaining five participants to ensure we had not overlooked any movements used for interaction. This enabled an iterative analysis of the actions and movements used in playing Eyetoy. We used Labanotation and its system of movement analysis to analyse and transcribe selected movements of individual participants. We did not transcribe the entire video footage, instead focusing on samples of movement phrases that illustrated the participant's characteristic movement styles (in line with the method of selective transcription for Interaction Analysis described by Jordan and Henderson (1995)).

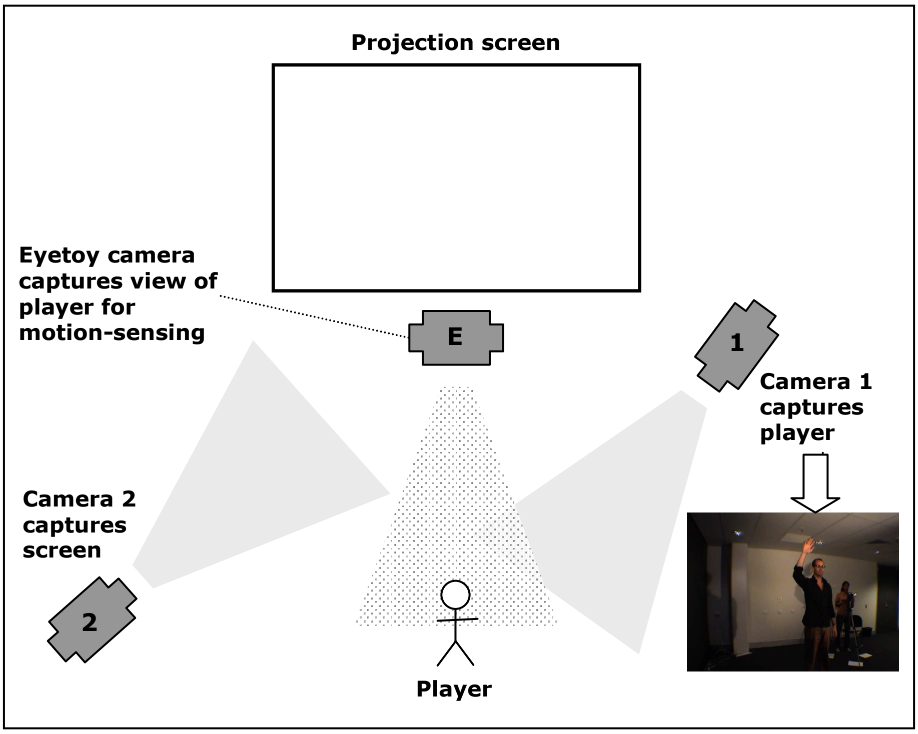

Figure 5.3 Experimental setup

The video recordings were viewed multiple times by the research team, individually and together, in order to determine:

- The flow of interaction for each game
- The actions taking place in each game
- The specific movements used to perform these actions

These viewings were correlated with notes taken during observation of actual game-play.

From this process a set of four actions (*Selection, Strike Moving Object at Fixed Target, Strike Fixed Target, Strike Moving Target*) was identified as basic to successful game-play. The actions in Table 5.4 were then further examined to determine the specific types of movements used to perform them (see fourth column of table). We identified an initial set of movements; these were further checked and performed with the games to ensure that they were effective for interaction, eventually settling into a set of seven characteristic movements (see Figure 5.5). Each characteristic movement in this set was defined and illustrated with an evocative example. Buur et al. (2004) also employ evocative or metaphoric descriptions of movement in their *Video Action Wall* method for tangible user interaction design. The movements identified constitute a taxonomy only for the movements produced by the two games we studied in detail. Other Eyetoy games use a set of movements which partially overlap with those in the table in Figure 5.5.

The actions and movements listed in the table in Figure 5.4 were further analysed within two separate activities: movement analysis using Labanotation and Suchman's analytic framework. Each of these will be elaborated upon in the next sections.

5.4 Movement analysis and Labanotation

The activity of analysis and transcription of movements using Labanotation is presented here. For each of the actions in Figure 5.4, each participant's selected movement phrase was transcribed into a movement script using the

Action	Description	Game	Movement
Selection	Navigation and selection of game choices and settings	Both	Wave
Strike Moving Object at Fixed Target	Coincide with object at target location	Beat Freak	Reach, flick
Strike Fixed Target	Strike as soon as object appears	Kung Foo	Slash, punch
Strike Moving Target	Strike as soon as object appears	Kung Foo	Slash, punch, slap, swat

Figure 5.4 Actions and characteristic movements for game-play

Movement	Description	Evocative Example
Reach	To extend the hand toward an object or destination	Stretching up for the biscuit tin
Wave	To move the hand or arm to and fro repeatedly	Waving goodbye
Slap	To hit something quickly with an open hand	Thigh slapping
Swat	To hit hard and abruptly	Swatting flies
Slash	To swing the arm quickly and freely through space	Cutting through grass with a scythe
Punch	To strike an object with a closed fist with force	Punching
Flick	To deliver a light, sharp, quickly retracted blow	Flicking away a piece of dust on one's coat

Figure 5.5 Characteristic movements of game-play

Structural form of Labanotation. The expressive quality of the movement was analysed using the *Effort* description. The process of notating was done by each researcher individually before arriving at an agreed form for each participant's movements. This involved a reflective cycle of revisiting the video data and re-enacting the observed and notated movements for a practical and bodily understanding of Laban's theory (after Newlove (1993)), while refining the transcription. One of the virtues of transcribing the movements into Labanotation was that it forced a certain rigour upon our practice of movement analysis as we had to agree upon the transcribed form in order to have a common understanding of the analysed movements. This required us to re-examine and observe more closely the recorded movements and the motivations for those movements.

For each of the four actions, a comparison of the notated movements across the three participants was then made to identify areas of similarity and difference. From this comparison, for each action we extracted the essential features of the movements required for the functioning of the interface from the player's perspective—we termed these *functional movements*.

A broad overview of the range of description available in Labanotation was provided in Chapter 3, section 3.4. We found in our project that we only used a small set of the descriptive forms of Labanotation; specifically directional destination, relationship (to virtual and physical objects) and dynamics (expressive quality) in terms of Effort. This was because of the particular forms of movement people used when playing Eyetoy. This does not imply that other kinds of systems would not exploit more of the options available within Labanotation.

5.4.1 Examples of Labanotating

In this section, a detailed transcription in Labanotation is provided for two of the four game actions—*Strike Moving Object at Fixed Target* in Beat Freak and *Strike Moving Target* in Kung Foo. These two examples were chosen because they most efficiently demonstrate the application of Labanotation in this project.

For an understanding of the model of the body and principles of movement used in Labanotation, refer back to Chapter 3, section 3.4. For our purposes here, we have deviated from the standard Laban convention for normal position of the feet being in ballet first position; instead, a normal carriage of the body is understood in this context as a person standing erect with feet hip-width apart and arms held relaxed by the side of the body, unless specified otherwise in the starting position. The symbols on the body staff below the double line represent the starting position of the body. Any movement is then described as a change from this starting position.

Structural description

For the Strike Moving Object at Fixed Target action the notated movements for participant 2 are presented in Figure 5.6. We have extended the diagram by augmenting it with symbols for game events occurring on the screen. This allows us to depict the point of interaction between the movements of the player and the events and input mechanism of the interface. The *point of interaction* is when the player's movements are treated as input or control to the system. It is suggested that Figure 5.6 is read with reference to the guidance provided directly below on how to read the diagram.

How to read the diagram: The structural form of Labanotation is read from the bottom to the top, with time in the vertical axis. Time can be split into measures (rows in the diagram), just as in musical scores. Each measure has been numbered to facilitate explanation. The vertical staff represents the body, the centreline being the centreline of the body, the right hand columns represent the right side of the body and likewise for the left. The columns are used for main parts of the body, such as S—Support and A—Arm; for example, movements of the arms are written in the 'A' column. Symbols for indicating direction and level of movement in space can be combined and placed in the columns associated with the major body parts. Timing and duration of movement are indicated by the position and length of the symbol. No symbol in a column implies no movement. A wide range of symbols is available to give more detailed information; for example, the degree of

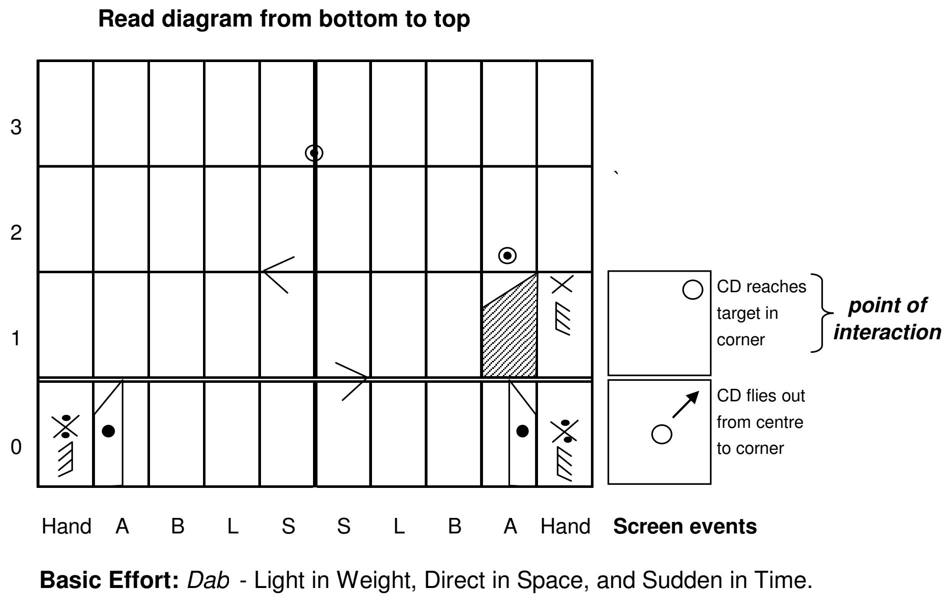

Figure 5.6 Labanotation for Beat Freak action Participant 2

contraction of the hand. See the legend in Figure 5.7 for symbols used here.

The notated movement for Strike Moving Object at Fixed Target action of participant 2 in Figure 5.6 shows, in row 0, the player in a starting position with both arms bent at the elbow (the position of the lower arm is indicated by the placement of the symbol in the outer half of the A—Arm column), the fists lightly closed (indicated by contraction of the hand) and held just in front of the navel and the weight evenly distributed on both feet, feet about hip width apart. The game events are indicated alongside the body staff—here a circle representing a flying CD is displayed emerging from the centre of the screen and moving towards the upper right corner of the screen. In the first measure 1, the player reaches to the right upper front with the right arm; the hand opening as they fully extend their arm. They shift their weight to the right (indicated by the caret symbol > in the Support column) as the right arm extends. The point of interaction occurs when the arm is fully extended to the upper right at the same time as the CD reaches the upper right speaker on the screen. Then in measure 2, as the player lowers their right arm to the starting position (indicated by the 'back to normal'

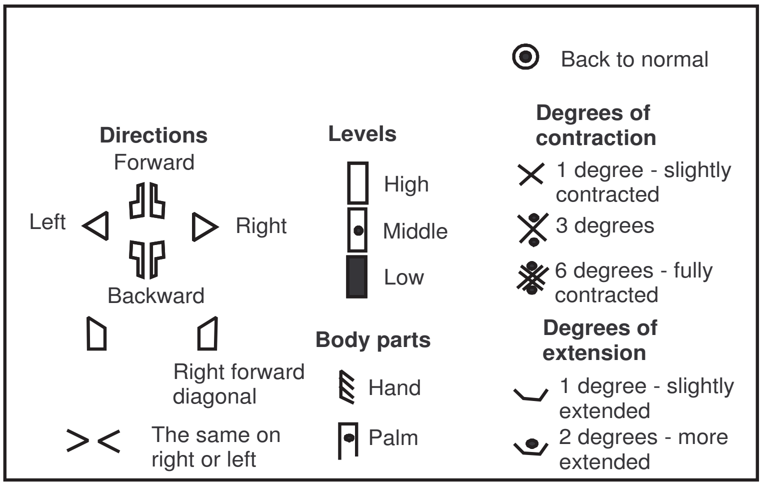

Figure 5.7 Legend of Labanotation symbols used in this study

symbol), they shift their weight to the left and then in measure 3, they return to centre. Here the use of the ‘back to normal’ symbol has been redefined to indicate a return to the starting position for that body part, rather than the usual convention of the normal carriage, in order to simplify a problematic transcription. The redefinition of symbols in the notation was confirmed as legitimate by a representative from the Labanotation centre.

For the Strike Moving Target action in the Kung Foo game the notated movements for participant 5 are presented in Figure 5.8. The notated movement shows, in row 0, the player in a starting position standing with feet wide apart, knees slightly bent, hands out to shoulder height, arms slightly contracted, palms facing forward. After the game event occurs—a henchman jumping out from lower left pagoda—in measure 1, the player strikes out with their left arm to the lower left. After successfully striking the target, in measure 2, the player returns to their original starting position (indicated here by the ‘back to normal’ symbol). Figure 5.9 portrays the corresponding performance of the Strike Moving Target action for participant 5.

Each action was performed by each participant with idiosyncratic movement styles. The general form of the movement tended to be similar across participants for each action, given that the game event dictated the point

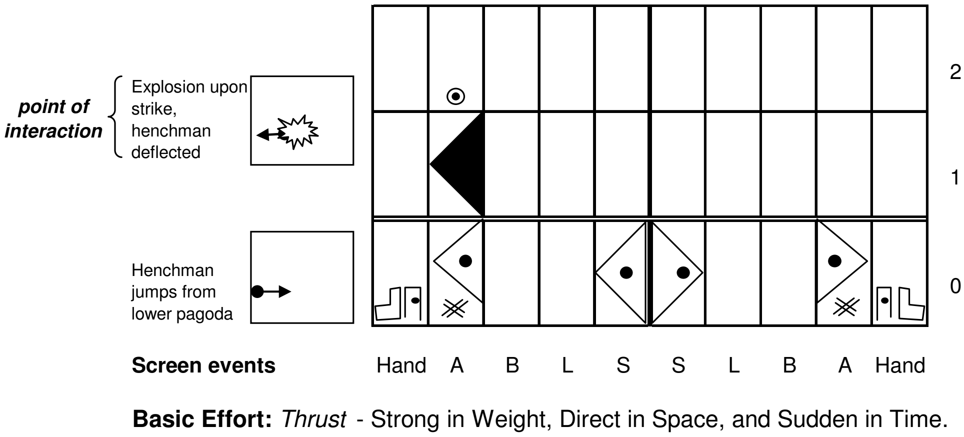

Figure 5.8 Labanotation for Kung Foo action Participant 5

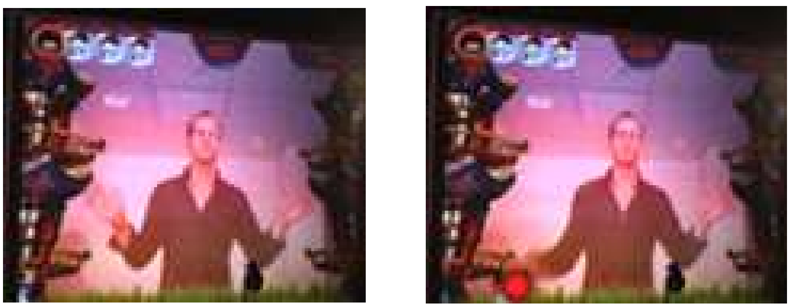

Figure 5.9 Performed movements for participant 5, Kung Foo

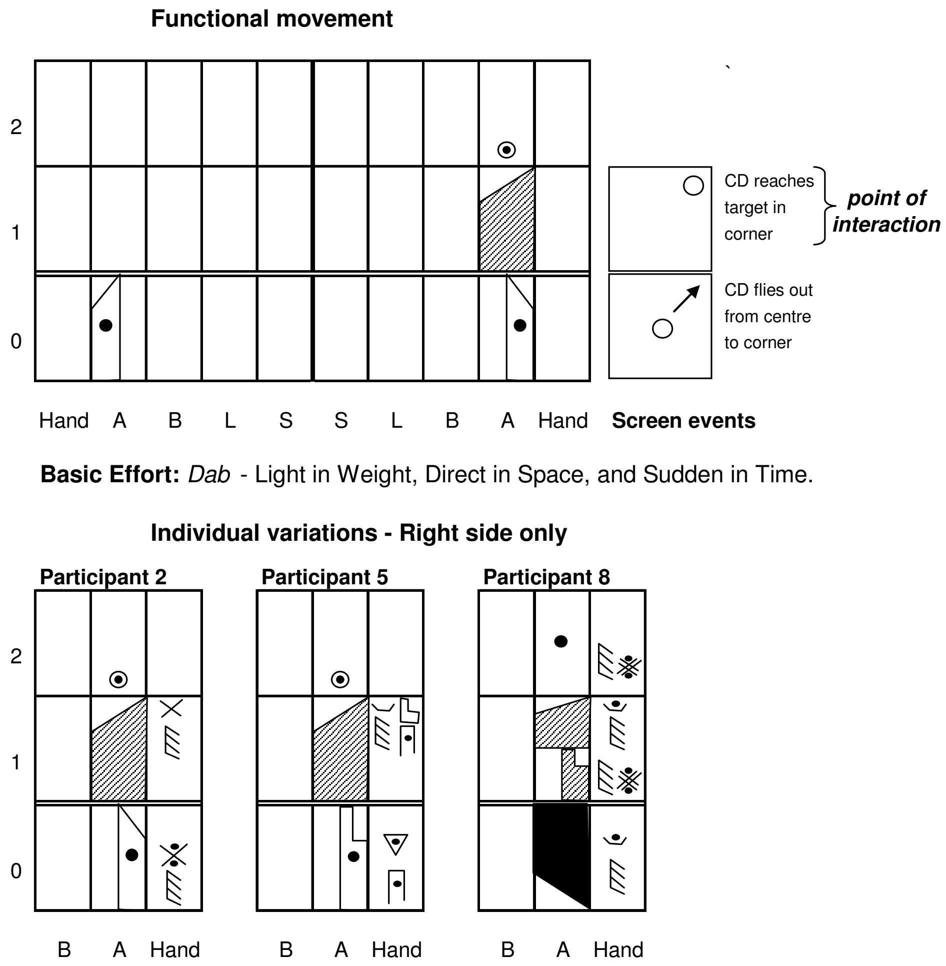

Figure 5.10 Functional movement and individual variations

in space and time for interaction. This similarity could be depicted on the functional movement script. The observed variations in performance of movements were in the particular ways people organised their bodily movement and the characteristic style of movement exhibited by each participant, as previously described in Figure 5.5. These variations and subtle nuances in performance could be suppressed on the functional movement script (see Figure 5.10) if they were incidental to the functioning of the interface. If it were important to explicitly describe allowable variations, then these could be included on the diagram in some form.

Effort description

In Beat Freak, the Effort characteristic for participant 2 was identified as a basic Effort action of Dab (Light in Weight, Direct in Space, Sudden in Time). We observed that all the participants exerted the same Effort characteristic of Dab for the Strike Moving Object at Fixed Target action in Beat Freak. Similarly, common Effort characteristics across participants were identified for the Kung Foo game actions (Thrust or Slash for the Strike Fixed Target and Strike Moving Target actions). The types of Effort identified for each game action resonated with the typical physical action associated with that game. In the Beat Freak game, the player reaches out to strike the flying CD at a known point in space as part of a rhythmic activity dictated by the beat of the music. A typical physical action was lightly and quickly reaching to a point in space and retracting. This could be classified as a Dab Effort action.

In the Kung Foo game, the player strikes attacking henchmen or breaks wooden boards as part of a martial arts fighting situation. Physical actions that express some degree of force, speed and directedness were typical and could be classified as a Thrust Effort action (Strong in Weight, Direct in Space and Sudden in Time). Sometimes participants performed physical actions with an Effort of Slash that indicated some spatial uncertainty or imprecision by the player. In the Kung Foo game, the point of interaction was less predictable than in the Beat Freak game, as the player is confronted with a swarm of attacking henchmen. The Effort of the observed movements in Kung Foo varied predominantly in the participants' relationship to Space. As can be seen from the Effort cube (Figure 3.8), a Slash is similar to a Thrust except that they are on opposite sides of the dimension of Space; the former is indirect and the latter is direct.

5.5 Interaction analysis—Suchman

The players' actions and movements were further analysed using Suchman's analytic framework for interaction analysis of human-machine interaction.

This enabled the exploration of the relationships between bodily actions and the corresponding responses from technology from the perspective provided by this particular framework.

We have taken Suchman's analytic framework and used it here to analyse the interaction between the player and the Eyetoy interface, for the two games chosen. We adapted the framework to fit our particular context, as follows. The column labelled "Actions not available to the machine" has been split into two, to bring out the details of the movement description for the user's actions. The column labelled "Actions available to the machine" describes the input of the user activity via the motion-sensing video camera. The column labelled "Effects available to the user" consists of the output available to the user in the form of visuals and audio. In the original framework, there is a fourth column on the right-hand side, labelled "Design rationale", for the machine. The term 'design rationale' is commonly used in software engineering and HCI to denote the motivations, justifications, trade-offs and reasoning behind design decisions Moran and Carroll (1996). We have relabelled this column as "Game context" to avoid confusion of terms and to clarify the game context in which specific actions are occurring. It captures the design assumptions about user behaviour.

An example of a fragment of the interaction analysis for the Beat Freak game-play by participant 8 is given in Figure 5.11. The data is purposely laid out in the table (after Suchman) so that the columns labelled "Actions available to the machine" and "Effects available to the user" constitute the interface of the system that is available to both human and machine.

The critical point here is that the machine has available only what is in the grey column of the table for interpretation of the interaction—and the human user has everything else! Laying out the interaction in this form makes clearly visible the perceptual asymmetry, between the human and the machine points of view, that Suchman wanted us to see in her original work. We can see that the player has an exceptionally rich perception and interpretation of the action and game activity. The resources continually available to the user consist of the visual display, sound output, the game action and events—all of which are synthesised by the user to create a space in which

The User			The Machine	
Actions not available to the machine		Actions available to the machine	Effects available to the user	Design rationale
User activity/action	Movement description	Motion detection via video camera	Output: Visual display and audio	Game context
Awaiting start of game.	Ready position: Standing feet hip width apart, both hands held at navel, closed fist.	Calibrated image of user	Gamescape Visual text: "Countdown"	Game starts
Attempt to hit CD as it intersects speaker cone.	Reach out to upper front left with left arm, fingers spread.	(no machine input besides image of user)	CD emerges from centre and travels to upper left speaker.	Event – CD launched
Successful strike on the beat.	Left hand intersects speaker cone simultaneously with CD.	Motion detection over area representing upper left speaker cone as CD passes through it	Speaker vibrates and CD shrinks. Sound of cymbal clash.	Event – successful strike
Return to ready position.	Lower left arm to ready position.	(no machine input besides image of user)	Gamescape with animated characters dancing along	Pending next event
Waiting for next event, rhythmic sway to music.	Shifting weight side to side.	(no machine input besides image of user)	Gamescape with animated characters dancing along	Pending next event

Figure 5.11 Interaction analysis for the Beat Freak game-play by participant 8

to perform meaningful physical actions within the context of the game. As humans we are able to create the necessary context for a satisfying experience, regardless of the sophistication of the technology. We create a world to inhabit and within which to perform movements as part of meaningful actions for interaction. The moment of interaction is embedded in a gestural phrase (Benford et al., 2005) that is part of an overall activity that gives the movements their meaning and distinctive quality. For example, in the Beat Freak game the player reaches out to strike the flying CD as part of a rhythmic activity dictated by the beat of the music. In Kung Foo, the player strikes attacking henchmen as part of a martial arts fighting situation.

In contrast, the machine (in the grey column) has limited resources available for interpretation of the action. This is related to the choice of input technology for Eyetoy—a single camera provides motion detection of the player's movements within its frame of view. The machine perception is thus limited to motion detection typically over a narrowly defined spatial area within a given time period, as directed by the context of a particular game event. For example, in Beat Freak, the machine detects motion only in the area corresponding to the speaker cone when the CD is passing through it. Likewise, in Kung Foo, the machine detects motion in the area(s) corresponding to the moving henchmen as they jump towards the centre of the screen. This particular technology implementation makes no attempt to track or recognise human movements—it simply detects motion.

The analytic framework derived from Suchman was valuable in two key ways. Firstly, it made clearly visible the resources available to the user and to the machine for perception of action. Its prime function was to lay out the sequence of interaction and the interpretation of the interaction from both the human and the machine points of view. Secondly, and most significantly in terms of understanding movement, we were able to describe the movements as actions occurring in context, without losing the situated and contextual aspects of the performed movements. For example, the player is involved in an act of striking an attacking opponent in Kung Foo. The movements performed to effect this action, in a particular instance, took the form of the player moving their left arm to the lower left side, with a slashing quality. In between defensive strikes, the player was observed to perform readying or preparatory movements, such as shifting their weight from side to side. The richness of perception for the player is in sharp contrast to the machine's simplicity of perception of the action. Here the machine makes no assumptions about what the player is doing with their body. This simple approach bypasses the difficult task of correctly interpreting human action and instead, enables a diversity of physical actions by the user to achieve the same goal of successful game-play.

5.6 A critique of Labanotation

Traditionally Labanotation has been used in dance and movement observation for recording both natural and choreographed movement and for exploring movement. Practitioners of Labanotation would normally be trained movers or observers of movement. The exploration of the use of Labanotation for representing movement that occurs in movement-based interaction with technology has identified a range of advantages and disadvantages for its potential use in design. In this section, these advantages and disadvantages are described through the concepts of functional and performed movement, simplicity and specificity, context of movement and ease of reading and writing, presented below.

5.6.1 Functional and performed movement

We can distinguish between functional and performed movement for the design of movement-based interaction. For a given game action, the functional movement represents the essential properties or the general form of the movement required for effective operation of the interface. A functional movement (or sequence of movements) will be performed by different people in individually characteristic ways, but should nonetheless achieve the same effect (for example, hitting a CD in Beat Freak to score points). Performed movement thus describes the actual, distinctive movements produced by particular bodies. These variations in individual performance of physical actions can be described in Labanotation. For example, the player is involved in an act of striking an attacking opponent in Kung Foo. The movements performed to achieve this action, in a particular instance, took the form of the player moving their left arm to the lower left side, with a slashing quality. In between defensive strikes the player was observed to perform readying or preparatory movements, such as shifting their weight from side to side. All of this detailed description of the actual movements can be represented in Labanotation. However this may result in a design representation that is unwieldy and obscures the relevant aspects of the interaction to be modelled. Relevance is of course dictated by the particular application under design. The choice of how to notate the movement depends upon the context and aspects to be emphasised in the recording. What may be more fruitful is to identify and represent the relevant properties of the movements as they occur in the flow of interaction and at the point of interaction. The functional movement script, augmented with computer interface elements, is intended to play this role, as it provides an overview of the interaction sequence with the movements of the *player as the central focus.*

5.6.2 Simplicity and specificity

Labanotation is an extensive and flexible notation system. One of its main principles in notating is to use simple description for simple movement. On the other hand, if you need to be very specific about the movements to be recorded or performed, then its comprehensive symbol set gives it great expressive power. This expressivity and flexibility enables choice for designers, about what they represent as significant and relevant aspects of movement that is treated as input to technology. In this project, we chose to record the observed movements of the players as fully as possible, to ensure that we had a deep understanding of the movements used for interaction and also to ensure that we understood the essence and power of the Labanotation system. From this rich description, we were then able to pare down the movements to the general form required for interaction with the Eyetoy interface.

One of the challenges is to explore the tension between simplicity and specificity for describing movement as input for interaction and the corresponding interpretation of that input by the input technology system (in this case, video-based computer vision), without unnecessarily constraining the possibilities for individual action and performance. To aid clarification of this challenge, we will refer to another similar game system, the Intel Play^{TM} Me2Cam, that is also based on human movement and computer vision (D'Hooge, 2001). This system has a more complex computer vision input technology that involves head and hand tracking. When we have a simple description of movement, it is more open to interpretation in performance. Depending on the form of input technology this could mean that more or less demands are put on the interpretation of the input data by the computer to extract sensible data. Conversely, the more specific the description, the less interpretation or leeway in performing the movement and possibly less variation in input data to be interpreted by the computer. Alternatively, more sophistication of the input technology is required to correctly recognise the input as a human movement. This echoes the accuracy/ambiguity polarity for movement description using natural language raised by Badler and Smoliar (1979) and Høysniemi and Hämäläinen (2004). The concern of Høysniemi and Hämäläinen (2004) is with the interpretation of movement by the computer vision system—the level of accuracy is related to the input device technology and the parts of the body being treated as input. In cases where the design of the computer vision system is still open, then a more ambiguous and less precise description is warranted.

Interestingly, the Eyetoy interface exploits simplicity through its input technology and subsequent ease of mapping from user input to machine response. The fact that it does nothing more than detect motion within well-defined spatial and temporal constraints (it does no tracking or sophisticated motion recognition), means that the user is at liberty to perform any kind of movement to accomplish a specific game action, as long as that movement is registered as motion by the machine in the appropriate place at the appropriate time. A player could be standing on their hands and motioning with their legs instead of using their arms! There is thus no discrimination between variations in individual movement styles for specific game actions. In this case a simple and flexible mechanism for mapping human input to machine response enables a richness and diversity in the performance of movements for user interaction. The mechanism underlying this form of interaction is composed of four elements: position, area, timing and duration. It can be easily programmed for different games and different levels of skill by varying the value and range of any of the elements. It also easily accommodates multiple players in the same playground, but cannot distinguish between them.

In comparison, the Me2Cam interface has a more complex input technology and correspondingly more complicated mapping from user input to machine response. It has been designed for a single player with the vision algorithm optimised for a single head and two hands. One of the games, Bubble Mania, involves the player and a giant bubble-making machine where different game behaviours result depending on whether the player hits a bubble with their hand or head. In terms of movement description, we would have to describe in some detail the possible and likely movements of the hand and head in relation to the rest of the body and to the bubbles in the game's virtual space. One of the strengths of Labanotation is its extendability to whatever level of detail is required for a particular system.

5.6.3 Context of movement

The context of movements performed in game interaction influences how a movement is represented and interpreted. What is considered significant for interaction varies with each Eyetoy game. The representation in Labanotation of the movements performed for the Eyetoy games as a movement script included reference to the game events occurring on the screen. Labanotation allows for reference to other people, objects, music and spatial environment. It can easily be extended to describe a person's relation to virtual or computerised events, objects and environment, as we have done for the Eyetoy games in our movement scripts (see Figure 5.10). The concern here is to find ways of representing movement that retain their reference to actual, lived movement as performed in a specific situation.

5.6.4 Reading and writing

Once familiarity is gained with the notation, the reading and writing of Labanotation becomes easier. It is a visual representation that uses an indirect representation of the moving body. The notation is not immediately intuitive, unlike a stick figure representation of the body (although a stick figure suffers from ambiguity and a lack of precision, especially in three dimensions). However, this is overcome once the notation system is learned as it is logical and systematic. It is based on a simple principle that the symbols for spatial direction and level of the major parts of the body indicate change. The body staff then becomes a strong graphic pattern of the movements occurring throughout the body over time. Patterns within sequences of movement become easily discernable. Easy comparison can be made across a set of performances of a movement sequence by different people for a given action. The similarities and variations are immediately visible, as illustrated in the individual movement scripts of performed movements (see Figure 5.10).

The symbols are simple to draw, but observing movements correctly requires training of the eye and a thorough understanding of the notation system and the human body. Personal enactment of the notated movements can facilitate learning. The virtue of learning such a movement notation system is that it offers a certain perspective on movement and a way of seeing and thinking about the moving body that may extend one's existing understandings; it is a tool to think with. For those that do not require such an in-depth understanding of human movement, but still need to visualise the outward form of the moving body, computerised animation systems exist that can read Labanotated movement scripts and generate a life-like human figure that dynamically performs the notated movements (Calvert et al., 2005). Computerised Laban editors are also available to facilitate the recording of notated movements (Neagle, Ng, and Ruddle, 2003).

Høysniemi and Hämäläinen (2004) provide a notable counter-example of attempting to use Labanotation in an iterative design process of a game that is controlled by children's intuitive movements. They found that the representation of movement in Labanotation was too detailed for the design needs of their system and found it difficult and laborious to use. They preferred to describe observed movements gathered from children playing Wizard-of-Oz game prototypes using more straightforward visualisation techniques such as video sequences. However, the written form of Labanotation has an economy and flexibility over video- or image-based representations for the exchange and communication of notated movements between designers, recalling the work of Harper and Sellen (1995) on the affordances of paper.

5.7 Findings

One of the significant findings from this first project was the recognition that the games provided a context in which to perform meaningful movements and the particular game context engendered different types or styles of movement, with different qualitative character. The two games studied engendered quite different movements. Beat Freak produced highly regular, repetitive, reaching movements of the arms to the high and low diagonals as dictated by the beat of the music. It was played in an almost semaphore-like way; an observation that can be potentially useful for interactions that require a limited set of stylised or idiomatic movements. In Kung Foo, the player(s) tended to perform fast, striking and slashing movements to the side of the body, with the arms or legs. Kung Foo has an interaction style that is spatially and temporally unpredictable. The interaction is driven by the game; game events such as attacking henchmen trigger action by the player.

Suchman's analytic framework provided a way of organising and structuring the interaction between player and machine that enabled a clear focus on the relationship between the movements and actions of the player and the sensing and interpretation of the player's actions by the machine. The description of the player's movements within the framework ensured that the movements could be understood in the context of the game-play, from both the perspective of the player and the perspective of the machine.

Laban movement analysis, but not the notation itself, provides a language and vocabulary that translates readily to interaction design. Both the functional and expressive aspects of movement can be described. Laban movement analysis is beneficial for developing movement observation skills and sensitivity and awareness to movement and the kinaesthetic aspects of movement. The actual process of notating in Labanotation forced rigour in movement observation, analysis and description. Part of the work of notating was re-enacting the movements of the players to acquire a bodily understanding of the movements and the system of movement analysis. Although Labanotation can be used for visually representing the moving body in interaction, with the body as the central focus, it does require some skill and effort in reading and writing that may prevent easy uptake of the Structural description in interaction design work. The language and vocabulary of Laban movement analysis can be readily used to describe the functional and expressive movements of the player in the frame of Suchman's analytic framework, thus combining movement analysis with interaction analysis (Loke et al., 2005a, 2007).

The above set of findings all contribute to the proposed design methodology. An additional finding, orthogonal to the methodology, is that the Eyetoy interface consisted of a simple and flexible mechanism for mapping human input to machine response and yet enabled a richness and diversity in the performance of movements for user interaction. This finding can be used as a design heuristic when considering the choice of input technology and the mapping of user actions to machine responses.

Chapter 6

Project II. Bystander

This project provides a case study of the design of *Bystander*, an interactive, immersive artwork built on video-based, motion-sensing technology. Bystander is a form of interactive, immersive environment that presents complex data through visual imagery, text and sound and utilises human presence and movement as input. The design of interactive, immersives spaces, such as Bystander, intended to be available to the public in gallery and museum settings, poses interesting, new challenges to the accepted practices of user- and use-oriented technology design. Existing methods, tools and techniques for representing users and situations of use need to be extended and new ones developed to explicitly consider the experiential, moving body (or bodies) in these kinds of interactive, immersive spaces.

It should be noted that our scope of design was limited to the exploration and application of user-centred design methods and tools. The overall design of the system was in the hands of the artists. They controlled the development process and were ultimately responsible for making design decisions across the board. Our experience of how these user-centred design methods and tools fitted into the development process has been reported on elsewhere (Robertson et al., 2004, 2006). Here, I specifically report on the extension of the traditional design tools of personas and scenarios to explicitly address human movement characteristics embedded in social interaction, resulting in *movement-oriented* personas and scenarios. In addition, a set of corresponding *movement schemas* in Labanotation was constructed to visually represent the spatial and social interaction of multiple users over time. Together these three design representations of moving bodies enabled the design team to work with the aspects of human movement relevant to Bystander and ensured that the user concerns were explicitly addressed and kept active throughout the evolving design. These three design representations of moving bodies were also integrated into another design tool, termed the *interactivity table*. It is an adaptation of Suchman's (1987) analytic framework, which enabled the exploration, interrogation and evaluation of the interaction between the audience members and the system. The choice of research methods has been explained in Chapter 4.

6.1 Overview of Bystander

In this section, the history, concept and final implementation of Bystander is recounted to provide a setting for the development and use of the user-centred design methods and tools. Bystander is the latest work in *Life After Wartime*, a suite of multimedia artworks produced by Ross Gibson and Kate Richards since 1999. All the works in the suite are based on a collection of several thousand photographs, taken by forensic detectives in Sydney, Australia, between 1945 and 1960. These were selected from a much larger archive of crime scene photographs stored at the Justice and Police Museum in Sydney. The photographs are from police files and show crime scenes; places where something potentially illegal, potentially violent, happened to some other living person in the past. The photographs and the file envelopes are all that are left from the original police files; the associated detective notes are no longer in existence. Gibson and Richards have intensively researched and organised the archive over some years, using a range of techniques to recognise existing patterns in the archive and to create new ones that, in Gibson's own words, "can add new meanings and moods that have the power of fictions but are historically founded" (Ross Gibson, interview). The photographs themselves are incredibly seductive, hugely evocative black-and-white images that can easily stand alone as museum or gallery artefacts in their own right (see Fig-

Figure 6.1 Photograph from archive of crime scenes

ure 6.1 for an example of a photograph). They evoke questions in those who view them such as “what happened here?”, “who is that person?” and “what have they done?” In addition, Gibson has contributed approximately 1500 original short haiku and prosaic texts to the ‘raw material’ for the Bystander project.

Bystander is designed as an immersive interface to this collection of images and texts. The artists’ concept for Bystander was of a *sacred room* for witnessing the fragments of past lives depicted in the images from crime scenes of Sydney in the period post-second world war. One of the primary concerns with Bystander as an interactive, immersive space, was that whatever form the interactivity and the interface took, it should not detract from the potential audience engagement with the historical and emotive power of the images themselves. Early prototyping and user testing suggested that gestural interaction could potentially detract from a satisfying user experience of this particular exhibited work and therefore, a simple treatment of human movement to be used as input would better support the experiential aims of the work. Ideas such as mapping a person’s proximity, position, focus or gesture to individual elements of the work (a single image or text haiku, for example) were seen as over-complicating the interaction and rejected. Ultimately the choice of position, proximity, mass/density and motion/stillness as inputs and the treatment of these inputs reflected the importance given to an individual's ability to engage contemplatively with the work and the need to accommodate a fluctuating and unpredictable number of multiple users in the space.

The artists' concept for the audience interactivity with the room was based on cultivating a contemplative audience engagement with a *spirit-world* of images, texts and sounds. They wanted a work where a quiet, attentive attitude from the audience would be rewarded with a greater divulgence of coherently related content. Restlessness and increased physical activity by the audience would result in the room sensing this lack of respectful contemplation and responding by becoming more chaotic in terms of the atmosphere created by the presented content. The relationship between the revealed media content is more coherent and more narrative when the audience is calm and attentive, less coherent and more associative when the audience is restless and physically active. In Gibson's words:

> The room will behave as if it is hyper-sensitive and 'haunted'. The more agitated the visitors, the more turbulent the artwork. Visitors will learn that they must be composed and attentively still in order to gain the 'trust' of the space, and from there they can develop a 'dance' of intimacy with the images, sounds and texts that surge and retreat in concert with the movement of the people inspecting the space. (Gibson and Robertson, 2002)

The conception of movement in this system was initially one where the patterns of motion and stillness of the visitors are interpreted as indicative of the level of audience engagement with the interactive artwork. Increased motion and physical activity is taken as a gauge of less attentive audience engagement. A quiet and physically still composure is interpreted as a highly attentive audience engagement. This was the original assumption. In practice it was not quite so straightforward. Notions of stillness had to be teased out.

The final model of the system behaviour was conceived as a 'world' with its own logic that is inhabited by media content (images, prosaic texts, haiku

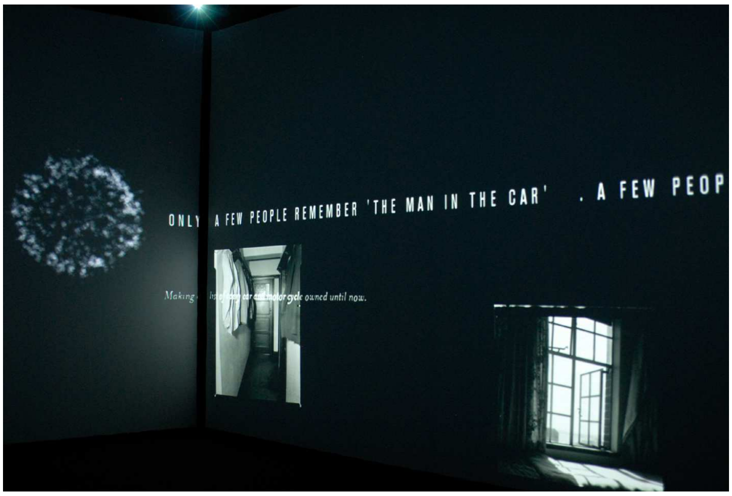

Figure 6.2 Image of Bystander visuals showing the flock, images and text haikus

texts, sound) and a dynamic, visual element called the *flock*. The flock is a particle animation and consists of an orb-like collection of shimmering, white particles that circles the walls of the room and echoes the state of the system. In its wake, a set of images and texts appears at key moments in the cycle of system behaviour (see Figure 6.2).

The design of the ‘world’ behaviours, rules and states was outside our scope of design and was handled by the artists and a software developer. To assist comprehension of the relationship between user activity and system behaviour, the mapping between user activity and system states is presented in Figure 6.3. The world can be in four states. The state of the system is dependent upon the presence and activity of audience members. This in turn, directs how the media content is presented in terms of size, density, detail, position, sound and motion. The world behaviour can be controlled and fine-tuned through a separate interface which provides access to the parameters relating input of audience activity to the system response.

Physically, the installation is a pentagon-shaped room of front-projected 4.5 metre by 3.4 metre video screens. Audience members enter through one corner of the pentagon. Audience movement is sensed using an infrared video camera mounted above the top of the screens in the centre of the room and pointed vertically downward. Sound is delivered by a 5.1 channel sound sys-

System input + processing of user activity via overhead infrared video camera	**Room state**
No people present.	**0** – Resting: When the room is empy without visitors, it is at its most divulgent in terms of content.
Tracking audience position, density, distribution and movement to determine room state. Minimal motion detected. Most people standing quietly.	**1** – Composed: Visitors have found how to be attentive, still and reverent. The audiovisual output is highly related and narratively coherent. For example, pictures from the same crime are displayed.
Tracking audience position, density, distribution and movement to determine room state. Some motion detected as people walk around room and enter/exit. Some people standing quietly.	**2** – Semi-disturbed: Nervousness has been introduced, the mid-point between calm and panic. Some disassociation between displayed content.
Tracking audience position, density, distribution and movement to determine room state. Lots of motion. Excess number of people for system's threshold.	**3** – Chaotic. Very disturbed, unbalanced and freaked out. This is reflected in the audiovisual output. The flock is berserk. Only prosaic and haiku texts are displayed; no images.

Figure 6.3 Mapping of user activity to system states

tem. All computing hardware is of fairly standard commodity specifications due to the need for the system to be portable and able to be mounted in a range of gallery and museum environments.

6.2 Understanding and representing moving bodies

This section describes how we represented the expected audience and their activities in the Bystander room. Traditional design representations of personas and scenarios were tailored to reflect the focus on human movement, given that audience activity and movement were direct input to the system. The rationale for using personas and scenarios is given in section 2.4.3. In this project they played an important role in design communication. They are a lightweight, yet very powerful technique, easily inserted into a process that is otherwise not user-centred. The *movement-oriented personas* and *movement-oriented scenarios* were grounded in data from user studies of visitors in similar immersive spaces in museums and galleries. The scenarios were organised into a *user activity script* for enactment during user testing and evaluation. A set of *movement schemas* was constructed in Labanotation to visually represent the movement and spatial trajectories of the audience activity. Care was taken to ensure these representations of moving bodies were generated within the context in which they had meaning and could retain their links to real human behaviour throughout the design process. A selection of personas, scenarios, movement schemas and the user activity script will be presented to illustrate how the various design representations were produced and how they were used in relation to each other. The details of the interaction between the audience members and the system was explored using another design tool, based on Suchman's (1987) analytic framework, described in section 6.2.5.

6.2.1 User studies

User studies were conducted by other researchers working on the project. I briefly summarise their work here, as it forms the basis for the construction of personas and scenarios. Two separate studies of audience behaviour in immersive spaces were done to ground the development of personas and scenarios in understandings of actual audience behaviour. The main study in gallery and museum spaces in Sydney involved several researchers who were at that stage not yet involved in Bystander (Kan, Robertson, Muller, and Sadler, 2005). A smaller parallel study of similar spaces in Paris was done by Toni Robertson. Both studies investigated audience behaviour within available examples of cultural/artistic installations that shared one or more qualities with the aims of Bystander. Traditional museums as well as a range of art gallery environments were visited in both cities because it was (correctly) assumed that audience behaviour would vary according to the prevailing social protocols of the particular institutions. The aim of the studies was to provide the design team with a working understanding of potential audience behaviours that could be mapped to the behaviour of the system.

Over a dozen immersive spaces were studied using participant/observation methods for periods ranging between one and three hours at a time. To get some sense of the effects of changing visitor frequency, density and demographics the spaces were visited at different times of day and on different days. There were two strands of investigation. The first was what actually happened in these spaces: who the audience were, how people were inhabiting the exhibition space and what kinds of activities they were doing. The second was the patterns of mobility and motor activity of the visitors to the exhibits.

Six main audience behaviours were identified and are presented below.

1. *Poke head in and retreat.* Rooms with narrow openings were often avoided or just peeked into briefly.

2. *Walk in, stand for a while and then go out.* These people did not move around the room but entered and stopped. Most remained for between 30 seconds to three minutes depending on what was happening.

3. *Skimming.* These people would cruise (often quite slowly) around the whole room (or gallery) and stop if/when their attention was taken by something.

4. *Try to make something happen.* Individuals would either work any obvious input devices that were available or else perform a range of gestures to try and get a response.

5. *Serious, quiet and contemplative engagement.* These people appear to have gone to the exhibit to 'experience' it. They would enter a room, sit down for a while if there were seats, and/or stayed and moved to different and better vantage points over time (between 5 and 20 minutes).

6. *Children.* Museums and some galleries function as childcare/entertainment places where people do not have to keep still. Large groups of school children move *en masse* through spaces.

A particular individual might exhibit various combinations of these behaviours during their visit. For example, a visitor might perform the first three behaviours, as they sample the various exhibits in the wider institution and decide where they will spend their time. They might then shift to serious engagement with a specific work, either alone or in collaboration with others.

These behaviours were common to each of the spaces studied and to both studies. But there was enormous variation in the prevalence of particular kinds of audience behaviour in different spaces, different institutions and at different times. The range of movement that characterised each behaviour provided the range of audience 'input' that Bystander needed to be able to respond to in some kind of coherent and robust way. At the same time a consideration of the effects of the different kinds of audience behaviour provided resources for the designers (in this case, decisions were ultimately made by the artists) to consider what those responses might be. The findings from these studies formed the basis of the personas and scenarios developed and used in the later stages of development.

An important source of understanding how people move and conduct themselves in museums and galleries comes from researchers in interaction and conversation analysis (Lehn et al., 2001; Heath et al., 2002; Hindmarsh et al., 2005) and museum visitor studies (Fernández and Benlloch, 2000). They have shown that people's experience and perception of an exhibit is fundamentally shaped by and through social interaction with others in the same space. The aspects of social interaction we found relevant to our work include how visitors collaborate and coordinate activity; have sensitivity to others' presence and orientation; encourage or discourage participation; continually monitor the environment; and maintain peripheral awareness of and align their activities to the conduct and performance of others, be they companions or strangers.

6.2.2 Movement-oriented personas and characters

Development of personas and scenarios was undertaken bearing in mind the importance of sufficiently situating the representations of users and their activities within the experience of the particular kind of technology that was being built (Bødker, 2000). A series of personas was derived from the understandings of audience behaviours gathered in the user studies, to represent the range of visitors to Bystander. Unlike Cooper's (1999) recommendation of having three to eight different personas for task-related scenarios of use in a work context, we found we needed to develop multiple instances of basic personas to allow us to populate the Bystander prototype over time so that different combinations and effects of public use could be investigated. For this purpose, a range of individual 'characters' was created from each persona.

Our persona descriptions extended traditional descriptions of user history, skills and goals to include two distinct characteristics specific to the kind of interactive, immersive space under design: (1) a motivation for why that persona might be interested in the exhibit, either alone or with others and (2) the particular ways of moving for that persona that arise out of the interaction between their unique physical characteristics and modes of being, the setting

Persona - *Old folk, often go together. Slow-moving, contemplative visitors.*
Character - Betty is a retired librarian. She lives in a small house about 20 minutes by train from the middle of the city. When she was first trained she worked in the state library cataloguing bequests from the estates of writers. Once her kids were old enough to go to school she got a job in her local library and worked there for years. She organised the switch from the old card catalogue to the computer catalogue and did all sorts of training courses so she could understand the changes and use the new technology. She bought herself a computer at home and uses email all the time to stay in touch with her friends and family. She is writing a book about her life for her family to keep. When the weather is nice she gets an all day concession ticket and goes into town. She likes to have lunch by the water and then go to the library, one of the museums and maybe a gallery or two. It is getting harder for her to get around now. She has a bad hip and the city is so busy - everyone is rushing and the traffic is awful. She worries about falling or being knocked over and knows that her eyesight and hearing are not as good as they used to be. Still, she is not ready to give up yet! Sometimes she meets up with her old friend Val who she met at the maternity hospital when they were both having their first babies.

Figure 6.4 Example of a persona—old folk

Persona - *Young mother and toddler.*
Character - Sarah, the young mother, often takes her young child to art galleries as she finds them a great place with lots of space for young children. Sometimes she goes with other friends and their small children. They usually spend half the day at the gallery, visiting various exhibits, having lunch and letting the children roam around. When visiting an exhibit, she either finds herself being dragged around by her toddler or if the child is sleepy, carrying the child or pushing a pram around. When the child is sleepy she is better able to enjoy and appreciate the exhibited work. If seating is available inside the exhibit, she might sit down and rest. If an exhibit has loud or frightening music, then they often have to leave as the child finds it too much. It is difficult for her to properly engage with any of the new interactive works, so she usually skims through or stays to watch someone else interacting.

Figure 6.5 Example of a persona—young mother and toddler

of the environment, the prevailing social protocols and the nature of the exhibited work. A selection of movement-oriented personas and characters is presented in Figure 6.4 and Figure 6.5, that demonstrate the inclusion of these two characteristics. The comprehensive set of personas and characters used in this study can be found in Robertson, Loke, Kan, Muller, and Sadler (2005).

Particular kinds of bodies give rise to particular ways of moving. Some of the persona descriptions contain references to *physical characteristics* that give rise to particular ways of moving. For example, the first persona, Betty has a bad hip and poor eyesight (see Figure 6.4). These particular physical characteristics may translate to Betty moving slowly and carefully, resting often and taking time to focus and look at the things around her. The details of how she might move are not given, only an indirect indication of the *way she might move*. The specification of *props, apparatus* or *relationship to another person* can influence the way a person might move in these kinds of immersive spaces. One example is the persona of the young mother, Sarah and her toddler (see Figure 6.5). Her movements are defined and shaped to some extent by the toddler and the pram. These constraints on her movement may lead to Sarah navigating through the space quite slowly, pausing often, rocking the pram or moving about holding the toddler by the hand. These two examples show different ways of including cues for movement-oriented characteristics of personas that can be linked to various audience behaviours and elaborated in scenario descriptions of audience activity. This form of description facilitates enactment and generation of the relevant kinds of movement and mobility for the system under design.

6.2.3 Movement-oriented scenarios and scripts

Scenarios of each character's movement and activity inside Bystander were developed and then joined together to form a *user activity script* that could structure the exploration and evaluations of various models and prototypes over time. The basic script was produced during a design session that involved developing and simulating various scenarios of audience activity and behaviour that were grounded by the observations made during the user studies. A scaled-down model of the room was constructed out of foamboard and cardboard cut-outs were made of different characters to make multiple instances of each of the personas (see Figure 6.6). Care was taken to ensure that the full range of audience behaviours observed in the user studies was captured in the script, as well as different configurations of people in the room so that full functional testing of the system could be done with particular regard to state definitions, boundary cases and transitions between states. A synopsis of the selected characters and scenarios is presented below.

Figure 6.6 Making a scaled-down model of room and cardboard characters during development of scenarios

The scenarios are built on a combination of audience behaviours, movement trajectories, positions of stillness and spatial configurations of people, with characters taking on the range of audience behaviours. Scenarios contain a set of key events which highlight aspects of the design that are of interest or issue, much like Burns et al. (1994)'s performance scripts containing event sequences.

First scenario. This scenario explores the situation where a couple of people enter the Bystander room, which is currently empty. The characters, Val and Betty, are representative of older, retired people with a keen interest in the arts. They embody the fifth type of audience behaviour—*serious, quiet and contemplative engagement*. They enter the space and stand just inside the entry. A key event then occurs where a teenager attempts to enter the room but is blocked by Val and Betty. The teenager embodies the first type of audience behaviour, the *head-poker*. After the head-poker leaves, Val and Betty commence moving around the space, firstly towards the centre of the room and then towards one of the walls. They tend to move slowly with periods of stillness, as they observe the flock circling the room, revealing sets of images and texts. They chat and occasionally point things out to each other.

Second scenario. This scenario is concerned with the fourth type of audience behaviour—*try and make something happen*, embodied in the character of Luke. He is interested in working out the interactivity of the exhibit and does this by exploring the space, moving about and gesturing, while looking for some kind of response from the system to his actions. Betty and Val are standing near a wall, looking at the far walls. They eventually join Luke near the centre of the room and engage him in conversation, as they are curious as to what he is doing and whether he has discovered anything about the exhibit that they haven't.

Third scenario. This scenario explores the impact of a large group of noisy schoolchildren arriving in the space. Prior to their arrival, a middle-aged couple, Bob and Elena, are present in the space. A young mother, Sarah and her toddler enter the space. The toddler drags the mother around the outer perimeter of the space. Then a key event occurs with the arrival of a group of active, noisy schoolchildren. They run around all over the room, some of them exiting and re-entering the space. Finally everyone leaves except for Bob and Elena. The audience behaviours captured in this scenario include the second, third and sixth types. Bob and Elena embody the second type—*walk in, stand for a while and then go out*—as their movement and trajectory is limited to entering and moving to the centre of the room and remaining there until the crowd leaves. The young mother and toddler embody the third type—*skimming*. The group of schoolchildren embodies the sixth type—*children*.

The user activity script was refined during the project, as the design evolved and user testing was conducted. For the first user testing session, a forty minute script was developed. Segments of the script were revised after the testing session and a few more scenarios were created to address specific issues and areas of the design. A sample of the script is presented in Figure 6.7. It links the scenarios to the movement schemas and details the timing and directions for movement activity, positioning, orientation and spatial paths of the characters.

6.2.4 Movement schemas in Labanotation

At the same time as the user activity script was developed, a set of movement schemas was constructed to illustrate the changing spatial configurations and trajectories of the users during the scenarios. The movement schema diagrams were drawn using Labanotation floorplans devised for group choreography (Hutchinson, 1977), as introduced in section 3.4.2. They provide an easily learnt, at-a-glance view of the overall activity in the room in terms of the path, position, orientation and movement of multiple users in space and time. The use of Labanotation floorplans provides the same visual perspective on the movements of the audience as the viewpoint of audience activity for the system from the aerial view provided by the overhead infrared video camera.

By matching these schemas to the script of scenarios it was possible to map the movements of individual characters both within Bystander and in

	Time Min:Sec	Scenario and Key Events	Activity: Movement/Stillness	Spatiality: Path/Position/Orientation	Schema
Scenario 1	01:00	*Slow-moving, contemplative visitors*. Betty and Val about to enter empty room.	Betty and Val enter room together and stand fairly still looking around with heads turning.	Stand just inside entrance.	1
	01:30	*Head-poker*. Young teenager enters, blocked by Betty and Val, so leaves.	Young teenager enters room, then exits.	Just inside entrance.	2
	02:00	Betty and Val decide to stay and watch more.	Betty and Val walk towards centre.	Straight path towards centre.	
	02:30 - 04:00	They watch the flock.	Slowly turning to watch flock, taking 1 or 2 steps each way.	Stand in centre facing wall w2.	
Scenario 3	0:33:00	*Slow-moving, contemplative visitors*. Bob and Elena arrive.	Bob and Elena walk straight to centre.	Straight path towards centre.	14
	0:34:00	*Skimmers*. Mother and toddler enter.	Mother and toddler enter, holding hands. Toddler runs around pulling the mother around.	Path around perimeter.	15
	0:35:00	*Children*. Group of 12 young school children arrive.	Lots of motion everywhere!	Constantly changing paths.	16
		Exit and re-entry of some children.	Running in and out of entrance.	Paths in and out of entrance.	
	0:36:00	Mother and toddler leave. School group leave.	People moving towards entrance.	Many paths towards entrance.	17

Figure 6.7 Excerpt from the user activity script for scenarios 1 and 3. Note that movement schema 2 is in Figure 6.8, movement schema 15 is in Figure 6.9 and movement schema 16 is in Figure 6.10.

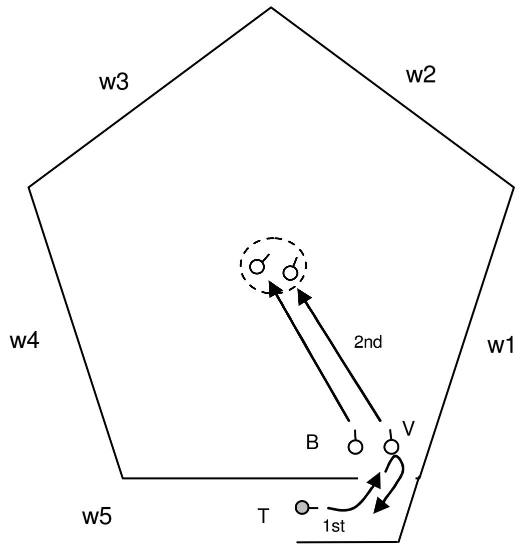

Figure 6.8 Movement schema 2 showing a head-poker

relation to other characters participating in the experience with them. This enabled us to ensure that the interaction with others that has been identified as defining of user experience of interactive art works, previously described in section 6.2.1, was represented within this design tool. Most importantly the movement schemas provided us with a way to visually represent findings from the user studies so these could be used to drive the testing and evaluation of the developing Bystander system. The movement schemas also assisted with enactment of the script as they provided visual markings of the spatial and social interaction between visitors, complementing the textual descriptions of the scenarios.

Figure 6.8, Figure 6.9 and Figure 6.10 are examples of such schemas, drawn from a set of twenty one. Refer to the legend in Figure 6.11 for an explanation of the notation symbols used here. The movement schema in Figure 6.8 corresponds to the part of the first scenario where a head-poker attempts to enter the room. The spatial trajectories have been numbered to show time sequential phrases of movement. In the first temporal phrase, the teenager (represented by the grey pin labelled T) attempts to enter the room but is blocked by Betty and Val (represented by the two white pins labelled B and V respectively), who are standing just inside the entrance. In the

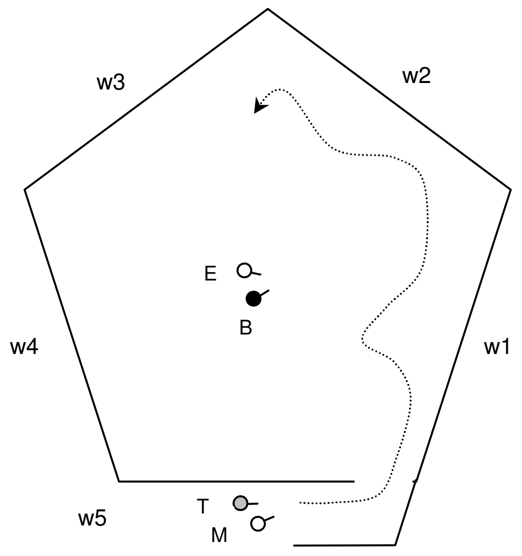

Figure 6.9 Movement schema 15 showing skimmers

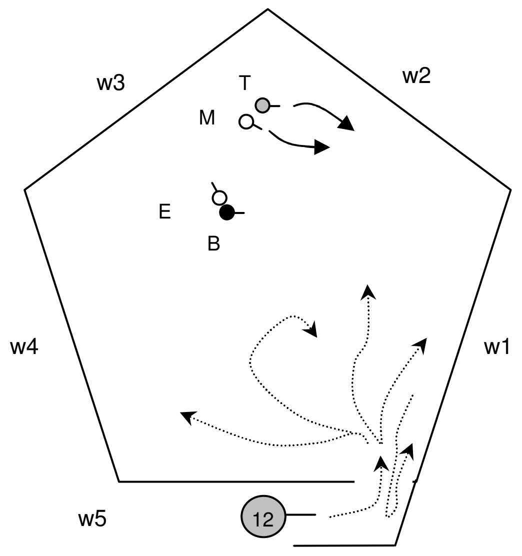

Figure 6.10 Movement schema 16 showing a group of children entering

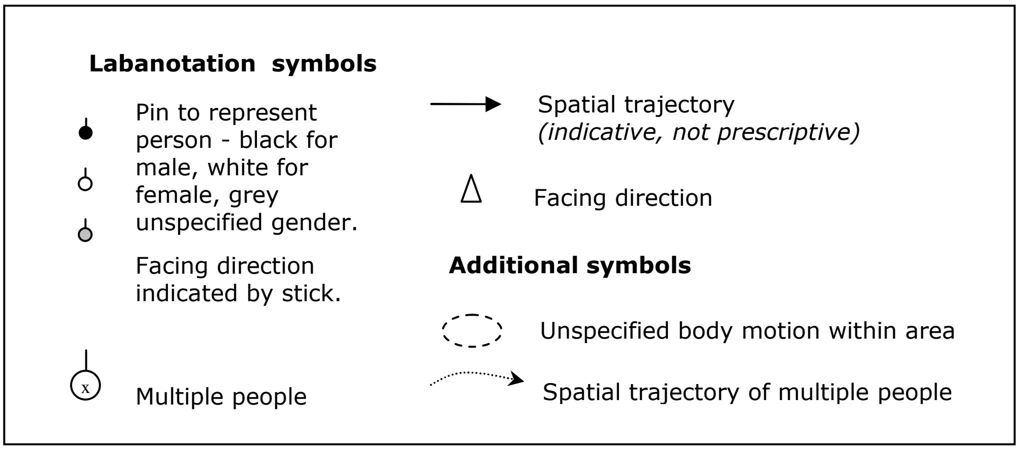

Figure 6.11 Legend for Labanotation symbols

second temporal phrase, Betty and Val move towards the centre of the room and stand there facing wall, w2. The dashed zone around them indicates that they are not standing completely still, but move around a little and talk to each other within a small area.

The movement schema in Figure 6.9 corresponds to the first part of the third scenario where a mother and toddler enter the room and proceed to skim around the edges. The room is already inhabited by the two characters, Elena and Bob (represented by the white pin labelled E and the black pin labelled B), standing near the centre of the room, facing walls w1 and w2. The mother and toddler (the white pin labelled M and the grey pin labelled T) enter the room and move around the periphery near the walls, w1 and w2.

The movement schema in Figure 6.10 corresponds to the second part of the third scenario where many people with lots of activity are present in the room. A group of 12 schoolchildren (represented by the big grey pin with the number 12) enter the room over a period of 60 seconds and disperse throughout, some exiting and re-entering. The characters, Elena and Bob (represented by the white pin labelled E and the black pin labelled B) remain where they are, facing away from each other. A mother and toddler (the white pin labelled M and the grey pin labelled T) move around the periphery near wall, w2. It is interesting to note that once relatively large numbers of people are in the room, their exact position and path becomes less significant to the system which is tracking the density, distribution and motion of people, rather than following their individual trajectories. As a result, indeterminate paths representing one or more people can be shown on the schema.

We needed to augment the standard Labanotation symbols with a few of our own to enable us to represent, for example, undifferentiated body movement or motion within a bounded area (see the dashed ellipse in Figure 6.8) and multiple people moving (see the dashed line of the trajectory in Figure 6.10). This was important firstly because the artistic authors of Bystander wanted audience presence and stillness to encourage revelation of the content and increased activity and motion to result in less coherent and more turbulent presentation of the content. Body movements (be they gestures, postural shifts or locomotion, etc.) were treated as motion in the room: a source of disturbance. Secondly, the designed sensitivity of the input system was such that it was oblivious to the exact nature of any movement in the room. We did not always need to be specific about the way a particular person moved their body. More relevant, was the fact that they were moving to some degree within some spatial bounds. During enactment, the person was free to improvise this movement, within the structure provided by that person's character and scenario. Given this rule of thumb, scenarios with many people can be depicted more roughly in a schema, as the need for precision lessens.

6.2.5 Suchman's analytic framework as a design tool

The design tools discussed so far—movement-oriented personas, movement-oriented scenarios, user activity script and movement schemas—were then linked together through another design representation, termed the *interactivity table*. It presented the script of scenarios of audience activity alongside the corresponding machine behaviour, so we could systematically examine the design of the interactivity.

We adapted Suchman's analytic framework to fit our particular design context, as follows. In Suchman's original framework (see Figure 2.1), the interaction between the user(s) and the machine is framed in terms of the resources available, or not, to either side. We followed the principle used by Suchman of presenting the actions and available perceptual resources for both human user and machine, but in a slightly different fashion, one more suitable for the purposes of exploring and mapping the interactivity between users and machine when human movement is direct input.

One of the drivers for the way the table was organised was related to the nature of the input data. A single overhead video camera was selected as the sole input device. The input to the system is a raw video stream of an overhead view of the room. This raw video stream can be processed in many ways to derive other kinds of data, depending on how we wish to interpret the input. Because of the diffuse nature of the input data, it is not straight forward to separate out actions of the user that are available, or not, to the machine. This separation is dependent on design decisions regarding choices of input technology and interpretation of input data. For Bystander, what became of issue was the machine perception and interpretation of moving bodies in the room. This of course stems back to design conceptions of movement and assumptions about user behaviour and the interpretation of that behaviour.

The matching of audience and system behaviour and perception allowed for the mapping of action and response, where appropriate, from both the user and the system perspectives. The user or audience perspective was broken down into columns labelled *Scenarios and Key Events*, *Audience Activity: Movement and Stillness* and *User Perception*. Brief descriptions of each scenario, characters and key events were provided. Audience activity was described in terms of audience behaviours, as well as specific details of position, orientation, direction of movement, degree of movement/stillness, spatial paths and configurations within these specific scenarios of use. These characteristics were further detailed in the corresponding visual movement schemas. The User Perception of the exhibited work described what various characters could perceive or of what they took notice. The User Perception column was used to speculate on what the users might be perceiving of the system behaviour in the form of its visual and sonic outputs. It was not used for prescribing user behaviour. Actual experiential data of user perception of the system behaviour could be gathered during user testing and evaluation to validate or extend understandings of user behaviour. To that end, we could confirm what the users perceive, for example, how noticeable are the transitions and changes in the system behaviour and what effect do they think their actions have on the system?

The machine or room perspective was broken down into columns labelled *Machine Perception*, *Room State*, *Flock/Sound Behaviour* and *Design Questions*. Machine Perception described what the system detected as input—basic data included the presence and position of individual figures and the degree of motion of people. Room State referred to one of the four states that the system could be in. Flock/Sound Behaviour described the nature of the system output in terms of the flock, the set of images and texts revealed and the sound effects. The Design Questions column allowed us to highlight areas of contention within the emerging design.

The resources available to the machine for perception of the user action, was determined by the video data input device. As the movements of the users were supposed to influence the behaviour of the system, it was a matter of deciding what particular aspects of the movement to detect and interpret. In the final design, the system detected presence, position, density of moving bodies and degree of motion in the space. It was the interpretation of the audience input data that continued to remain open in the design through several iterations. Presenting the design questions regarding the mapping of audience input to system response within the analytic framework of the *interactivity table* meant that they could be continually addressed as the design evolved.

One of the original uses of Suchman's analytic framework was the identification of breakdowns or misalignments between user actions and machine detection and interpretation. In this project, user testing during development was the primary source of identifying misalignments (an option Suchman did not have). At the same time the interactivity table enabled reasoning about what was available to the users and the machine to resolve identified misalignments.

I will now discuss in some detail how the *interactivity table* enabled the designers to continually interrogate the nature of, and refine the design of, the interactivity. The first and third scenarios introduced earlier are now presented in the form of the *interactivity table*. It is presented here in two separate tables purely for formatting reasons. The *Time* column connects the two tables. In practice, it is a single table in landscape format, with the *User Perception* and *Machine Perception* columns side-by-side. Figure 6.12 contains the audience or user perspective and Figure 6.13 contains the room or machine perspective. Links are included for the movement schemas corresponding to each scenario.

The first scenario begins with Betty (see persona, Figure 6.4) and her friend, Val, entering the space. When they first enter, they stand fairly still just inside the entrance, looking around to watch the flock revealing images and text on the wall opposite. At this point in time, the system should detect two figures and transition to state 1, where the flock changes in some way but still coherently presents images and text. A design question is, what is considered 'still'?

The second scenario involves a young teenager attempting to enter the room. But the entrance is blocked by Betty and Val, so the teenager leaves. The question arises for the designers, as to whether the young teenager (category of audience behaviour—a 'head-poker') is detected and registered by the system as a presence that will affect the subsequent behaviour of the system. Then (at time 2:00) Betty and Val walk towards the centre of the room. The system should detect 2 figures moving towards centre. A design question is, is this sufficient movement to trigger a transition to state 2? (See Figure 6.3 for a definition of the system states.)

Betty and Val remain in the centre for a couple of minutes, slowly surveying the exhibited material, turning and moving around occasionally. The system should detect 2 figures at the centre. The design question is, does position matter to the room? The system behaviour depends on the answers to the design questions. The description of the characters' movement in space and time is represented visually in movement schema 2 (see Figure 6.8).

	Time Min:Sec	Scenario and Key Events	User Perception	Activity: Movement/Stillness	Schema
Scenario 1	01:00	*Slow-moving, contemplative visitors*. Betty and Val about to enter empty room.	See flock revealing on wall, w2.	Betty and Val enter room together and stand fairly still looking around with heads turning.	1
	01:30	*Head-poker*. Young teenager enters, blocked by Betty and Val, so leaves.	What they see depends on whether or not the room perceives the head poker	Young teenager enters room, then exits.	2
	02:00	Betty and Val decide to stay and watch more.	See flock moving, some images and text unfold.	Betty and Val walk towards centre.	
	02:30 - 04:00	They watch the flock.	See flock moving, more images and text unfold.	Slowly turning to watch flock, taking 1 or 2 steps each way.	
Scenario 3	0:33:00	Bob and Elena arrive.	Watching flock slowly reveal images and text	Bob and Elena walk straight to centre.	14
	0:34:00	Mother and toddler enter.	Mother and toddler not taking in much.	Mother and toddler enter, holding hands. Toddler runs around pulling the mother around.	15
	0:35:00	Group of 12 young school children arrive.	Bob and Elena notice dramatic transition of flock and reveals as the room becomes more chaotic.	Lots of motion everywhere!	16
		Exit and re-entry of some children.		Running in and out of entry.	
	0:36:00	Mother and toddler leave. School group leave.	Bob and Elena notice flock calming down.	People moving towards entrance.	17

Figure 6.12 Audience Perspective—Interactivity Table, Scenarios 1 and 3

Time Min:Sec	Flock/Sound behaviour	Room State	Machine Perception	Design Questions
01:00	Flock coherent presentation on wall, w2.	State 1.	Detection of 2 figures, some motion.	What is considered 'still'? Standing still may realistically translate to slow, peaceful, gentle body movements and locomotion within a very small area.
01:30	Flock coherent presentation.		Ingress of 1 figure.	Has this person been detected? May want dead zone at entry.
02:00	Does it change?	State change?	Detection of 2 figures moving towards centre.	Is this sufficient movement to trigger a state shift to state 2?
02:30 - 04:00	Flock behaviour depends on answers to design questions.		Detection of 1-2 figures at centre.	Does position matter to the room?
0:33:00	Flock coherent presentation	State 1.	Ingress of 2 figures	
0:34:00	Depends on state change.	State 2?	Ingress of 2 people. Detection of 2 figures moving. Detection of 2 figures fairly still.	Does the history of presence and activity in the room have any bearing on the system behaviour?
0:35:00	Flock very disturbed.	State 4	Ingress of 12 people.	The activity of hyperactive children enables transition to state 4.
			Egress and ingress of x people.	
0:36:00	Flock semi-disturbed.	Transition to state 2.	Egress of 14 people within 30 seconds.	What is the transition like?

Figure 6.13 Machine Perspective—Interactivity Table, Scenarios 1 and 3

The third scenario begins (at time 33:00) with Bob and Elena arriving in the room. They walk to the centre of the room and remain there watching. The system should detect two figures and transition to state 1, where the flock changes in some way but still coherently presents images and texts. One minute later (at time 34:00), a mother and toddler enter. The toddler drags the mother around the perimeter of the room. The system should detect two more figures and possibly transition to state 2. A design question is, does the history of presence and activity in the room have any bearing on the system behaviour?

The next event (at time 35:00) is a group of 12 young school children arriving and running wildly around the room. The system detects the ingress of 12 more figures. It transitions to state 4, where the flock is very disturbed. Bob and Elena notice a dramatic transition of flock, image and text reveals as the room becomes more chaotic. Over the next minute, several children exit and re-enter the room. The system detects the egress and ingress of several figures. At time 36:00, all the school children and the mother and toddler exit the room. The system detects the egress of 14 people within 30 seconds. It transitions to state 2, where the flock is less disturbed. Elena and Bob notice the flock calming down. A design question is, what is the transition like?

6.3 Enacting design representations of moving bodies

User testing was conducted with the design team and typical users during the development of Bystander. The primary aims of the user testing sessions were firstly, to verify the robust functioning of the system for various combinations of audience activity, secondly, to test the ideas for interactivity built into the current prototype and thirdly, to gain insights into the user experience of the system. Each iteration of testing was focused on the aspects of user experience that were possible, given the current form of the prototype environment. Enactment of the user activity script was used to drive the user testing. Details of how the user testing sessions were set up and conducted follow.

Two user testing sessions were conducted using a temporary test room housing the working prototype in its exhibition format. The actual form of the test room evolved over the two iterations of testing. In the first testing session, the pentagon-shaped test room consisted of three contiguous curtained walls; the other two walls and the entry to the room were marked on the floor with masking tape. The visual display consisted solely of a circling flock of white particles with no photographic images or text. There was also no sound linked to anything that was happening within the room. The focus of user testing was thus directed to the users' engagement and response to the flock, the physical shape and size of the room and the interaction with other people. In the second testing session, the test room became more like the final form of the environment, with close to full image, text and sound content, but with placeholders for the images. The focus of testing expanded, from that covered in the first session, to also include the users' engagement and response to the images, texts and sounds. The user testing sessions were videotaped from two perspectives—one fixed camera was discreetly located in a corner of the room and one roving camera was operated by one of the researchers inside the room. Video capture of scenario enactment through the overhead infrared video camera provided a source of audience input data for informing the mapping of audience behaviour to system behaviour.

For each testing session, a group of people representing the users were required to act out the user activity script. These people included members of the design team and people outside the design team that were typical of the expected audience. Participants were provided with the user activity script and the set of linked movement schemas that described a sequence of scenarios over a forty minute period. Characters were allotted to each participant and they were briefed on the purpose of the script, their roles in playing out the script and how to follow the movement schemas. During actual enactment, the participants were directed through the script to ensure their positioning, orientation, speed and spatial paths corresponded to the scenarios. They were free to improvise their actual behaviour and

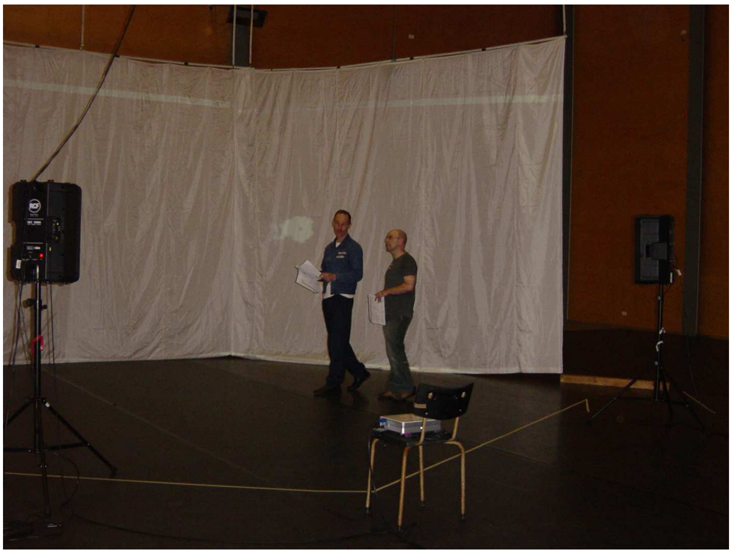

Figure 6.14 Scenario enactment in a full-scale prototype environment with the characters, Betty and Val

movement, as long as it remained faithful to their character and the scenario directions. Figure 6.14 shows a photograph of the scenario enactment with the characters, Betty and Val, played by two members of the design team.

Directly after the enactment session, users were interviewed about their experience of Bystander. The interviews were videotaped. The interview data was analysed to understand the range of experiences and nature of engagement with Bystander. I particularly took note of the relations between people moving (and staying still) and the nature of their engagement with the system. Some of these findings were fed back into the design of the system. The three major findings from the user testing sessions relevant to this thesis were the value of enactment and immersion for design reflection-in-action, the importance of situated understandings of the notions of presence, movement and stillness and an understanding of the relations between movement, stillness and audience engagement in Bystander. Each of the findings will be discussed in more detail in the following sections.

6.3.1 Enactment and physical immersion for design reflection-in-action

Two experiential methods of design reflection—*enactment* and *immersion*—proved critical for grounding the conceptual design and providing situated points of reference for resolving design issues. Prior to the scenario enactment, much of the conceptual exploration of audience-room interactivity was speculative and ungrounded. The user testing sessions provided the design team with opportunities to directly experience a full-scale working prototype, drawing on felt, sensory experience through scenario enactment and immersion.

Some researchers have found value in the acting out of scenarios by improvisation-trained theatre actors (with designers observing and interjecting) rather than walked through by designers and users (e.g., Howard et al., 2002). Our experience of designing Bystander highlighted the importance of the designers themselves being involved in the scenario enactment, with the designers role-playing as users (Burns et al., 1994; Buchenau and Suri, 2000; Brandt and Grunnet, 2000). The use of personas and scenarios from the very beginning of the project gave the design team a way of orienting to the user experience. Taking on various personas allowed the designers to disengage from their own immediate concerns and roles and take on the life of another person. This enabled them to perceive and engage with the prototype environment in different ways. The persona descriptions provided a background and structure for character immersion, which was intensified with the particular expressive bodily and movement characteristics of that persona. The use of personas helped members of the design team to elicit different experiences of the interactive work and physical space. One member expressed that her experience as various personas generated interest for her in the content in different ways. The movement-oriented scenarios then provided direction and structure for exploring and engaging with the environment and for orienting to the user experience. As another member articulated, "The scenarios brought very strong ideas and intuitions about user experience ... some surprising revelations from being in a role and being in a scenario." In our case, direct experience of the moving body in relation to other bodies, in the envisioned situation of use, enabled designers to access tacit understandings and qualities related to bodily experience. For us, scenario enactment provided a structuring device for designers to experience the kinds of movement and activity of multiple users in Bystander.

The designers' physical immersion in the working prototype vitally grounded their understandings of the emerging design and provided opportunities for "reflection-in-action" (Schön, 1983). This physical immersion gave them a felt, bodily understanding of the interactive work which was not possible until a full-scale prototype was available. I extend Schön's notion of "reflection-in-action" to explicitly acknowledge the role of the experiential, moving body in design reflection of interactive, immersive spaces that utilise human movement as direct input. We can experience and evaluate the prototype design through actively sensing, feeling and moving in the space, in interaction with others and the system itself. This kind of reflection arises in part from a felt, bodily experience; from learning anchored in a sensory experience of a visual, aural and kinaesthetic nature. When the experiential, moving body is one of the design materials, it becomes imperative for designers to develop understandings of the emerging design that are anchored in their own sensing, feeling and moving bodies (Buur et al., 2004; Jensen et al., 2005; Larssen et al., 2007a). In this way, imaginings of potential interactions and experiential opportunities within the specific interactive work are brought back to the realm of actual bodies, always situated and socially constituted, with distinctive perceptual and motor abilities that enable and constrain the possible kinds of interactions and experiences.

6.3.2 Situated understandings of notions of presence, movement and stillness

This lived experience of immersion in a working prototype by the design team resulted in a refinement of our shared understandings of the specific interactive nature of Bystander. A number of issues regarding the design could now be more fully explored and understood, in particular, notions of presence, movement and stillness. Notions of presence, movement and stillness, in relation to real, human bodies, remained speculative during the design process and could only be fully understood through iterations of user testing with a full-scale prototype. The important thing to note is that these notions are constituted by the particularities of the system in its situated use. These same questions (e.g., "What is stillness?") are raised by researchers in the area of computer vision and computerised human motion analysis (Pers, Vuckovic, Dezman, and Kovacic, 2003).

What counted as presence in the space?

The user studies had found that activity around the entrance to the space needed to be addressed separately from the rest of the space. This was because some gallery visitors could just peek in or enter only briefly and then leave again. There were design questions that needed to be asked about what actually counted as presence in the space itself. The working assumption had always allowed for sensors to be placed at the entrance but these were dropped completely after the first scenario enactment on the basis that entry clearly did not equate with presence and presence could be more appropriately sensed by other means.

How would people move in the space?

This remained an open question until immersion in the full-scale working prototype was possible. Once changing configurations of people were present in the Bystander room, it then became evident that certain patterns of movement were emerging as described in section 6.3.3. These observations of the patterns of movements in relation to audience engagement specific to Bystander then tentatively grounded some of the assumptions that we had been using regarding how people would move in the space and complemented the understandings of audience behaviour drawn from the user studies. It was not until exhibition of the completed work and observations of actual visitors that we could know with conviction how people would move in the space (see section 6.4).

What constituted stillness in the space?

The artists' intention for the work was that audience stillness equated with a more contemplative and attentive engagement with the content. Other interactive works often encourage the opposite relationship—for example, a design driver for the interactive furniture installation, *Un-Private House*, included encouragement of visitor social interaction and activity through interaction with the exhibit (Omojola, Post, Hancher, Maguire, Pappu, Schoner, Russo, Fletcher, and Gershenfeld, 2000). This raised the question of what constitutes stillness, as people are rarely ever completely still in these environments. User studies also found that stillness can sometimes be associated with a lack of engagement when, for example, people are ignoring the exhibited work to talk to each other about something else (Kan et al., 2005). We needed an understanding of stillness that was defined in relation to people's experience of the content and behaviour of the room. The motivations for movement identified from user testing (see next section for details) indicated that audience engagement with the content did not necessarily correlate with physical stillness. A range of motion/stillness was observed for individual audience engagement with the work, if we take engagement to be indicated as a visible attention to the presented content. This range of motion/stillness included standing on the spot, shifting of weight, turning of the head, turning on the spot and walking in various directions, to maintain visual connection with the material. What was revealed here was the problematic nature of equating stillness with increased audience engagement for motion-sensing, interactive works.

6.3.3 Movement, stillness and audience engagement

The scenario enactments provided the design team with an extraordinarily strong sense of the physical and social aspects of the audience experience and how these related to the patterns of movement arising from the scenario enactment. A range of motivations for moving in relation to engagement with Bystander was identified from the interviews with users. Different people had quite different experiences regarding how, where and why they wanted to move or position themselves in the space. There was a tension between moving into the centre and moving to the periphery or corners, motivated by the set of factors below.

Moving to a position to keep the visuals in front

Each of the five walls was 4.5 metres wide by 3.4 metres high. Images and texts of varying sizes were dynamically displayed on the walls. Some people found that they needed to move a fair distance away from a given wall in order to have the content in full view. People tended to locate themselves in a position that allowed them to easily view the current set of images and texts, sometimes moving backwards to keep the visuals in front. Based on these findings, it was decided to constrain the display of the set of images and texts to three of the five walls at a time, so that a person could more easily take in the full set of images and texts in order to make sense of it.

Following the flock by moving around or watching from a fixed position

Some people were drawn to following the flock as it circled around the room, either by moving around the room to follow the flock or watching it from a fixed position. A small number of people reported suffering from vertigo if they fixated for too long on following the flock circling around the room. As a result it was decided that the speed of the flock should be slowed down sufficiently to avoid any ill effects.

Moving closer to the location of spatialised sound

The soundscape and dynamic sound effects were played through a set of five speakers to provide spatialised sound in the room. Some people moved toward or turned to look at the location of the source of sound if it seemed to be behind them.

Positioning of people in relation to others and physical characteristics of the space

The dimensions of the pentagon-shaped room (7 metres wide) produced a fairly contained space. This restricted to some extent the available paths of movement and positions for comfortable viewing, particularly when large numbers of people were present in the space. When a small number of people were present in the room, people were freer to wander at their leisure or take up a comfortable viewing position in the room. In contrast, when the room was filled with people, and especially with active children, it became more difficult for individuals to appreciate the work and find a comfortable viewing position. An individual's line of sight was often interrupted when there were many people in the room—this finding raised questions about varying the flight path of the flock relative to how many people were in the room.

What this analysis revealed was that the patterns of movement of the audience were predominantly *patterns of watching*. At this stage in the user testing, it was unclear what the influence of others in the space had on a person's experience of the interactive work, as the scenario enactment dictated to a large extent the relations between audience members.

6.4 Exhibition—how did visitors move?

The completed work was exhibited to the general public at Performance Space, Carriageworks, Sydney, Australia in August 2007. The patterns of activity and movement of actual visitors were observed and analysed from video recordings of the output of the overhead infrared video camera. The direct output of the infrared video camera fed into the EyesWeb (Camurri et al., 2000, 2003a,b) system for processing of the audience input data. A computer monitor displayed the screen for the interface to the EyesWeb system. The video data was a recording of this screen, showing the movement analysis treatment by EyesWeb of the audience activity.

Only small numbers of people visited the exhibition. A total of one and a half hours of video footage was recorded of visitor presence in Bystander.

This footage was transcribed and analysed with a focus on the movement activity and engagement of visitors. The results of the analysis were organised into a table showing over time, the movements and positioning of people, the category of audience behaviour and patterns of watching. A visual representation of the movements and positioning data was drawn in Labanotation floor plans. A 1 minute 46 second excerpt of the table is presented in Figure 6.15. It covers a range of movement-related audience behaviours and patterns of watching. The associated Labanotation floor plan is illustrated in Figure 6.16 (see Figure 6.11 for the legend). A catalogue of the patterns of watching is presented in Figure 6.17. These patterns of watching indicate the relations between movement, stillness and audience engagement. In this case, audience engagement is observed and interpreted as visual connection with the visual elements of Bystander, namely the flock, images and text haikus. Figure 6.18 shows a series of three stills of actual visitor activity taken from the overhead camera aerial view.

Visitors tended to enter the space and find a position for viewing the exhibited work. Many people stayed in one spot, only turning their head or torso to follow the flock or shifting images and texts. Some people moved often, walking forwards, backwards or sideways to find a better or different viewing position. When new people entered the space, the people already inside shifted their positions to accommodate the newcomers. This spatial distancing between people was amplified if they appeared to be strangers. When only one or two people were in the space, they tended to stand in the centre of the room. Most people exhibited very few expressive or large movements and tended to adopt a physically quiet manner. Some people remained physically still except for the occasional shift of weight or turn of the head. Others could not stay still for long and shifted position often, shifting weight, self-touching and fiddling with paper or parts of their clothing. Less common, yet observed, behaviours included sitting or lying down to survey the exhibited material. Unusual behaviours included a young woman closely following the flock as if in a dance and two young children running around inside and diving onto the floor. Two girls made a concerted effort to test the interactivity by swinging their arms around for extended periods. Another

Duration (sec)	Time (min:sec)	Movements and positioning	Category of audience behaviour	Patterns of watching
a (57s)	5:30	Person p1 lies down in centre to view wall w4, with hands propped up behind head.	5 - serious, quiet, contemplative engagement	Staying still
	5:55	Head turns to view wall w1.		Turning head to maintain visual connection
	6:14	Rolls onto left side to view wall w2.		Turning body to maintain visual connection
b (17s)	6:21	Some one entering. Person p1 rolls over to right side to view wall w4		Turning body to maintain visual connection
	6:35	New person p3 stands just inside doorway.	2 - enter, stand for a while	
c (12s)	6:38	Person p3 starts to walk along wall w1. Another person p4 enters.	3 – skimming	
	6:45	Person p3 and person p4 talking to each other.		
d (10s)	6:50	Person p3 walks to other end of wall w1.		Moving to find better viewing position
e (4s)	7:00	Person p4 walks a little to left, close to wall w5. Person p3 walks next to wall w2.		
f (6s)	7:04	Person p1 rolls over to view wall w2.		Turning body to maintain visual connection

Figure 6.15 Excerpt of observed visitor movements and positioning, audience behaviours and patterns of watching. Each duration labelled a, b, c ... corresponds to a temporal phase in the Labanotation floor plan.

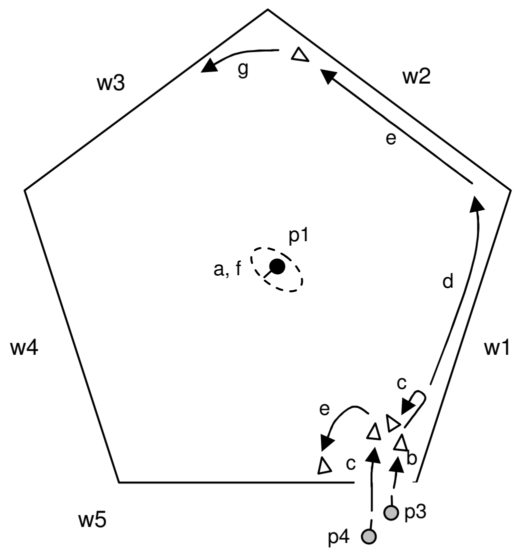

Figure 6.16 Transcription of visitor movements and positioning, drawn in a Labanotation floor plan, for a 1 minute, 46 second excerpt

1. Staying still
2. Shifting of weight
3. Turning body/torso to maintain visual connection
4. Turning head to maintain visual connection
5. Moving to find better viewing position
6. Moving to periphery
7. Moving to centre
8. Moving backwards to keep visuals in front
9. Moving towards visuals

Figure 6.17 Catalogue of patterns of watching: movement and stillness in audience engagement with Bystander

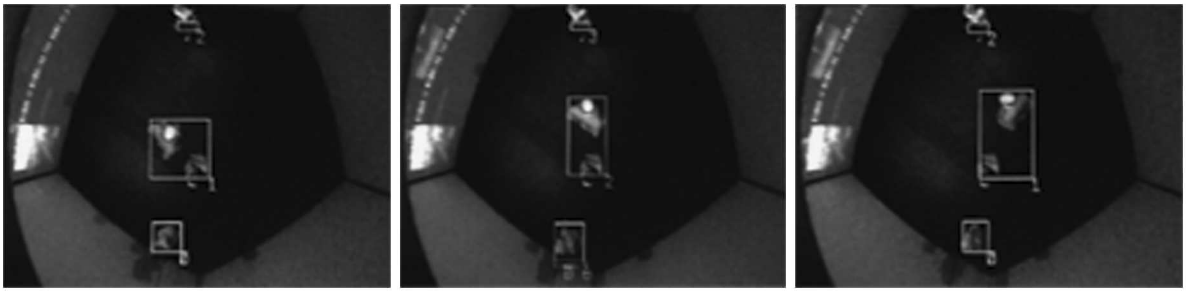

Figure 6.18 A series of three stills of actual visitor activity taken from the overhead camera aerial view

visitor brought a dog in with him.

The observation and analysis of actual visitors' activity and movement in the exhibition space from the video data revealed patterns of activity and movement very similar to what was generated during scenario enactment with the full-scale prototypes. We found that the observed movements of actual visitors were similar to the kinds of movements generated in the scenario enactments. The categories of audience behaviours from the user studies of other immersive spaces, which informed the scenario construction, were all observed to varying degrees in the actual visitors to the exhibited work. This finding served to validate (in the sense defined in Chapter 4) the construction of our personas, scenarios and movement schemas and added to the existing body of observations of visitor behaviour in gallery and museum exhibitions of interactive works (Lehn et al., 2001; Heath et al., 2002; Hindmarsh et al., 2005; Fernández and Benlloch, 2000). It should be noted that Carriageworks is a very specialised art exhibition space and not a general public space like a museum or a large public gallery. This meant that the movements and patterns of watching of the visitors tended to reflect the seriousness of engagement. In a large public gallery we may have obtained different or additional kinds of movements and patterns of watching.

6.5 Findings

The three design representations of moving bodies presented in this chapter—*movement-oriented personas*, *movement-oriented scenarios* and *movement schemas*—were extremely useful for exploring and reflecting on the kinds of movement people generate in interactive, immersive spaces like Bystander (Robertson et al., 2004; Loke and Robertson, 2005; Loke et al., 2005b; Robertson et al., 2006; Loke and Robertson, 2008b). The design representations provided direction and structure for designers to orient to the user experience. The movement-oriented personas and scenarios were informed by user studies of gallery and museum visitors to similar interactive, immersive spaces. The user studies identified six categories of audience behaviour that specifically focused on people's movements and passage in and out of the space. The scenarios were devised to include these audience behaviours in combinations that provided the full range of input to the system. This simultaneously ensured that the experiential effect for the audience could be gauged as well as the robust response of the system to the varying inputs of people moving in the space.

The movement schemas in Labanotation floorplans are a visual representation of the movements and spatial trajectories of the people in the space. They present an at-a-glance overview of the changing presence, position, orientation, spatial path and degree of body motion of the set of people in the space. Each schema is linked to a particular scenario and visually indicates the categories of audience behaviour that are captured in the scenario. The schemas provide guidance for scenario enactment on the scripted movements and social interaction with other people in the space.

The design representations of moving bodies also supported two experiential methods of design reflection-in-action—enactment and immersion—that were vital for grounding designers' understandings of the specific interactive nature of the work in their own sensing, feeling and moving bodies and for providing situated understandings of notions of presence, movement and stillness. The use of these methods and tools in the design of Bystander enabled us to cater for a range of user experiences for shifting configurations of people in the interactive, immersive space.

The 'workability' or validation through continued use of the design representations of moving bodies is supported by the successful insertion of these user-centred design tools into an otherwise non-user-centred design process. It is also supported by the uptake of the design tools into one of the artist's ongoing professional practice, as evidenced by this quote (Richards, 2006, personal communication).

> The designers' techniques, brought sophistication and clarity to the development, design and production stages of Bystander. My own creative and production processes have been strongly informed by the experience of working with these techniques.

The adaptation of Suchman's analytic framework, the *interactivity table*, was a useful design tool as it enabled us to explore, interrogate and reflect upon the developing design of Bystander. It integrated the scenarios of user activity and movement with the system behaviour and framed the interactivity in terms of the resources available to both user and machine for perception of the other's action. It framed the design questions and issues within the scenarios of user activity and machine interpretation and response, ensuring that any design assumptions about user behaviour were made explicit and continually interrogated throughout the evolving design.

The patterns of movement and stillness of the audience in relation to engagement with Bystander were predominantly *patterns of watching*. A catalogue of the patterns of watching (see Figure 6.17) was derived from the analysis of actual visitor activity to the exhibited work in a public setting. These patterns of watching contribute to the existing literature on understandings of audience behaviour in interactive, immersive environments and gallery/museum settings.

Chapter 7

Project III. Falling into Dance

The third project continues previous work, with the aim of validating and extending the findings from the first two projects. One of the primary motivations was to extend the range and kinds of movement to be sensed, from everyday movement (in Bystander) and limited range of arm gestures (in Eyetoy) to more heightened and choreographed forms of movement. More complex forms of movement were examined, such as the action of falling and choreographed phrases of movement.

The primary aim of the third project was achieved through a *constructed design situation*, using a hypothetical, future system as a vehicle for further exploring how movement could be understood, described, represented, experienced and enacted in the design of such movement-based interactive systems. Unlike the second project, Bystander, there was no readily available design project in which to situate this work. Creating a constructed design situation enabled prolonged attention to and visibility of the design artefacts and their transformations throughout the project.

I chose to work with trained dancers and physical performers for their expertise in using the moving body as a design material (Schön, 1987). I saw the practices of dance, movement improvisation and choreography as a rich source of potential methods and tools that could be reapplied in this field of movement-based interaction design. A series of studies was undertaken to trial and identify a range of methods and tools for working with the moving body.

The first study was of the *falling* body by skilled movers. What is it to fall? The action of falling is a common occurrence in our movement patterns as children, but over time recedes from the movement repertoire of most adults, returning when we are old. We can take the action of falling for the purposes of 'making strange', moving into unfamiliar territory, stretching our everyday range of movement and experiencing a new, or revitalising an old, movement pattern and pathway. Using accounts of falling by skilled movers, we can question and re-examine our usual, everyday conceptions of falling. Skilled movers function as the ethnographic 'exotic'. New insights and understandings about the moving body in the act of falling can stimulate design concepts for new forms of movement-based interaction. Another motivation for studying the act of falling is that it is not part of the established movement lexicon in digital praxis. This makes it open for investigation, unlike gestural actions such as pointing and grasping, which are well known and researched in human-computer interaction and virtual reality (Poupyrev, Billinghurst, Weghorst, and Ichikawa, 1996; Bowman and Hodges, 1997; Pavlovic et al., 1997; Badler et al., 2000; Schiphorst et al., 2002; Brereton et al., 2003; Fagerberg et al., 2003; Kirk et al., 2005). Other kinds of movements could have been selected for the study and served the same purpose. The choice of falling is thus representative of other kinds of actions that can be sensed by a computer.

The aim of the study was to explore the act of falling from a first-person, experiential perspective *and* from an external, observational perspective, corresponding to that of the machine. Together the two accounts produce an understanding and description of the moving body in the act of falling that can act as a foundation for subsequent design work. The analysis generated a range of different descriptions and representations of the falling body. These included, from a first-person experiential perspective, accounts of the process and experience of falling and characteristic components of movement for describing the act of falling and from an external, observational perspective, movement sequences of the moving body, silhouettes of changing spatial shapes of the moving body and Laban Effort-Shape descriptions of the qualitative, dynamic character of the movement.

The second study explored ways of generating and choreographing movement. Methods that dancers, trained in movement improvisation and performance making, used to generate, devise and document movement were examined as sources of potential methods for technology designers. Spatial movement schemas (using Labanotation floor plans) and machine input schemas were trialled as tools for representing the movement choreography and corresponding interactive treatment, respectively. The results from this study contributed to a set of methods and tools for working with the moving body. These included methods for generating and choreographing movement and tools for describing and representing movement. The methods for generating and choreographing movement included scoring techniques from movement improvisation practices, working from image and text and working with parameters of speed, scale and direction. The tools for describing and representing movement included textual descriptions of movement motivation and choreography, visual representations of the choreographed movements in Labanotation, sequences of motion stills and Laban Effort-Shape analysis.

7.1 Study I—The falling body

This study examined the act of falling as a specific form of movement that is on the periphery of our everyday realm of movement and has a complex changing form through space and time. Interviews and physical demonstrations were conducted with trained dancers and physical performers to examine the process and felt experience of falling. These sessions were filmed on digital video tape and also recorded with a digital audio recorder for transcription purposes. The video footage and audio recordings were utilised as records of the session for later iterative analysis. Analysis was performed on the raw data from two perspectives—an experiential perspective and an external or machine perspective. The analysis generated a range of different descriptions and representations of the falling body. These included first-person accounts of the process and experience of falling, characteristic components of movement for describing the act of falling from an experiential perspective, movement sequences of the moving body, silhouettes of changing spatial shapes of the moving body, and Laban Effort-Shape descriptions of the qualitative, dynamic character of the movement. This set of descriptions and representations can be extended to any movement, not just falling. The results of the analysis are described in more detail below.

7.1.1 Interviews and physical demonstrations

Interviews and physical demonstrations were conducted with a set of eight participants. There were six female and two male participants. All participants were trained as dancers or physical performers in a range of dance and movement practices including acrobatics, butoh, contemporary dance, stilt-walking, physical theatre, Feldenkrais and improvisation. Each participant took part in a half-hour session that required them to physically demonstrate acts of falling using the bodily techniques in which they were trained. During this session, they were interviewed about the act of falling, specifically to determine the techniques for falling, the sensation of falling and how it fits into their practice, both in training and in performance.

Participants undertook their own warm-up prior to the demonstration. Each session began with the participants improvising their own movement and initiating acts of falling to the ground. After a few minutes, the interview began with the researcher asking questions and prompting clarification. Participants would answer verbally and quite often begin to move again to demonstrate aspects of the action/process of falling.

Accessing in-the-moment sensations

The participants would often repeat the action of falling to access in-the-moment sensations and to pay conscious attention to what they were doing while falling. Here is an example from participant 2's explanation. The text, in square brackets, describes the actual physical actions executed by the participant.

> But if you have energy that is going downwards—one way to get down, like another thing that might be interesting is falling into a roll, [falls

> into a roll] because then you actually kind of distribute the energy differently. Does that make sense? So even—something like—[falls backwards and rolls] that's actually ... because the energy becomes something else, I'm using the momentum, it actually sort of softens it ... that was probably more comfortable then. Or if I go [falls], it just sort of—if I try to stop it, like if I let myself splat, then I've got to stop the energy. And I guess that's also what I'm doing when I'm going in the other direction, I'm minimising the amount of force, by thinking that way—it's working against gravity, breaking up the amount of energy that's going to the ground, or something. I'm not sure.

For this particular participant, more awareness and insight into his process and sensation of falling were acquired as he continued to experiment with different ways of falling. He began the session by simply moving around and falling, without any conscious thought about how to do it, as evidenced in this quote.

> When I'm doing it I don't really think at all. I don't really go okay I'm making my body do this and this and this. I learnt how to do it and the patterning in my body is already geared towards certain things, that I know will make me feel comfortable or safe.

As the session continued, he was able to give more precise descriptions of his movement process, techniques and felt sensations. This was the case for most of the participants, with the exception of one professional dancer for whom verbal articulation of her technique became less accessible as the session progressed.

Learning a Technique

Some participants instructed one of the researchers in learning a given technique. This was done to gain more insight into breaking down the technique and to acquire a bodily understanding by the researcher. Here is an example of participant 8 teaching the technique of a shoulder roll.

So, the first thing is, if we just start like this [sitting on floor with legs stretched out in front]. So this is what we call a shoulder roll. So you can go either way. So what I'm going to do is—just have a look first. I'm going to put my arm out like this [right arm out to shoulder height], and turn my head that way [head turned to left and down], having a look at my left knee [rolls backward over right shoulder]. Look at my left knee—that's it. And back that way. [rolls forward over right shoulder]

So basically once you learn this, you can take it into a full run backwards. And you can go either way—if you feel more comfortable that way [rolls backward over left shoulder]. So, the thing about this technique, which is great, is that the back of the head—you avoid the back of the head on the floor [slaps floor]. It means you can roll at a great pace, without clunking your head. If you do a backward roll, it's very difficult—a straight backward roll, it's very difficult not to clunk your head.

Okay, let's go. This arm [right] goes out to the side, and this one kind of comes round like this—you look at your knee, you roll over. Go from sitting. And we'll go like this [rocks back with knees bent], and you can bend your knees. You can use that momentum. You're going to look at your left knee. [Researcher rolls back] Look at your left knee. Yep, that's it. Good. Try it again. So basically you just want to do that [tilts head down to left side]. The head sort of touches, but it's not clunking at all. I'm just using this [taps knee] as a guide. You can actually just look straight ahead. But then, at the last minute ... I'm actually looking that way.

So what we could do next, is go from standing. We're just going to take one step back like this [lowers to floor with right knee bent], put our hands down [on floor by side of hips], and then go over onto the knees, and push off the floor up to stand. That's it. Once we get that kind of smooth, we can start to do it from a walk. And eventually we could take it into running backwards. You can use a shoulder roll to come out of all kinds of fast-moving falls.

This excerpt illustrates the breakdown of the technique into a sequence of preparatory exercises. With learning to fall, one commonly starts on the ground and then works back up to initiate the fall from standing. In order to fall safely, we need to first establish familiarity with contacting the ground. After that we learn how to resolve the trajectory of the fall into the ground. Once this is achieved, we can then begin to execute the technique more freely in different situations. As participant 8 demonstrates here, this technique can be done from walking or running backwards.

7.1.2 Analysis from the experiential perspective

The raw data was transformed and analysed to gain an understanding of the act of falling as experienced by the people performing the movement. Written transcriptions of the interviews were taken from the audio/video records. The video footage was edited to produce a summary of each participant's demonstration and explanation of falling. These *video summaries* were useful for returning to a dynamic, visual replay of a particular participant's way of falling and function like selected transcripts as described by Jordan and Henderson (1995) in the use of video data for interaction analysis. The data was then analysed to produce two forms of experientially-based descriptions of the act of falling—first-person experiential accounts and a summary of participant descriptions organised into characteristic components of movement.

First-person experiential accounts

The written transcriptions were edited into a more compact form, termed a *first-person experiential account*. The first-person experiential accounts were reviewed with participants in a follow-up session to ensure that they were a faithful record and representation of their understanding of falling. Figure 7.1 contains a sample of excerpts from verbatim transcripts. The first-person experiential accounts and the video summaries fed into the next activity of analysing the salient aspects of the act of falling.

Participant 3. There's certainly a sense of great release in the upper body, as long as I have a basic arrangement of landing here and shooting out. (Be)cause I notice with this side, I think there are complications with falling first [slaps left thigh], so this [left arm pointing out to left and jabbing] - the order of things. There's also a lot of - I'm feeling fear, about doing it, I mean not great fear, but just enough to be kind of hesitant. You can't afford to be hesitant if you're going to be falling, I guess.
Participant 4. On a mechanical level, I guess I kind of take into awareness where my head is in relation to the rest of me. And I find that equilibrium with my head first I think. And then, in the act of falling, there's a relationship between where my head is and my pelvis, and my head and my feet, so that by finding a way where they can be in some kind of alignment I save myself. So I'm always kind of mapping where I am. As I'm going down, I let the legs and the arms catch some aspect and then, the passage into the floor is dispersed through the body.
Participant 6. It's an image of extension and then release, tension release. There's an idea of a, almost like a hook, or a long string from the clouds, at the head. And then it's been cut. And then the head is being pulled back up again. The cut gives that real weight to the body ... it becomes - an impact ... the most important thing is to have that image, so then you're imagining, if that's cut then it's a crumpling.
Participant 7. I get a lot out of just the sense of weight, so exactly that. So if that's [touching the crown of the head] being pulled up, I've just been strung up then this is an entire weightedness. You really try and get the sense of, like a sack of potatoes, really heavy in the body. This is being kind of hooked up there. And so then that really heavy feeling. Particularly in the fingertips, in the legs and the feet and the thighs and the butt, especially in the pelvis. I tend to work with slightly bent knees. To get a sense of that suspension.
Participant 8. Going off-centre (is the stimulus), which is something. Always finding in different situations of your movement, where you can find an off-centre moment, I suppose. And I guess talking about off-centre, it's like finding interesting configurations. Like before when I was collapsing, I could collapse by degrees. I'm actually just collapsing by small bits, as opposed to a big drop. And what I'm looking for when I'm doing it, is interesting configurations, that surprise me. What I find interesting, that's interesting [as he collapses incrementally]. And then, playing with the dynamics, I might, so how can I get from here up to standing, quickly or ...

Figure 7.1 First-person experiential accounts of falling

Characteristic components of describing the act of falling

Both the original footage and the summary videos were viewed multiple times to identify the salient aspects of the act of falling as experienced by the participants. Phrases uttered by the participants themselves were selected from the transcripts. These phrases reflected each participant's individual ways of articulating their understanding of their own movement processes. These phrases were then grouped into three characteristic components of movement, as defined below.

- *Movement process and technique*: The process of the movement and the technique for performing the movement are inter-related. Process is the dynamic unfolding of a bodily movement in space and time. The process may be split into distinct stages for a given movement, depending on the complexity of the movement. Technique is an established means for directing or informing the movement process.
- *Sensing and awareness—internal and external*: what senses are actively engaged and how; the senses include the visual, aural, tactile, and proprioceptive/kinaesthetic; awareness and relating of internal and external environment.
- *Felt quality*: the particular sensation or feeling as experienced in the whole or part of the body.

Each of these characteristic components will be elucidated with examples from the participants in relation to the act of falling.

Movement Process and Technique. The movement can be analysed as a process of the body changing relationally in space and time. This movement process can be broken down into a series of distinct stages, which are dependent on the particular movement being analysed. For falling, there are three distinct stages in the process of falling—initiating the fall, descending and contacting the ground. The technique for informing or directing the movement process is an intrinsic part of the performance of the movement.

There is a range of techniques, peculiar to the act of falling, for initiating the fall, controlling the descent and contacting the ground safely. These techniques can be broadly categorised as being mechanically based or image based. In mechanically based techniques, the focus and emphasis are on the order, organisation and sequencing of body parts in relation to each other and the environment as the movement unfolds. However, the conscious focus on the detailed mechanics of the movement lessens as the technique is mastered. As participant 8 explains, you "give over the rational; technique goes into automatic pilot."

Here are some examples of this category of technique for the three stages of falling. Participant 8 goes off-centre to initiate the fall, whereas participant 1 drops her weight vertically down to the ground. Participant 4 uses an internal muscular lift to slow down the descent and participant 1 controls the slide out to the side by extending the other arm away from the direction in which she is moving. Participant 2 contacts the ground safely by making the contact with the ground take the greatest amount of time and cover the greatest surface area of the body, whereas participant 3 releases any tension and softens into the floor. In general, all participants worked with softening into the ground as they landed.

In image based techniques, the focus and emphasis is on working strongly with the image to direct and inform the movement process. If you surrender fully to the image, the body follows. There is less attention given to specific body parts moving in a certain order. Participants 6 and 7 use the image of a string being cut from the crown of the head to initiate the fall and the image of the body as a bag of bones to descend and contact the ground. A different example is of participant 5's use of the image of being pushed purely to initiate the falling.

Sensing and Awareness—Internal and External. This characteristic component refers to the active sensing and awareness of one's body in relation to itself and to the external environment. The visual, aural, tactile, and proprioceptive/kinaesthetic senses are included here, but not taste and smell as they were not mentioned by any of the participants in this study. In regard to falling, it was interesting to tease out the relationship between the visual and kinaesthetic senses and to understand how they were utilised in the act of falling.

Protecting the head is crucial when falling. Looking at participant 4's first-person experiential account (see Figure 7.1), we can see that she is constantly mapping where her body is in internal relationship to itself. She first ascertains where her head is in relation to the rest of her body and then maps where her pelvis and feet are in relation to her head. In the act of falling, we draw continuously on our kinaesthetic sensing to know what the body is doing and how it is aligned at any particular moment.

The visual sense is predominantly used to check where one is in the space and in relation to others. The awareness of the external environment is reliant primarily on the visual sense. Participant 6 explains that "Visual sensing keeps me aware of the outside, otherwise I can become too internal". Participant 8 explains, "You need that visual to know where you are in the space, to remember what plane you are on, especially when you've thrown yourself off-centre." The two senses work together to provide an ongoing awareness of the internal relations and state of one's body in relation to the external environment.

Felt Quality. The felt quality of the movement refers to the sensation or feeling in the body. It is an inextricable part of any movement. It may be informed by the kinaesthetic sense; the sense that governs our self-perception of movement (Sheets-Johnstone, 1999a). Looking at an excerpt from participant 2's account, he separates out the felt quality of the *descent* from the felt quality of the *landing*. The text in italics indicates the descriptions of the felt quality.

> It's hard now ... but I'm trying to think about it before we started chatting, about what that feeling was ... *it feels very free* ... it feels like my body, *I'm letting go, I'm releasing*, I'm letting go of my body, I'm releasing my body, first from my leg I guess and then—the way I think about it is, I guess my head sort of feels like it's, I'm not holding my head or anything, it feels very much like it's, *like I'm a rag doll* or something. So it's just a release, and just release my body into the ground, sort of thing. And with that, the feelings that I kind of get aren't really emotive, but they're—oh, I'm trying to separate out the experience of actually doing it, the actual falling, 'cause once you've

> landed it's slightly different. And the feeling actually in the moment of falling is quite a—yeah you'd probably say it is *exhilarating*, but it's so quick. It's over in less than a second that I get more caught up in the actual—the landing. And the *clunkiness* of that [laughter]. So the experience of actually hitting the ground, that's not exhilarating! [laughter] That's something else.

Participant 3 provides a different account of the felt quality in the act of falling. For her it is a feeling of "suspension and precariousness, teetering over the edge—dissolving into that."

Figure 7.2, Figure 7.3 and Figure 7.4 present the range of participant descriptions of falling, sifted and organised into the three characteristic components of movement. They provide a condensed summary of the aspects of falling, as described by the participants themselves. What this analysis reveals is a diverse range of understandings of the process and experience of falling for these eight participants.

7.1.3 Analysis from the external or machine perspective

When considering the action of falling as input to a video-based motion sensor, it can be modelled and analysed from an *external* or *machine* perspective in many ways. A rudimentary baseline of representations of the falling body is presented to which more abstract and complex transformations can be applied.

Movement sequences were extracted from the video footage of each participant performing a particular instance of falling. These movement sequences allowed a closer analysis of the moving body in its trajectory through space/time. They were annotated with descriptions of the process and technique of falling. The movement sequences for participant 1 and participant 4 are shown in Figure 7.5 and Figure 7.6, respectively. The time between each image or snapshot in the sequence is 0.4 seconds.

A series of silhouettes was made from these movement sequences to draw out the spatial shaping of the body for different types of falls (see Figure 7.7

Participant description
Initiating the fall
P4 Finding pathways into the floor
P3 Finding steps to take you off-centre
P1 Momentum of dropping down
P2 I thought "just fall'"
P2 Release from the centre
P5 Like being pushed. An outside force.
P8 Going off-centre
P8 Finding interesting configurations
P1 Toppling like a rock
P6/P7 Image of extension and then release - like a string being cut
Controlling the fall
P4 Internal muscular lift to slow down
P2 Working in opposite direction to the fall
P1 You could even control that more by taking your weight to the opposite side
P8 Finding a way to support yourself down, with your hand
P8 Collapsing by degrees
P7 The cut gives that real weight to the body. Then it's a crumpling.
Contacting the ground
P3 Bodily technique is release on the floor
P2 An unfolding. Letting my body roll into the ground
P2 Relax and soften
P2 Making the contact with the ground take the greatest amount of time and cover the greatest surface area
P6 Different surfaces give different sensibilities
P5 Impetus of falling to the floor, and recovery
P3 Absorbing it in the joints
P3 Distal initiation
P3 The direction that you're moving in kind of pulls you out of just being - what not to do
P4 Let the legs and arms catch some aspect, and then the passage into the floor is dispersed through the body
P8 Rolling down the body
P8 If you don't let go and you've got tension, then you become a body full of angles that are all going to contact the floor and be really clunky
P7 Body is like a bag of bones

Figure 7.2 Characteristic component of movement—movement process/technique—for describing the act of falling, from an experiential perspective. Each description is labelled with an index to the participant, for example, P4 refers to Participant 4.

Participant description
P4 Always mapping where I am
P7 Aware of your body within a larger space
P4 Visual preoccupation can interfere with kinaesthetic sensing
P6 Awareness of others, their rhythms
P6 Visual sensing keeps me aware of the outside, otherwise can become too internal
P8 You need that visual to know where you are in the space, to remember what plane you are on, especially when you've thrown yourself off-centre

Figure 7.3 Characteristic component of movement—sensing and awareness—for describing the act of falling, from an experiential perspective. Each description is labelled with an index to the participant, for example, P4 refers to Participant 4.

Participant description
P3 Paradox of light and heavy
P3 Suspension and precariousness, teetering over the edge - dissolving into that
P5 Out of surrender
P1 A sensation of falling, but you're in complete control
P6 Sense of suspension
P6 Sense of weight, like a sack of potatoes
P2 Feels exhilarating, then clunky

Figure 7.4 Characteristic component of movement—felt quality—for describing the act of falling, from an experiential perspective. Each description is labelled with an index to the participant, for example, P4 refers to Participant 4.

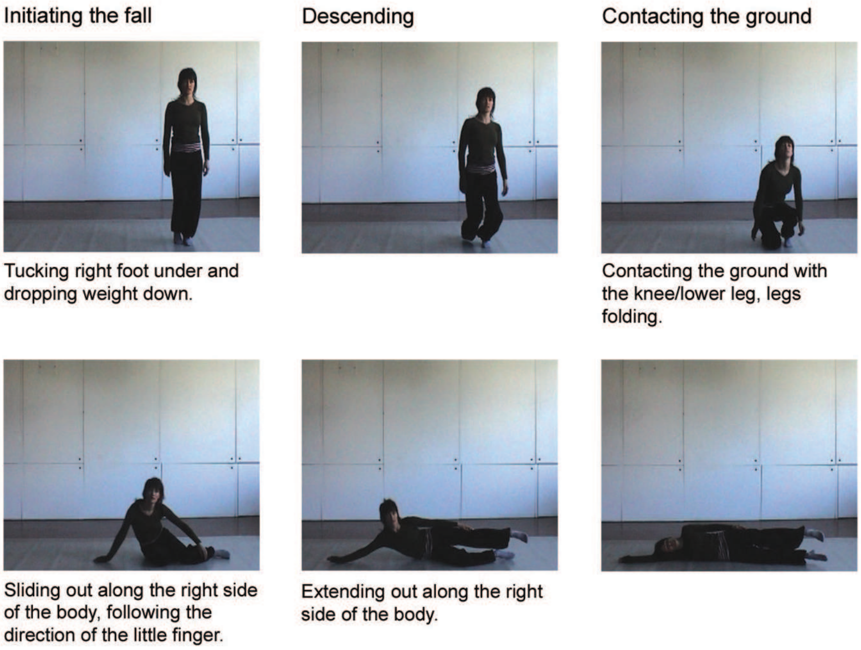

Figure 7.5 Movement sequence for participant 1 in the act of falling, annotated with descriptions of the process and technique of falling

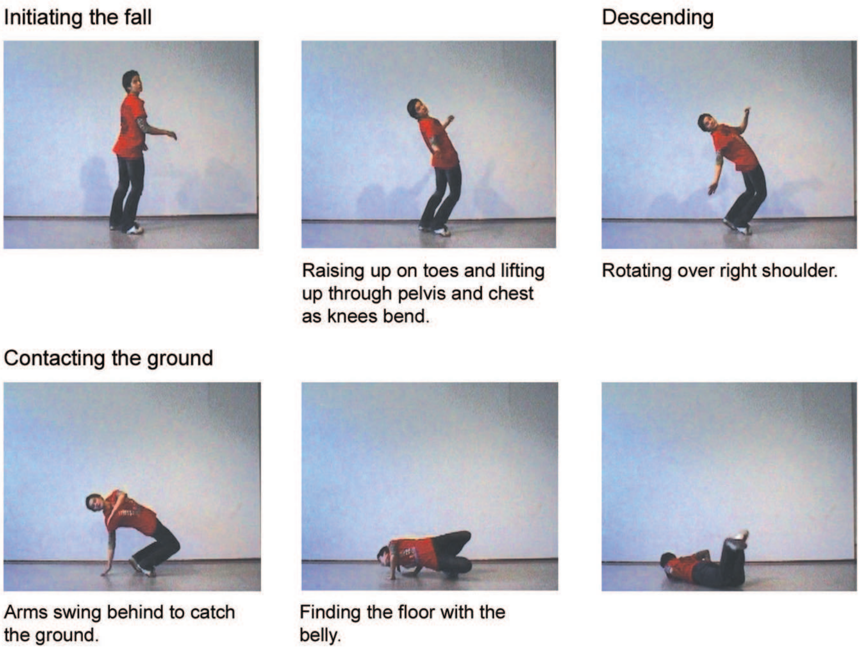

Figure 7.6 Movement sequence for participant 4 in the act of falling, annotated with descriptions of the process and technique of falling

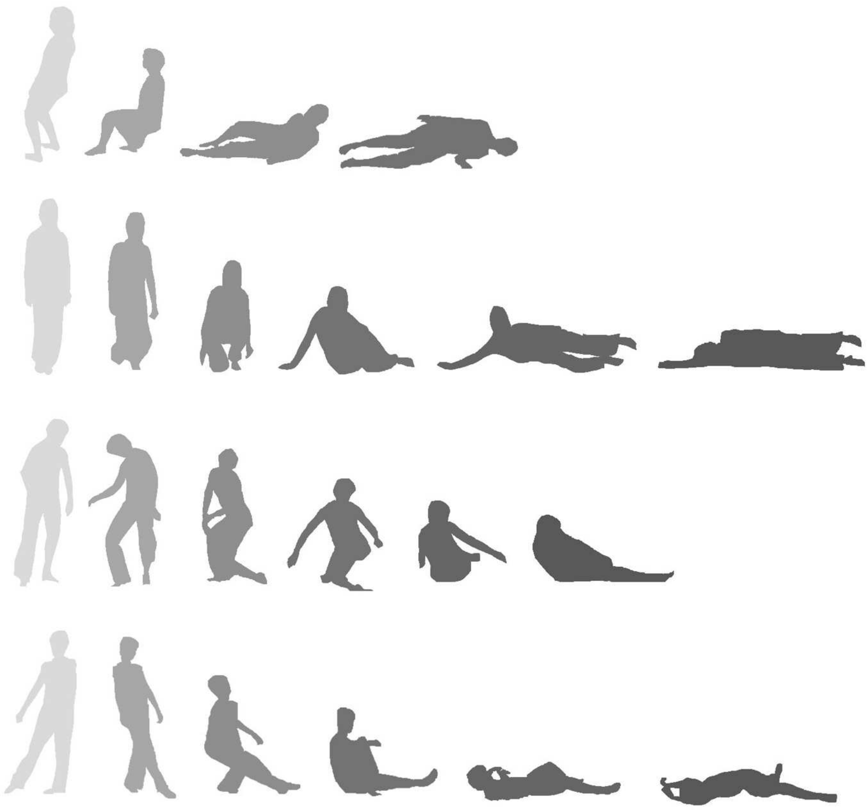

Figure 7.7 Silhouettes of participants falling

for a sample of participants). The intensity of the shading increases as the trajectory of the fall progresses.

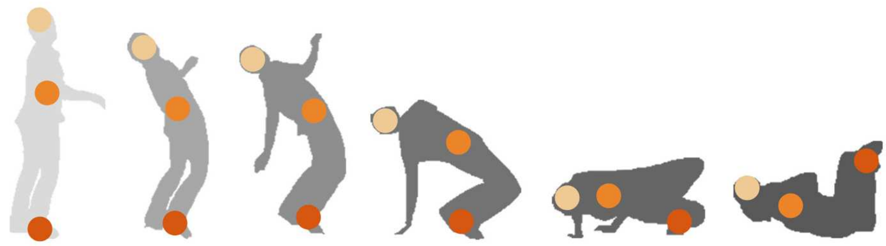

Figure 7.8 Mapping of changing positions of the head, centre of torso and feet for participant 4

From these two representations a range of different parameters can be derived. These parameters include:

- Trajectory of body
- Changing position and relation of body parts along the trajectory
- Distinct types of falls
- Dynamically changing pattern of spatial shaping
- Timing, rhythm
- Qualitative, dynamic character

Figure 7.8 shows the mapping or tracking of body parts over the trajectory of the fall. The changing positions of the head, centre of torso and feet are shown for participant 4. As for the movement sequences and silhouettes, each snapshot in time is spread out spatially in the representation so the body and any overlaid data can be clearly seen at that instant.

Figure 7.9 illustrates the dynamically changing pattern of spatial shaping for participant 4, where each snapshot in the sequence is overlaid on the previous one. The shade of grey deepens over time to indicate the progression of the movement.

The qualitative, dynamic character of the movement can be described using the Effort-Shape component of Laban's system of movement analysis. The spatial shaping of the body can be analysed in terms of what forms the body makes and the relation of the body to itself and its environment.

Figure 7.9 Dynamically changing pattern of spatial shaping for participant 4

The following two examples serve to illustrate the application of the Laban Effort-Shape descriptions.

The qualitative, dynamic character of participant 1's fall could be expressed as a sudden, smooth drop and slide, or in more evocative and metaphorical terms, like a stone plummeting and ricocheting. In this instance, the Effort is direct in Space, sudden in Time, free in Flow and strong in Weight for the drop to the ground, then light in Weight for the slide along the ground. The Shape is predominantly pin-like in form as the body begins standing erect and finishes on the ground extended along the central axis of the body. The Shape changes to a semi-contracted, ball-like form in the middle section of the trajectory as the legs fold to enable the descent to the ground. The Shape Quality is sinking during the descent, then spreading during the contact with the ground. See Figure 7.10 for a visual reference to these qualities.

The qualitative, dynamic character of participant 4's fall is suspended and buoyant within a controlled, circular descent. The corresponding Effort is indirect in Space, sustained in Time, light in Weight and bound in Flow. The Shape begins arc-like in form as the body arcs backwards in spinal extension through a curved trajectory towards the ground. It then becomes more screw-like as contact is made with the ground. The Shape Quality is sinking, retreating and spreading in the descent to the ground. As the hands and front of the body contact the ground, the Shape Quality changes

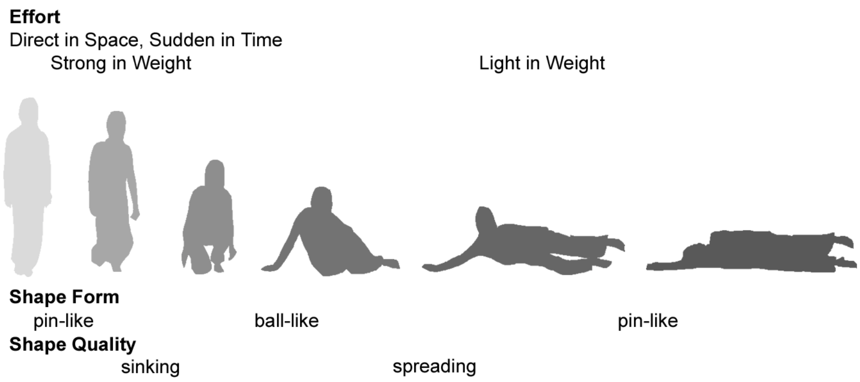

Figure 7.10 Effort-Shape description for participant 1

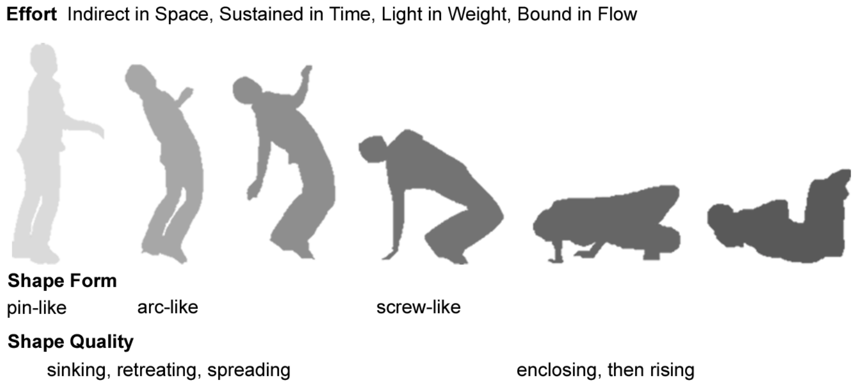

Figure 7.11 Effort-Shape description for participant 4

to enclosing, then rising as the fall is resolved. See Figure 7.11 for a visual reference to these qualities.

With any of this kind of movement analysis, the observation of other's movement is validated or confirmed through an enactment of the same movement by the analyst/researcher, whenever possible. It is not enough to have an intellectual understanding of the process and qualities of movement. This understanding must be complemented with a bodily understanding, which is acquired through actual movement enactment and experimentation.

Computerised motion recognition systems like EyesWeb exist that process the in-coming video stream using algorithms based on Effort-Shape parameters (Camurri et al., 2000, 2003a). The EyesWeb expressive gesture processing library offers modules for motion, space and trajectory analysis

(Camurri et al., 2003b). These kinds of systems are seeking to recognise the more expressive components of human movement. The use of LMA and representations emphasising silhouettes and spatial shaping of the body in this study fits well with this kind of computerised motion recognition system.

7.1.4 Findings

The analysis of the first study generated a range of different descriptions and representations of the falling body. From an experiential perspective, these included first-person accounts of the process and experience of falling and characteristic components of movement for describing the act of falling. The descriptions of the movement process and the felt experience of movement in the act of falling varied considerably across participants. This rich variation suggests unexplored opportunities for accessing the creative potential of the moving body in design work—preliminary exploration was then conducted in the second study.

From an external, observational perspective, these included movement sequences of the moving body, silhouettes of changing spatial shapes of the moving body and Laban Effort-Shape descriptions of the qualitative, dynamic character of the movement. These representations act as a bridge between the movements of people and the formulation of recognition algorithms.

The activities of the study, the data and the results of analysis were examined as sources of methods and tools for potential inclusion in the proposed design methodology of Moving and Making Strange. From this study of falling I identified a range of methods and tools that formed the beginnings of the design methodology. An early version of the methodology was first published in Loke and Robertson (2007). The methodology in its initial form contained two key areas: ways of accessing the experiential, moving body and ways of describing and representing movement. On reflection, a missing part of the methodology was methods for inventing and devising movement. These methods form part of the practices of *making strange* with the moving body. They provide ways of experiencing and exploring movement outside of the familiar or everyday. The second study in the series addresses this gap in the methodology by exploring ways of choreographing movement for use in the design of movement-based interaction. Choreography is defined here as the activity of generating, devising and documenting movement.

7.2 Study II—Inventing and choreographing movement

The primary aim of the study was to explore ways of inventing and devising movement for use in the design of movement-based interaction, by drawing on the practices of dancers and physical performers trained in movement improvisation and performance-making. A secondary aim of the study was to explore forms of representing the choreographed movements and the corresponding interactive treatments of the movements. I was particularly interested, still, in the act of falling and how it could be utilised both choreographically and interactively in these kinds of spaces. The same motivations hold for using falling, as given in the first study.

Two workshops were conducted with dancers who had previously participated in the study of falling and were trained in movement improvisation and performance-making. The first workshop was conducted with two dancers, Esther and Michael (pseudonyms), to explore the use of falling as input to an interactive space built on motion-sensing technologies.

The first finding from the first workshop was that techniques for generating improvised movement, such as *scoring*, could be useful in design exploration and enactment of movements for use in interactive systems. Scoring provides a structure for generating and devising movement based on a set of elements or parameters that can be varied as desired. For example, a simple score consists of three elements of walking, standing still and moving in place. Other parameters of speed, duration, timing, scale, focus, use of space and so on, can be added to the score.

The second finding from the first workshop proved critical to the success of the study. The session failed to produce adequate data for exploring interactive treatments of choreographed movements and the corresponding representations of both the movements and the machine interpretations of the movements. On reflection, the session was set up with too few contextual constraints for the dancers to work within, resulting in the production of dislocated fragments of choreographed movements that lacked coherency and significance. This highlighted the need for a *specific* and *well-defined context* or *domain* within which to generate meaningful movements, with regard to the *framing* of the activity of inventing and devising movement. This reinforced an earlier finding from Project I, a study of movements performed in interaction with Sony Playstation2© Eyetoy games, where the context of the games enabled people to perform meaningful movements. As a consequence of this finding, an iteration in research design was conducted to try to get the required data, by placing the research within a well-defined domain.

In order to focus specifically on the relation between choreographed movements and machine interpretations of those movements, a constructed design situation was set up involving the initial development of a choreographic work sited within a video-based, motion-sensing interactive space. The system needed to accommodate a range of human movement, from the ordinary, everyday movements of people to the skilled, choreographed movements of dancers.

A second workshop was held with two dancers, Esther and Gloria (pseudonyms). A fellow researcher also assisted with the workshop. The preparation, conduct and results of the workshop are described next.

7.2.1 The Divine and Bodily Experience

The finding from the first workshop demanded the need for a specific and well-defined context or domain within which to generate meaningful movements. To this end the design of the interactive space was structured and constrained in the following ways. The default physical and technical configuration for the space was a four-screen projection system and an overhead video camera for sensing the activity in the space. A series of four acts was conceived that would address different kinds of movement, different combinations of audience and performers and different models of interaction between people and the system. Two of the four acts are described in Figure 7.12. Act 2 was assigned to Gloria and Act 3 to Esther.

A theme was chosen for the work of *The Divine and Bodily Experience*. It was selected for being an abundant resource of bodily and movement experiences engendered by existing religious and cultural practices, considered to be culturally shared and familiar to people. The meanings and motivations for bodily actions, movements and postures could be informed by such practices. It also provided a richer, recognised context for acts of falling. It was hoped that this theme would provide sufficient inspiration for choreography of movement and imaginings of what the interactive, immersive space might look, sound and feel like. In a choreographic sense, there was room for artistic interpretation of the theme, rather than a stereotypical representation or reproduction of ritual movements. The point here is that the particular theme chosen is not significant in itself, but for its ability to generate meaningful movements and for its accessibility to performers.

An *inspirational resource kit* was given to the two dancers in advance of the workshop to assist with briefing, delineating and inspiring the choreographic work they were to bring to the workshop. The kit provided a set of thematic constraints and various resources for inspiring and documenting the choreographic work. However, they were free to interpret the thematic content and bring in their own interests and training. The specific religious practice of Buddhism was chosen as the thematic content for the kit, as much for the ready availability of images and texts, as for well-established traditions of cultivating transcendence through the body. The kit contained image tiles, evocative texts, movement description cards, floor plan of space (A3 size), CD of music/sound samples and written descriptions of the acts and scenarios. A photograph of the contents of the kit is given in Figure 7.13.

A set of initial scenarios was provided to seed the design work and to give some indication of the possible behaviour of the system in response to the activity of people in the space (a selection is presented in Figure 7.14).

Act 2. Ritualising the Space In this act there will be a mix of performers and audience in the space. The performers will be performing more choreographed, exaggerated movements than the audience and will be invoking a ritualistic atmosphere. The system will respond to certain configurations or trajectories of performers and to specific movements or gestures, by changing the visual and sound output in some way. The thematic content is concerned with rites and bodily forms of worship that occur inside temples.

Act 3. Swooning in Ecstasy This act is a continuation of Act 2, but now more heightened and dramatic acts of falling are introduced that symbolise succumbing to or uniting with the divine forces. As with Act 2, the system will respond to certain configurations or trajectories of performers and to specific movements or gestures, by changing the visual, sound and lighting output in some way. The thematic content is concerned with heightened, transformative states.

Figure 7.12 Description of acts 2 and 3

Figure 7.13 Contents of inspirational resource kit

Scenario 2. Four performers enter the space. They move slowly amongst the audience, repeatedly performing a Qi-Gong like movement. Sounds of chanting emanate from the space. The projected images are now from inside a temple.

Scenario 3. Two of the performers begin to whirl on the spot. This triggers an operatic voice. The other two performers are invoking the divine from above. Then they swoon and spiral to the floor, or slowly collapse, and remain there. This triggers a change in the projected images. They slowly rise again, using an image of being pulled up by a string from the crown of the head.

Figure 7.14 Scenario fragments—initial

These fragmentary scenarios would be reworked into a coherent account of the activity of the performers, audience and system after the workshop to reflect the ideas and decisions made during the workshop.

This use of scenarios continues and extends earlier research, conducted in Project II, into the production and use of *movement-oriented* scenarios for exploring the interactivity of interactive, immersive spaces based on motion-sensing technologies. These movement-oriented scenarios focus on the activity and movement of people (typically users as audience) in the space, described in terms appropriate to the kind of space under design. Here the focus shifts from audience to performers. This enabled the examination of more complex and choreographed kinds of movement, compared to the everyday.

In the workshop, the dancers presented and explained how they used the kit. Each dancer then demonstrated and led the other workshop participants in performing the choreographed movements. The workshop concluded with the group discussing and documenting possible interactive treatments of the choreographed movements. The activities of the workshop were filmed for later analysis.

The analysis of the data generated from the workshop and the results of the study are now described in two sections that reflect the core activities of

(1) *generating* and *devising* movement and (2) *documenting* choreographed movement, accompanied by machine interpretations of the movement.

7.2.2 Generating and devising movement

This section describes the analysis of the activity of generating and devising movement. The development of each dancer's movement ideas and choreography is described, including their use of the resource kit for inspiration and documentation. Their different ways of choreographing movement were carefully examined to identify methods for generating and devising movement that could be useful for technology designers.

Using the kit

Esther worked with most of the resources from the kit—the evocative texts, the image tiles, the movement description cards, but not the music (she preferred to add music later, as she felt that music can dictate the choreography too strongly). She began by selecting a few lines of text that triggered a movement idea. She documented her movement choreography ideas on the large sheet of cardboard by using the image tiles and textual descriptions to build a thread or sequence. Interestingly, she placed all of it around the outside of the square representing the physical space of the system and did not use this space. A photograph of her use of the kit is in Figure 7.15. Here are selected quotations describing her way of working with the kit,

> It was selecting one of those (evocative texts) that I felt—something that gave me a movement impulse. Even the word 'suspense' ... I started to think about suspension, and that was something from the last session that I was working with, that sense of teetering and suspension. We live in a constant state of suspense and ambiguity. So from suspense, I thought of acts of suspension and trying to relate that to my act, which is *Swooning in Ecstasy*. I started to think about how something would build into some kind of swooning, or ecstatic state. I then started to look at the tiles, and I guess the images—I didn't choose them aesthetically, it was more about whether I had some kind

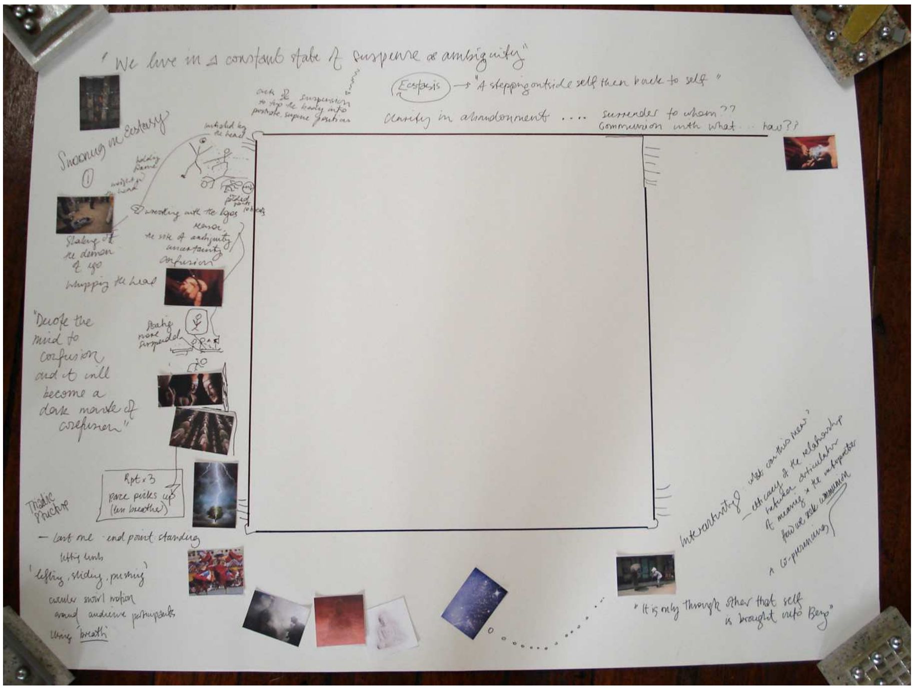

Figure 7.15 Esther's use of the kit for documenting her choreographic and movement ideas

> of feeling state from them. This was the first one I chose, which was quite interesting. These two. And in a way I feel a kind of generative narrative—not a narrative, but something that may relate to how the movement unfolds.
>
> I started to think about what swooning meant for me, in a way. I came up with this 'clarity in abandonment'—how that can also be translated in a movement sense. But then I started to move into things like, the Heideggerian idea of 'ecstasis', which is the Greek, stepping outside yourself, and back to self. It's his idea of temporality. And so that gave me a movement, kinaesthetic sensation about this stepping out, stepping in. But also the clarity in abandonment, so having a movement form that still has a form, still quite grounded, but the sense of surrender and abandonment that happens in swooning. Especially in the choreographic sense, I didn't want it to be a mess of—

Looking at her documentation, we can see that it is organised around the images and concepts. The focus is on the body movement arising from these images and concepts. A series of stick figures depicts the sequence of movements in a choreographic phrase, noting the temporal development in terms of pace and repetition.

Gloria did not use the kit after the initial inspection of the contents. Instead she chose to develop her movement/choreographic ideas from the movement practice of Qi Gong (also spelt chi kung). She made brief notes in a small book. At the beginning of the session she transferred these ideas onto the large sheet of cardboard and found some image tiles that resonated with her ideas. A photograph of her use of the kit is given in Figure 7.16.

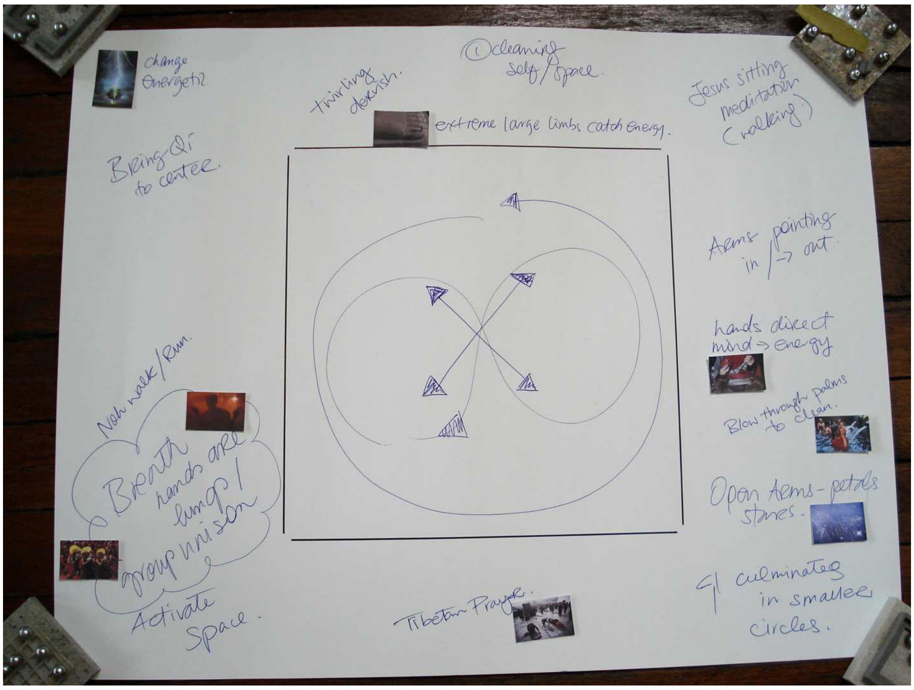

Figure 7.16 Gloria's use of the kit for documenting her choreographic and movement ideas

Here is a selected quotation describing her way of working with the kit,

> Well that was sort of interesting. I did it the way I usually do things. Having seen this initially and liked it, not knowing how I was going to use it, and did it my usual way. And then, it actually fits. It's good, all these pictures which I wasn't actually thinking about when I constructed it, well actually that one fits that, and that one fits that.

> So it sort of worked in retrospect.

In response to a question of what was her normal process,

> Just to do things. Feel it, do it and then scribble it out in a notebook. But more to actually feel what it means, as opposed to write it down. But then this (the images in the kit) actually made it quite easy to understand.

Looking at Gloria's documentation using the kit in Figure 7.16, we can see the ideas she had for structuring space and generating movement. There are strong spatial shapes and directions for moving in trajectories through space, for example, circle, figure-eight and radiating out from centre to corners. The body/movement ideas are predominantly expressed as a combination of gestures, energy (chi) flow and imagery. The image of a woman bathing with her hands held up to her face in a prayer position is annotated with the text "blow through palms to clean". The image of a star-studded sky is annotated with the text of "open arms—petals, stars". These two examples indicate the type of gesture and imagery to be used in performing these movements. As yet there is no specific sequencing or development of these movement ideas into a definitive choreography.

The dancers' quite different ways of working with the kit brought out the multiple functions of an artefact in design—in this case, the set of image tiles played a dual role: an *inspirational* role in terms of provoking and generating ideas and a *documentary* role in terms of providing an alternative form of articulating or presenting an idea. The movement/choreographic ideas are expressed or articulated through a combination of text, sketching and images. This documentation using the kit can then act as a resource for returning to the original ideas as conceived by the dancers.

Methods for generating and devising movement

A closer examination of Esther's process of using the kit reveals a method of generating and devising movement that begins from multiple entry points: a piece of text or a word can invoke a movement impulse or inspire thinking

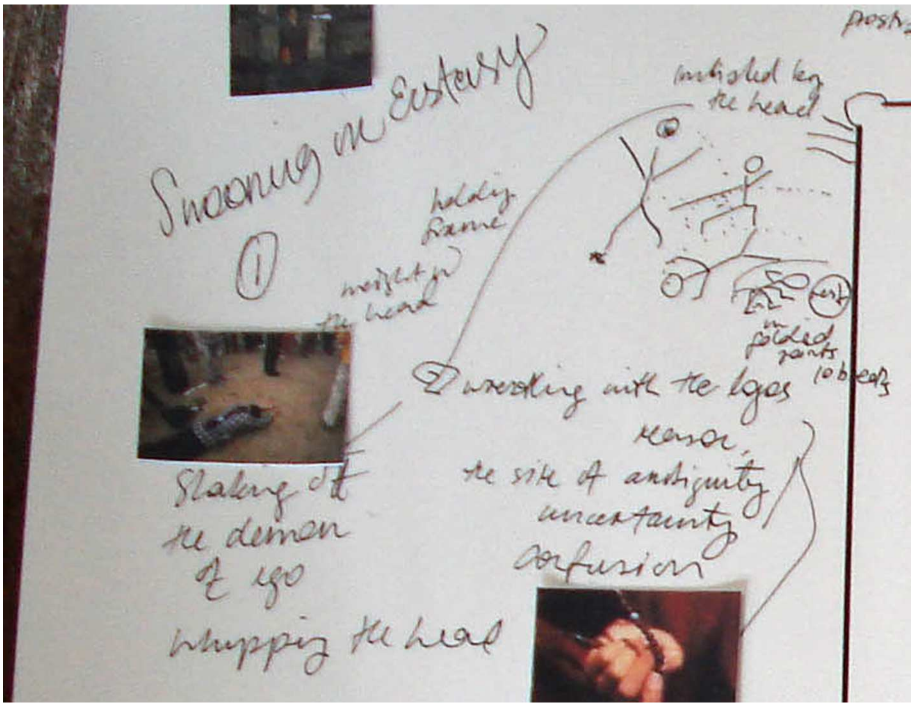

Figure 7.17 Close-up of Esther's use of the kit

on related or associated concepts; images can evoke a feeling state. A concept can give rise to a movement or kinaesthetic sensation that can then be developed choreographically.

A specific example illustrated in Figure 7.17 begins with an image of a woman lying prostrate on the ground. The annotated text by Esther reads "slaking of the demon of ego, whipping the head". The next reference to the head is "wrestling with the logos", which then leads to the stick figures depicting a sequence of positions, where the movement transitions are initiated with the head. In this example, there is a clear connection between the original image, the concepts and the movement choreography.

An examination of Gloria's process of choreographing movement (from observations and video footage) reveals another method for devising movement. She begins with a movement phrase taken from a traditional movement form. She then experiments with variations of the movement phrase through actual movement improvisation. She uses imagery and energy qualities to inform the character and shape of the movement. She uses her intuitive sense of feeling things in the body to decide what works for this choreography. For example, with the "blow through palms to clean" gesture, she begins by breathing into the hands in prayer position, focusing on the rhythm of the breath. She plays with the hands expressing the expansion and contraction of the lungs, varying the scale and speed of the hand movements, until a certain arrangement of gestures and body movements is reached. The point of crystallisation of the choreography is not explicitly explained by her other than as a confirmation felt in-the-body through the integrated acts of sensing, feeling and moving.

Gloria's method of devising movement highlights a crucial aspect of working with the moving body, which is to have an understanding of movement 'in-the-body'. Movement possibilities are experienced and developed through the sensing, feeling and moving body. Rather than simply observing the movements of another, the imperative here is for designers to explore and perform the movement ideas, so that they can acquire an understanding of movement that is rooted in their own felt, bodily knowing.

7.2.3 Documenting movement

This section describes ways of documenting choreographed movement and the accompanying machine interpretations of that movement. Descriptions and representations of the movement choreography and interactive treatment were produced both during and after the workshop. A sample of these descriptions and representations is presented here to illustrate the range of textual descriptions and visual diagrams that can be used to capture the salient aspects of the moving body, for use in the design of movement-based interaction. Each of these descriptions and representations is discussed in terms of the role they can play in the design of movement-based interaction.

Directions for choreographed movement

These are descriptions of the inspiration and direction for choreographed movement, resulting from the workshop. This set of written descriptions of the choreographed movement for the performers was refined into a more coherent account from the original wordings and ideas contributed by the dancers. The refined version was reviewed by the dancers to ensure that it was faithful to their original work and nothing had been omitted or misinterpreted. These descriptions are a written record of the choreographed movement, that details the specifics of how the body moves, the motivation for the movement and the kind of act in which the movement is contained. They provide directions for performing the movement. They overlap in part with the scenarios. An example from Act 3 is presented in Figure 7.18.

Act 3 - Swooning in Ecstasy, Section 2

The four performers begin to weave around the space, performing a *lifting limb* motif with both arms. One arm lifts the crook of the elbow of the other arm, then slides along the arm and then pushes the limb away in some direction. At certain points in the space, a performer may drop from standing to the *sitting buddha* position in front of an audience member. Or a performer may slowly crumble to the ground from standing. They slowly rise again, using the image of being pulled up by a string at the crown of the head.

The lifting limb motif of lifting, sliding, pushing works in a triadic structure. It is something that builds in pace over three repetitions.

"It's a lift, slide, push to work into a swooning. That way you can start working around people (audience members). It's probably a bit more chaotic: staggering, fleeting energies. It is possible for the performer to work three levels with the `lift, slide, push' phrase, once developed."

The final phase becomes a sitting in front of people - like the buddha. It is a weighted drop from standing into a squatting position. An aura of stillness is maintained until the position is shifted.

Figure 7.18 Directions for choreographed movement

Movement sequences

The movement sequences are a visual representation of the key movement phrases and postures of the body in the form of a series of images. They serve as visual reminders of what the movement looks like: the organisation of the

Figure 7.19 Movement sequence of Act 3, Section 1, with Laban Shape analysis

body and its parts, the shape of the body and the relationship of the body to its environment. They correspond to the directions for choreographed movement of the performers. They were extracted from the video footage and photo documentation taken in the design session. An example of a movement sequence with Laban Shape analysis is given in Figure 7.19. It corresponds to the original choreographic ideas documented in Figure 7.17. The performer is sequencing through a series of four postures. The transitions between the postures are initiated by the head. The last transition is rolling back up to a standing position. Only the postures are shown in the movement sequence here. The Shape analysis is explained in the next section.

The movement sequences may be useful for informing the design of the interactivity in terms of what the system can see or detect and its subsequent response, as required in the design of the input-processing-output loop, the traditional task of HCI. Comparison of the movement sequences over time can assist in determining the points of transition or differentiation, which in turn can be used for triggering specific system responses. It should be noted that the video footage of the choreography was taken from a side-on view rather than an overhead view due to the lack of technical infrastructure to support the mounting of an overhead video camera. This substitution does not detract from the process advocated here for exploring the mapping from an experiential movement perspective to a machine perspective. For any concrete design situation, the appropriate views would be acquired.

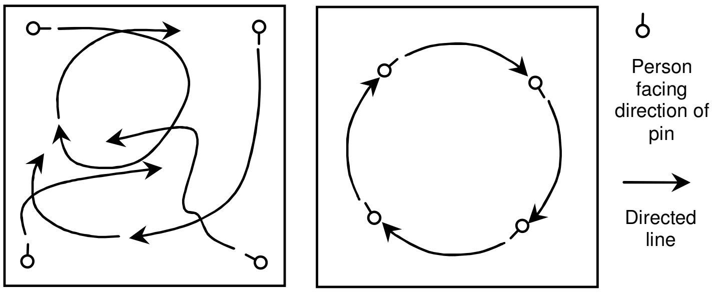

Figure 7.20 Spatial movement schemas for Act 2, Section 1

Shape analysis

The Shape analysis is a description of the changing forms and spatial qualities of the moving body. The Laban system of movement analysis was used to analyse and describe the spatial shaping of the body in relation to itself and to its environment (Lamb and Watson, 1979). See Chapter 3, section 3.4 for more details on the Laban system. An example of Shape analysis for a movement sequence is given in Figure 7.19. The Shape Form for the key postures varies from ball-like for the first posture to wall-like for the second posture where the performer is in a splayed position on the ground, then back to ball-like as the performer contracts back to a crouching position. The Shape Quality is sinking and enclosing for the first transition from standing to the crouched posture with leg extended in front. It becomes spreading and advancing as the performer dives into the splayed position belly-down. It then becomes enclosing as the performer gathers her limbs in towards her centre and pushes off into a crouch.

Spatial movement schemas

The spatial movement schemas are based on Labanotation floor plans (Hutchinson, 1977). They provide an at-a-glance view of the changing configurations and spatial trajectories of people present and moving in the space. They focus predominantly on the activity of the performers. Audience can be added to the schemas or mapped out on a separate overlay. An example of a pair of spatial movement schemas for act 2, section 1 is given in Figure 7.20. The diagram on the left shows the trajectories of four performers entering from the four corners of the space and weaving around the space. The diagram on the right shows the four performers moving along a circular path in a clockwise direction.

Machine input schemas

Machine input schemas illustrate the choice of machine inputs, detection and interpretation of the input and the corresponding system response. For example, for the first section of the second act, *Ritualising the Space*, it was decided during the workshop that the incoming video data would be processed to detect the speed and shape of the trajectory of the performers. In response, the system would produce a wall of sound that intensified with increasing speed. Over time, the trace pattern of motion that emerges is circular in shape. This is just one possible interpretation of the performers' movements that focuses on the speed and shape of the trajectory produced by their locomotion through the space. The 'Collecting Qi' gesture was also nominated for detection, as the spatial shaping of the body was considered to be easily differentiable from the rest of the movements. The nomenclature for the Shape analysis descriptions could be referenced here, to provide a language for mapping between the experiential movement perspective and the machine perspective. The gesture itself could also be loaded with symbolic meanings, which could be expressed through visual or aural forms of system output. An example of a machine input schema diagram for Act 2, Section 1 is presented in Figure 7.21.

7.2.4 Findings

Preliminary work on generating and choreographing movement as part of the second study resulted in a key finding which was critical to the success of the study. With regard to the framing of the activity of generating and devising movement, the need for a *specific and well-defined context or domain* within which to generate meaningful movements was highlighted. This reinforced an earlier finding from the first project, where the context of the Eyetoy games

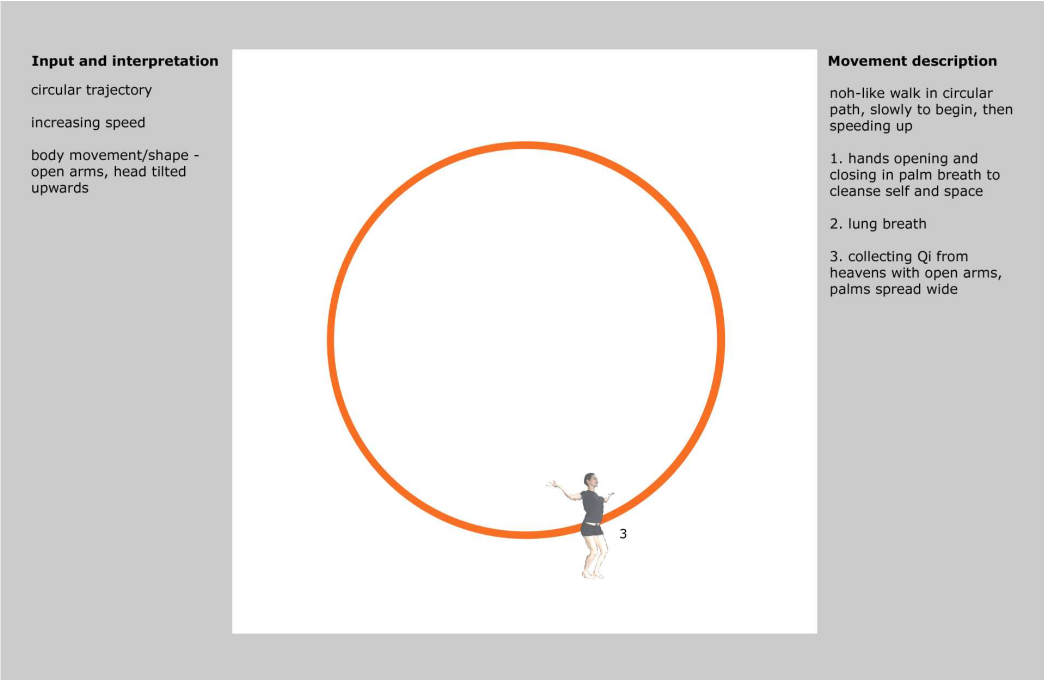

Figure 7.21 Machine input schema for Act 2, Section 1

enabled people to perform meaningful movements.

The continued application of Laban's system of movement analysis and notation in this project confirmed the usefulness of the system for describing and visually representing relevant aspects of movement to be treated as input to motion-sensing technologies, in particular Labanotation floor plans and Effort-Shape analysis.

The results from the second study contributed to a set of methods and tools for working with the moving body. These included methods for generating and choreographing movement and tools for describing and representing movement. The methods for generating and choreographing movement included scoring techniques from movement improvisation practices, working from image and text and working with kinetic variations of speed, scale and direction and qualities of movement. The tools for describing and representing movement included textual descriptions of movement motivation and choreography, visual representations of the choreographed movements in Labanotation floor plans, sequences of motion stills, Laban Effort-Shape analysis, spatial movement schemas and machine input schemas. The results of this second study were then examined for potential expansion or refinement of the design methodology of Moving and Making Strange, described in Chapter 9 and published in Loke and Robertson (2008a).

7.3 Findings

The primary aim of the project was to validate and extend the findings from the first two projects. This was achieved in the following ways. Firstly, the Laban movement analysis and notation system was trialled in both studies. In the first study, the Effort-Shape analysis was applied to individual bodies in the act of falling. The Effort analysis had previously been applied in the Eyetoy project, where individual body movements were predominantly gestures of the arms. The act of falling provided a more complex, total body range of movement for analysis. The spatial shaping of the body became more significant and offered adequate data for Shape analysis. In the second study, Shape analysis was applied to individual bodies and Labanotation floor plans were used to describe the paths of movement and spatial configurations of multiple bodies. The Labanotation floor plans had previously been used successfully in the Bystander project. The Effort-Shape analysis was repeatedly trialled as it can potentially act as a bridging representation between the movements of people and computerised motion recognition systems that detect the dynamic, qualitative aspects of movement.

Movement-oriented scenarios were used in Bystander to represent the activity and movements of multiple people. Here they were used to first seed the choreographic work with initial descriptions of performers moving in the space and then later to detail the choreographed performer activity.

Suchman's analytic framework was not used in this project, as the details of the machine behaviour were outside the scope of the project. The hypothetical system of the second study was used only to provide a context for the generation of choreographed movement and speculations about possible interactive treatments, so that suitable representations could be constructed.

The act of falling was chosen for its potential to bring new insights into the use of movement in the design process. It operated as a device for making strange, by working with skilled movers as the ethnographic 'exotic'. The knowledge gained of their process and experience of falling resulted in a new appreciation of the diverse movement experiences available within a single action and suggested avenues for potential use of falling in motion-sensing, interactive works. The research methods utilised in the data collection and analysis could be a useful approach for designers wishing to investigate other movements, not just falling, for the purposes of making strange and creative design work grounded in experiences of movement.

Chapter 8

Reflection on Tools

This chapter is a reflection on the development and use of two potential design tools trialled throughout the research projects. The two strands of investigation were (1) the adaptation of Suchman's analytic framework as a design tool and (2) the application of Laban movement analysis and Labanotation to the design of movement-based interactive technologies. The two potential design tools reflected on here are part of the contributions of the thesis.

8.1 Suchman's analytic framework as a design tool

This section discusses the adaptation and use of Suchman's analytic framework in the Eyetoy and Bystander projects. It shows the potential of the framework to be used as a design tool and to be adapted to design situations involving movement-based interactive systems.

8.1.1 Eyetoy

In the Eyetoy project, Suchman's analytic framework was applied to the analysis of the interaction between the player and the Eyetoy system, for the two games chosen. The framework was adapted to enable a close focus

The User			The Machine	
Actions not available to the machine		Actions available to the machine	Effects available to the user	Design rationale
User activity/action	Movement description	Motion detection via video camera	Output: Visual display and audio	Game context

Figure 8.1 Adaptation of Suchman's analytic framework for use in analysing interaction of players with the Eyetoy games

on the physical actions and movements of the player and the corresponding detection and interpretation of those actions and movements by the machine. As depicted in Figure 8.1, the column labelled "Actions not available to the machine" has been split into two, to bring out the details of the movement description for the user's actions. The column labelled "Actions available to the machine" describes the form of input, as the actions detectable by the machine are determined by the choice of input devices. In this case, it describes the input of the user activity via the motion-sensing video camera. The column labelled "Effects available to the user" consists of the output available to the user in the form of a visual display and audio. In the original framework, there is a fourth column on the right-hand side, labelled "Design rationale", for the machine. We have relabelled this column "Game context" to clarify the game context in which specific actions are occurring. This describes the machine's interpretation of the user action.

The analytic framework derived from Suchman was valuable in two key ways. Firstly, it made clearly visible the resources available to the user and to the machine for perception of action. Its prime function was to lay out the sequence of interaction and the interpretation of the interaction from both the human and the machine points of view. Secondly, and most significantly in terms of understanding movement, we were able to describe the movements as actions occurring in the context of a specific instance of game-play. The player's actions were described at the level of activity in relation to the state of game-play and also at the level of physical body movements performed as part of their overall activity. This close focus on the body movements of the player enabled the separation of aspects of movement that were accessible,

The User Perspective			The Machine Perspective			Design Questions
Actions not available to the machine		Actions available to the machine	Effects available to the user	Internal machine behaviour not available to the user		
Scenario and Key Events	User Perception	User Activity: Movement/Stillness	Machine Effects (Audiovisual)	Machine State	Machine Perception	

Figure 8.2 Adaptation of Suchman's analytic framework for use in exploring and mapping movement-based interactivity in Bystander

or not, to the machine. In the Eyetoy games, the implementation choices regarding the interpretation of video data input determined the access to the player's activity and movement by the machine. This particular technology implementation makes no attempt to track or recognise human movements—it simply detects motion in predefined spatial and temporal zones according to the state of game-play. This then determined the actions of the user available to the machine, as depicted in the middle grey column of the table.

What this analysis also revealed was the kind of assumptions about user behaviour embedded in the Eyetoy system. Interestingly, the design choice not to track the moving body nor to identify specific kinds of physical actions performed by the user, enabled a wide range of diverse physical actions by the user to fulfil the interactional needs of the Eyetoy interface.

8.1.2 Bystander

In the Bystander project, Suchman's framework was adapted to function as a design tool, termed the *interactivity table*. We followed the general principle used by Suchman of presenting the actions and available perceptual resources for both human user and machine in the interaction, but in a slightly different fashion, one more suitable for the purposes of exploring and mapping the interactivity between users and machine when human movement is direct input.

The *interactivity table* presents the script of scenarios of audience activity and movement alongside the corresponding machine behaviour, so the design of the interactivity between user and machine can be systematically examined. Figure 8.2 illustrates the general structure of the interactivity table.

In Suchman's original framework (see Figure 2.1), the interaction between the user(s) and the machine is framed in terms of the resources available, or not, to either side. The two columns of the table labelled "Actions available to the machine" and "Effects available to the user" constitute the interface of the system that is available to both human and machine. We have retained this organisation in the interactivity table with the column, "User Activity: Movement/Stillness" positioned alongside the column, "Machine Effects (Audiovisual)"—indicated by the grey columns in the table. The actions of the user *not* available to the machine include the scenarios of user activity and the interpretation of the action by the user represented in the columns, "Scenarios and Key Events" and "User Perception", respectively. The interpretation of the action by the machine is represented in the column, "Machine Perception". This column together with "Machine State" equate to Suchman's original "Design Rationale" column and have been more appropriately named, "Internal machine behaviour not available to the user". The subsequent machine response available to the user is given in the column "Machine Effects (Audiovisual)". We added a new column on the far right labelled "Design Questions". This enabled design questions, issues and contentions regarding the mapping of audience input to system response to be explicitly linked to the particular instance in the script of user activity and machine behaviour.

During the development of Bystander, the machine interpretation of the audience input data was of some contention. The resources available to the machine for perception of the user action were determined by the video data input device. As the movements of the users were supposed to influence the behaviour of the system, it was a matter of deciding what particular aspects of the movement to detect and interpret. In the final design, the system detected presence, position, density of moving bodies and degree of motion in the space through a single overhead video camera. The representations of audience activity and movement (deemed to be actions available to the machine in the interactivity table)—textual descriptions and visual movement schemas—would reflect these design decisions regarding the choice of input technology and interpretation of the input.

The interactivity table was a very useful tool for identifying and explicating design assumptions about user behaviour, particularly understandings of the relation between audience engagement with interactive artworks and their physical activity and movement. Multiple interpretations of user intention can be derived from the same observable physical behaviour and patterns of movement, as revealed during user testing of Bystander. Recognising the inherent ambiguity in interpretations of intentional action from purely visual means highlights the challenges in using human movement as direct input to interactive systems. Bystander sidesteps this problem by diminishing the power of the user to control the system in any determinate way; instead, the user is left to make sense of the effects of the system by constructing their own meaning from the interaction.

8.1.3 Summary—Suchman's analytic framework as a design tool

As can be seen from the above discussion, Suchman's framework can be flexibly adapted as a design tool according to the particular needs of the design situation. The fundamental framing of the interaction in terms of resources available to both user and machine for action and perception was applied in both the Eyetoy and Bystander projects. The framework was adapted to focus more specifically on the movements of users occurring in the context of user activity, as part of the human-machine interaction and correspondingly, on the machine detection and interpretation of those movements. The framework enabled exploration and mapping of the relationship between movements of the user and the machine response. It also proved valuable for making explicit design assumptions about user behaviour, in particular the meaning and interpretation of movement, that become embedded in movement-based interactive systems.

8.2 Laban movement analysis and Labanotation

This section traces the application of Laban movement analysis and Labanotation in the Eyetoy, Bystander and Falling into Dance projects. It discusses the potential strengths and weaknesses of the movement analysis system and notation for use in design of movement-based interaction.

8.2.1 Eyetoy

In the Eyetoy project, Laban movement analysis and Labanotation were applied to the movements of the player interacting with the Eyetoy games. The specific parts of Labanotation applied were the Structural description and the Effort description. The Structural description provides a visual representation of the movements of the player, with the body as the central focus. Symbols are used to indicate movement of body parts in terms of spatial direction, spatial level and time. The graphic representation of the body-in-motion provided by the Structural description is not immediately intuitive. Skill is required in reading and writing the notation. This may prevent easy uptake of the Structural description by designers. The Effort description provides a way of seeing and describing the dynamic, expressive aspects of movement in terms of a person's relation to motion factors of Space, Time, Weight and Flow. It has a corresponding notation, although this was not used in this project as the primary focus was on understanding and applying the Effort description. Now that computerised motion recognition systems can also detect to some degree the qualitative, expressive and dynamic aspects of movement, designers need a system and vocabulary for analysing and describing movement in its many forms—Laban movement analysis can provide this. Other researchers have adopted the language of Laban movement analysis into their work (e.g., Buur et al., 2004; Jensen et al., 2005).

One of the strengths of transcribing movements with Labanotation was the learning of the Laban system of movement analysis. Learning took place by observing, transcribing and re-enacting movements. Understanding of the system of movement analysis was anchored in a bodily understanding through physical exploration.

8.2.2 Bystander

In Bystander, Labanotation floor plans, intended for group choreography, were used for representing the social and contextual aspects of interaction that influence how and where people move and locate themselves in the space in relation to others. Spatial trajectories were mapped onto floor plans indicating the position, orientation, direction and path taken through space and time of individual and multiple people, for various scenarios of user activity. Here the notation was used for both descriptive and prescriptive purposes. On the one hand, it describes the imagined activity of the visitors to Bystander, where that activity is grounded in observations of actual audience behaviours to similar immersive exhibits. On the other hand, the notated movements then become a prescription for enacting and evoking movement during user testing. The floor plans provided an easy-to-read visual representation of audience movements corresponding to the textual descriptions of scenarios of audience activity. They also assisted reasoning about potential movements and corresponding machine responses.

8.2.3 Falling into Dance

For the Falling into Dance project, Effort-Shape analysis was applied to the movement sequences of people performing actions of falling in Study I and choreographed phrases of movement in Study II. The action of falling and the choreographed phrases of movement are complex forms of movement with dynamically changing relationships to space, weight, time and flow. The use of the Effort description ensures these aspects of movement are observed and described. The Shape analysis provides a range of descriptors for observing and describing the changing spatial forms and spatial qualities of the moving body. Both Effort and Shape characteristics of the body-in-motion can be used as parameters to computerised motion recognition systems. Existing systems such as EyesWeb provide available, off-the-shelf technology for the recognition of expressive and dynamic aspects of movement (Camurri et al., 2000, 2003a,b).

Labanotation floor plans were used to represent the overhead view, corresponding to the machine input view, of the spatial trajectories of multiple movers for the choreographed phrases of movement in Study II. This was useful for reasoning about the interactive treatment of the movements from the machine perspective.

8.2.4 Summary—Laban movement analysis and Labanotation

It is clear from the above discussion that there is value in adopting Laban movement analysis into the discourse and practice of interaction design. It provides a language and vocabulary for talking and reasoning about movement across disciplines. It is also valuable for developing movement sensitivity, bodily understandings and observation skills of the body-in-motion. Labanotation offers a range of symbols for notating the specific details of the moving body in space and time (Structural description), the dynamic and expressive qualities of movement (Effort-Shape) and spatial paths and configurations of individual and multiple bodies (floor plans). Of the three symbol sets, the floor plans are the most readily accessible to the untrained eye. The other two require a level of training, skill and effort that may outweigh the utility of the notation for designers. The specific use of any of the forms of notation will depend on the needs of the design situation and the aspects of movement deemed to be of significance.

8.3 Summary—Reflection on Tools

The exploration of existing analytic frameworks and systems of analysis to use as design tools resulted in tools that could be included in the proposed design methodology, presented in the next chapter. The adaptation of Suchman's analytic framework as a design tool provides the necessary resource for interrogating the nature of the interactivity between human activity and movement and corresponding machine behaviour, through a systematic appraisal of the possible alignments and slippages between the two. The application of Laban movement analysis and Labanotation in design of movement-based interaction provides a language, vocabulary and notation for reasoning about, representing and experiencing the moving body. The part of the notation for group choreography is the most readily accessible to designers untrained in the system.

Chapter 9

A Design Methodology of Moving and Making Strange

> Calling attention to ourselves in movement in this way [by performing free variations on our own habitual movement patterns to appreciate first-hand what is kinetically there], we have the possibility of discovering what is invariantly there in any felt experience of movement. This is because whatever the habitual movement, it now feels strange, even uncomfortable. Just such oddness jars us into an awareness of what we qualitatively marginalize in our habitual ways of doing things. By *making the familiar strange*, we familiarize ourselves anew with the familiar. (Sheets-Johnstone, 1999a, The Primacy of Movement, p.143, my emphasis)

This chapter presents the primary contribution of the thesis, the design methodology of Moving and Making Strange. The design methodology is underpinned by a commitment to designing movement-based interaction from experiences of movement. It stems from a phenomenologically-inspired inquiry into the moving body, where we investigate our own experiences of movement, together with the experiences of others. The chapter is organised into three main sections. The first section introduces the notion of making strange and its usage in other arenas; the second section explains the genesis of the methodology and the third section defines what is in the methodology and how to use the various methods and tools.

9.1 Making strange

Making strange. Making the familiar strange. Making strange with the familiar. Defamiliarising. The term defamiliarisation was introduced by Victor Shklovsky, a member of the Russian formalist school of literary theory. In his essay, *Art as Technique*, published in 1917, he proposes that the method of defamiliarisation is used in art and literature to remove the automatism of perception.

> The purpose of art is to impart the sensation of things as they are perceived and not as they are known. The technique of art is to make objects 'unfamiliar,' to make forms difficult, to increase the difficulty and length of perception because the process of perception is an aesthetic end in itself and must be prolonged. (Shklovsky, 2000, first published in 1917)

Making strange or defamiliarising is a basic strategy in artistic expression (Danto, 1981), creative design practice and in ethnography (Marcus and Fischer, 1986). For example, turning a picture upside-down interrupts our habitual patterns of visual perception and allows us to see the composition from a new perspective (Edwards, 1979). Alternatively, we could turn our body upside-down to gain a similar, yet different, change in perspective! Edward de Bono (1994) advocates a similar approach with his set of thinking tools that aim to counteract the natural tendency of the mind to operate within engrained patterns of perception. In design, the *cultural probes* of Gaver et al. (1999) employ the basic strategy of defamiliarisation by prompting participants to reflect on their everyday lives through the materials comprising the probes. Djajadiningrat et al. (2000) also work from a stance of making strange with their *interaction relabelling* method for the design of aesthetic interactions with products. Here possible interactions with an existing mechanical device are mapped to functions of a future electronic device. The use of unrelated devices enables innovative design thinking outside of the standard interaction style and opens up the spectrum of actions that can be used. Gaver, Beaver, and Benford (2003) suggest ambiguity as a resource for design that can foster close personal engagement with interactive artefacts. A questioning attitude is invoked in the interpretative relationship between person and artefact.

Geertz (1973) describes anthropology's preoccupation with the exotic as a device for making the familiar strange. The breaching experiments of Garfinkel (1967) were designed to disturb familiar ways of perceiving everyday life. Marcus and Fischer (1986) identify two forms of defamiliarisation prevalent in anthropology—epistemological critique and cross-cultural juxtaposition. Bell et al. (2005) employ a method of making strange, or defamiliarising, understandings of the home in the design of domestic technologies. They use ethnographic techniques together with defamiliarisation as a literary technique for writing narratives of the home to "rethink assumptions built into domestic technologies" (Bell et al., 2005).

The notion of "making the familiar strange" is described in relation to the *moving body* by the phenomenologist, Sheets-Johnstone (1999a) in the opening quote. Through varying our normal movement patterns and processes we can unsettle our habitual perceptions of the world and ourselves. One way of reacquainting ourselves with familiar or habitual movements is to do a familiar movement differently, to perform the movement with a range of kinetic variations and so reveal the specific felt quality of the original movement. As Sheets-Johnstone (1999a) describes with the act of walking,

> Changing not only our leg swings, for instance, by initiating movement from our ankle joints by a spring action rather than from our hip joints, but changing our arm swing, the curvature of our spine, the cadence of our walk, the amplitude of our step, and so on.

Similarly, performing a movement outside or on the periphery of our everyday realm, such as learning a new physical skill or performing an unfamiliar movement, such as falling, can also bring us into a fresh encounter with our movement possibilities and break us out of habitual ways of thinking about movement.

In the context of the design of movement-based interaction, this unsettling or *making strange* through the moving body serves the purpose of breaking out of old patterns of perception to arrive at fresh appreciations and perspectives for design that are anchored in the sensing, feeling and moving body. Creative thinking in design requires an overturning of our habitual perceptions and conceptions of things or, in this case, of the sensing, feeling and moving body.

9.2 Genesis of methodology

The methodology is characterised by two fundamental needs that directly address the second and third research questions of the thesis. The first is ways of accessing the experiential nature of the moving body, that are rooted in our own bodily knowing and/or the lived experience of other moving bodies. The second is the production and use of descriptions and representations of the moving body for design. In particular, representations that facilitate the mapping of the interaction between human activity, in terms of movements performed and the experience of such movements, and possible interpretations of the moving body by the machine. In this methodology, it is not enough to understand and describe movement from the perspective of the observer alone. An adequate understanding and description of the experiential, moving body can only be formed through an integration of multiple perspectives, including the first-person understanding of the mover, the observational perspective of the designer/researcher and the direct experience of movement by the designer/researcher. One of the main principles of the design methodology is a return to the active, experiencing body. Many of the methods are concerned with acquiring direct experience of the moving body in various design activities. These methods I term 'experiential methods'.

The methodology in its current form is an expansion and refinement of the methodology first presented in Loke and Robertson (2007), resulting from the first study of the third project (section 7.1). The activities, data and results of analysis for all three projects were further examined as sources of methods and tools for potential inclusion in the developing methodology. The methods and tools were abstracted from their original domain and reframed to be applicable, at least as a starting point, to any movement under investigation. The use of these methods and tools may be tailored and adapted according

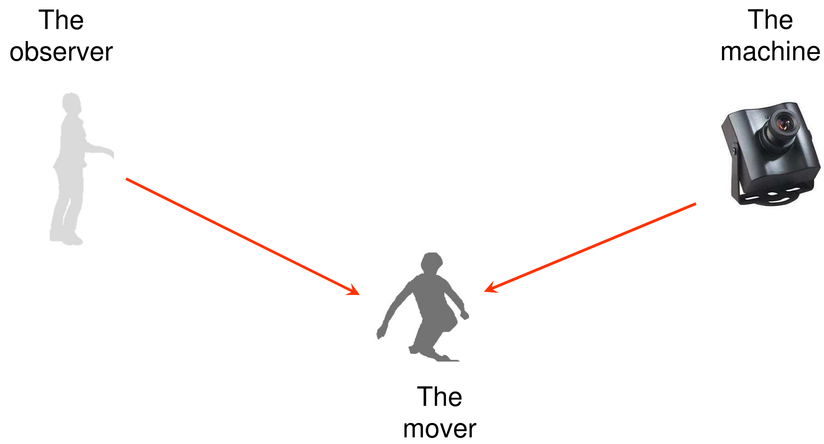

Figure 9.1 The three perspectives of the mover, the observer and the machine offered in the design methodology of Moving and Making Strange

to the specific research or design context.

9.3 What is in the methodology

The methodology offers methods and tools for exploring, experiencing, understanding, describing and representing the moving body that can assist designers in making movement and interaction choices that are grounded in the sensing, feeling and moving body. It is intended as a tool-kit for designers, from which they can select methods and tools as appropriate or add their own. It is *not* a prescription for designing. The methodology is characterised by the use of multiple, different perspectives, which enables the designer to shift between the three perspectives of the mover, the observer and the machine (see Figure 9.1).

The methods and tools are organised by activity. A diagram of the activities and how they are related is given in Figure 9.2. This diagram can function as a navigational aid to the methodology. Figure 9.3 then provides the set of methods and tools utilised in a specific activity and the particular perspectives and data offered by that activity.

In the following sections, a consistent format is used to describe each activity and its methods and tools, as follows. A schematic diagram introduces

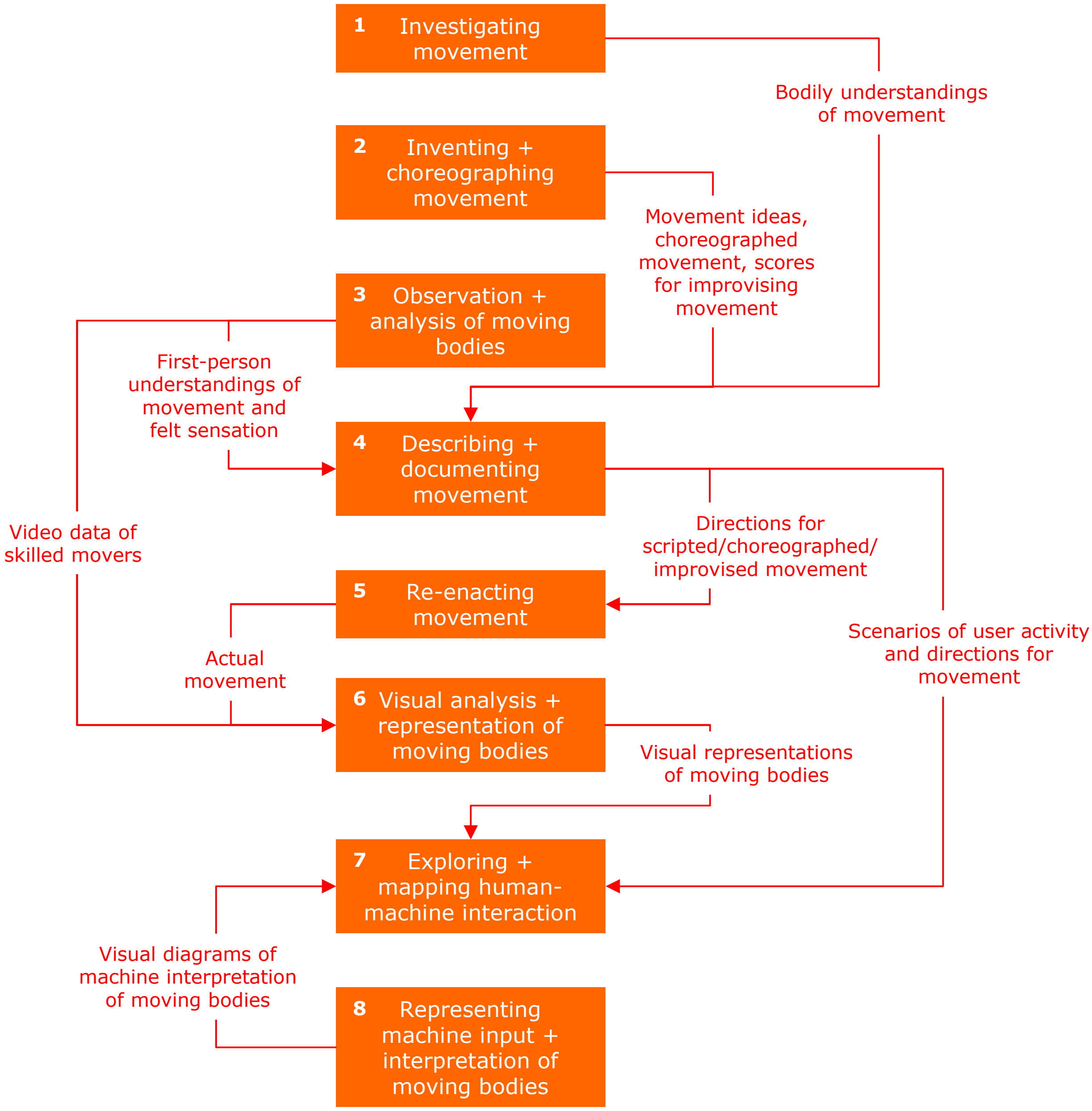

Figure 9.2 The design methodology of Moving and Making Strange: Diagram of activities and how they are related. The labels on the arrows indicate the data generated by one activity and the direction of the arrow indicates the flow of data from one activity to another. The activities are numbered purely to assist identification; the numbering does not indicate a linear order.

Activity	Method/tool	Perspective/Data
1 Investigating movement	Kinetic variations of speed, scale and direction Exploring internal and external perception Finding pathways Breaking down a technique Imagery	First-person experiential data and perspective on movement possibilities and corresponding felt sensations
2 Inventing and choreographing movement	Working with parameters and qualities of movement: o Scoring o Variations on a traditional movement form or gesture From words/concepts/images	First-person experiential data and perspective on movement possibilities, forms, patterns, motivations and corresponding felt sensations
3 Observation, interrogation and analysis of moving bodies	Physical demonstration and interrogation Understanding movement from a first-person experiential perspective: o First-person experiential accounts o Characteristic components of movement Understanding how the movement is performed from an observational perspective	First-person experiential data on process and felt sensation of movement Observational data on the sequencing and bodily organisation of the body-in-motion
4 Describing and documenting movement	Describing user activity: moving personas and movement-oriented scenarios Describing skilled or choreographed movement: combination of images, text, annotations and sketching Laban movement analysis: Structural and Effort/Shape descriptions	Observational perspective documenting the movements of people and the motivations for movement
5 Re-enacting movement	Re-enacting movement-oriented scenarios, movement scores and directions for choreographed movement	First-person experiential understandings of movement during user testing/evaluation
6 Visual analysis and representation of moving bodies	Movement sequences and silhouettes Spatial movement schemas in Labanotation floorplans	Observational perspective for visually analysing and representing human movement
7 Exploring and mapping human-machine interaction	Interactivity table (adapted from Suchman's analytic framework)	Mapping between the human and machine perspectives, both from an observational perspective
8 Representing machine input and interpretation of moving bodies	Machine input schemas	Machine perspective of the input and interpretation of moving bodies

Figure 9.3 Summary of activities, methods and tools and the perspectives/data they offer in the design methodology of Moving and Making Strange

the activity, highlighted in an orange box, in its context within the methodology (the grey boxes indicate the activities to which it is linked). The purpose of the activity is then described, including the kind of data or perspective offered by the methods/tools (summarised in Figure 9.3) and the relations between the various activities (summarised in Figure 9.2). Each method/tool is described, including examples of specific usage of the methods and tools drawn from the three research projects. Where appropriate, exercises are offered for investigating, generating and enacting movement. Each section concludes with reference to related work of other researchers or practitioners.

9.3.1 Investigating movement

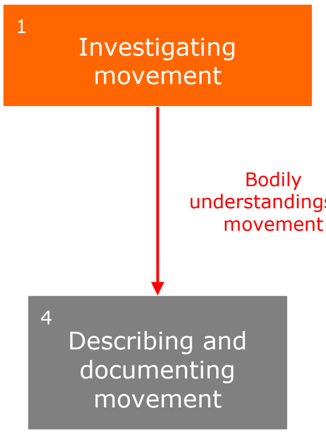

Figure 9.4 The activity of investigating movement and its place in the methodology

This area of the methodology is concerned with accessing the experiential, moving body *directly* with one's own body. This is achieved through movement inquiry and practices of *making strange*. One can begin an inquiry into the potential movement possibilities and felt sensations of one's own body by performing a familiar movement differently or by performing an unfamiliar movement. We can select physically challenging or unorthodox movements, such as falling, for investigation. The movement inquiry can be deepened through repetition of movements to consciously access in-the-moment sensations and process. The methods and techniques presented here provide ways of exploring and improvising with the moving body to cultivate skill and a refined awareness of the sensing, feeling and moving body. They form but a small part of an established repertoire of movement improvisation techniques from dance and movement practices. The bodily understandings of movement gained from these techniques provide a foundation for the activity of describing and documenting movement (see Figure 9.4). Just as importantly, the creative potential of the experiential, moving body is opened up and available for use in the design process.

Kinetic variations of speed, scale and direction

One can perform a movement with kinetic variations of speed, scale and direction to produce different dynamics and qualities of movement. For example, swinging your arm to and fro very slowly and smoothly or with a jagged stutter. The focus here is on the relation between the movement and the felt sensation of movement.

An exercise for investigating kinetic variations of movement is given in Figure 9.5.

Exploring internal and external perception

The sensing of the external environment is performed predominantly with the visual and tactile organs of perception, the eyes and the skin, respectively. The sensing of the dynamics of our body-in-motion and the internal environment of the body is governed by the kinaesthetic sense. There are simple exercises to heighten awareness of the different senses and understand how they influence our ability to perform various kinds of movements. For example, exploring the act of balancing on one leg with the eyes open and then with the eyes closed. With the eyes open, our vision assists with balancing and stabilising ourselves in space. With the eyes closed, a more internal understanding of what is involved in balancing on one leg opens up. The field of somatics focuses particularly on cultivating awareness of movements and corresponding felt sensations and relationships in the body (Feldenkrais, 1972; Bartenieff and Lewis, 1980; Hanna, 1988; Cohen, 1993).

An exercise for exploring the head righting reflex in balancing and the involvement of our visual and kinasthetic sensing is given in Figure 9.6.

Finding pathways

We can experiment with finding pathways into a pattern or form of movement by varying the source of initiation of movement from different parts of the body. For example, walking through space with the right hip or the knees or the back of the head leading. The use of the *head-as-a-limb* in Body-Mind Centering is thought to open up the imagination (Cohen, 1993, p.133). Here

Investigating the act of walking by varying the speed, direction and scale of the movement

The aim here is to develop sensing and awareness of your body-mind through a playful inquiry into movement possibilities with your own body. A good place to start is with the act of walking. Experiment with your normal way of walking through variations of direction and speed. Start walking at your normal pace. Walk in different directions – forwards, backwards, sideways and notice how this affects the action of the walk and the feeling of your body.

Then double the speed of your pace and notice what happens to the movements. And then walk at half your normal walking pace and then at quarter speed. Make clear decisions about which of the four speeds you chose. What do you notice, internally and externally?

Now walk as slowly as possible and notice how this changes the length of your stride. Then vary the length of your stride all the time at very slow speed.

Then use the stride of your normal walk but move at 1 cm per second maximum total body speed. Then at 1mm per second.

As you play with different parameters, take your awareness to how each change feels in the body and what the ground feels like under your feet.

As you walk, experiment with changing the focus of your gaze. Look at different points in the space, or let your focus be soft and directed to a wide area. Change the direction of your focus and vary the duration you look before changing to a new focus. Do the changes in focus affect the felt sensation of the movement? Note also what parts of the body are harnessed to achieve the movement.

Find language for the felt sensations by working with a partner. One person move and the other observe, then change roles and discuss your experiences afterwards. Note the different forms of language each person employs in describing movement and its qualities. Exchange understandings of the relation between variations of speed, scale and direction to the felt sensation of the movement.

Inspired and sourced from the Bodyweather movement investigations, led by Tess de Quincey in Sydney, Australia 2007.

Figure 9.5 An exercise for investigating kinetic variations of movement

Exploring the labyrinthine head righting reflex

1. Work in partners. One person plays on a large gymnastic ball in prone, supine, sidelying or sitting position. The other person observes the head righting movements to vertical as the person moves to keep their balance on the ball and to catch themselves when falling to the ground.

2. Remove the influence of the Optical Righting Reaction by closing your eyes.

Sourced from the Body-Mind Centering system of movement study, Bonnie Bainbridge Cohen, Sensing, Feeling and Action, 1993, p.127

Figure 9.6 An exercise for exploring the head righting reflex in balancing and the involvement of our visual and kinasthetic sensing

the head is actively exploring and leading the body through space. It is not rigidly held nor overly yielding to gravity.

Breaking down a technique

A specific form of movement can be learnt and understood by breaking down the technique into a sequence of preparatory exercises. For example, the technique of falling by sliding out to the side from upright, can be mastered by starting from a kneeling position on the ground and then progressing to standing.

Imagery

A different kind of technique uses imagery to shape body movements and generate distinct movement qualities, such as 'like a heavy stone' or 'like a floating feather'. The image can be localised to a part of the body or it can be extended beyond the physical body. For example, you might move your leg as if it contained a viscous fluid. Or you might imagine that a long string was pulling you up by the crown of the head towards the heavens.

An exercise for generating movement through imagery is given in Figure 9.7. This exercise is often used as a Butoh training technique.

Generating movement through imagery

This exercise is based on the notion that the body is predominantly water.

Standing upright, feel water slowly rising up through the soles of your feet to the top of your head. At first this process can take 10-15 minutes. It becomes an internal meditation. Have a sense of buoyancy and lightness. You can allow your arms and hands to follow. Take the time to feel water infusing every small part of your body as it rises. Allow the body to be moved by the water. The physical shell is passive. Allow the imagination to activate your movement. For example, you can imagine that you are a strap of seaweed anchored to a rock. Gently undulating waves caress your form and move it in the water. Allow your mind to free itself from being in control of the body. The water inside is moved by the water outside. See if you can feel individual cells, filled with fluid, rolling and sliding over each other.

This process can be reversed. That is, feel the water gradually drain out through the feet.

Contributed by Bronwyn Turnbull, inspired and sourced from Noguchi Taiso.

Figure 9.7 An exercise for generating movement through imagery

Related work

- *Fundamentals of movement*: Bartenieff and Lewis (1980), Laban (1971), Newlove (1993), *Body-Mind Centering*: Cohen (1993), Hartley (1995), *Somatics*: Feldenkrais (1972), Hanna (1988)
- *Movement improvisation*: Blom and Chaplin (1988), *Butoh*: Fraleigh (1999)
- *Movement games*: Donovan and Brereton (2004)
- *Mask work*: Jacucci (2006)

9.3.2 Inventing and choreographing movement

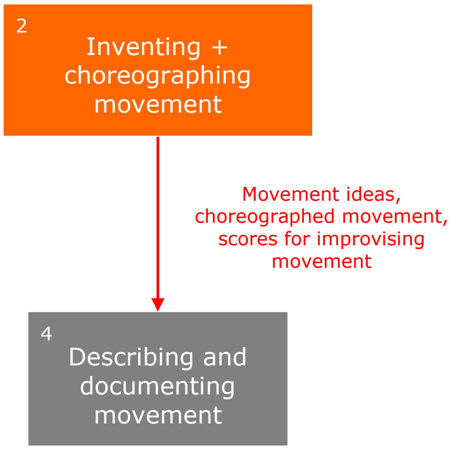

Figure 9.8 The activity of inventing and choreographing movement and its place in the methodology

The methods and tools presented here are for choreographing movement, that is, for inventing and devising new forms of movement. In future movement-based interactive spaces, we will need different kinds of movements with meanings that are, as yet, unthought. These new movements may be improvised, choreographed, emergent or structured movement systems. This activity feeds into the activity of describing and documenting movement (see Figure 9.8).

Ways of inventing and devising movement can be broadly split into two categories: (1) working with parameters and qualities of movement and (2) through inspiration from concepts, text, images and other means of intellectual thinking that is then translated into movement. A design imperative for generating meaningful movements is the importance of providing a specific and well-defined context or domain.

Methods for inventing and devising movement are part of the practices of *making strange* through movement inquiry and overlap in part with the methods for accessing the experiential, moving body. This is an area of the methodology that can be substantially expanded in the future by continuing to work with choreographers and movement improvisation practitioners.

Working with parameters and qualities of movement

The activity of inventing and devising new movements can begin with the sensing, feeling, moving body. The method of *scoring* used in practices of movement improvisation provides a structure for generating and devising movement based on a set of elements or parameters that can be varied as desired. For example, a simple score consists of three elements; walking, standing still and squatting. Parameters or constraints related to speed, duration, timing, scale, focus, use of space and so on, can be added to the score. Scores can be used for improvising movement whilst exploring movement ideas for interaction or for generation and enactment of movement in user testing (see section 9.3.5).

Another approach is to begin with a traditional movement form or gesture. This form or gesture can then be choreographically developed by varying the parameters and qualities of movement. For example, in Project III (Falling into Dance) Gloria begins with the "blow through palms to clean" gesture from a Qi Gong form. She begins by breathing into the hands in prayer position and focusing on the rhythm of the breath. She plays with the hands expressing the expansion and contraction of the lungs, varying the scale and speed of the hand movements, until a certain arrangement of gestures and body movements is reached.

From words/concepts/images

Methods for inventing and devising movement can begin with a word, concept or image. These can generate or inspire a movement impulse, kinaesthetic sensation, a particular way of moving, spatial arrangements of the body in relation to itself, other bodies and the body in space and so on. Choosing a specific context or domain is critical to generating meaningful movement. A specific and well-defined context gives structure and meaning to movements.

Related work

- *Dance and movement improvisation*: Blom and Chaplin (1988), Forsythe and Sulcas (2000), Laban (1971), Newlove (1993)

- *Designers working with movement for interaction*: Hummels et al. (2007), Jensen (2007), Jensen et al. (2005), Klooster and Overbeeke (2005), Moen (2005, 2007), Schiphorst and Andersen (2004)

9.3.3 Observation, interrogation and analysis of moving bodies

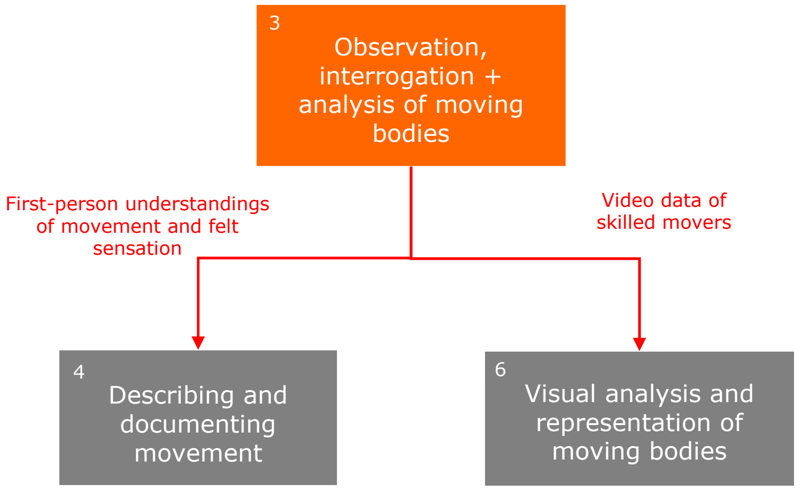

Figure 9.9 The activity of observation, interrogation and analysis of moving bodies and its place in the methodology

The experiential, moving body can be accessed indirectly through observation, interrogation and analysis of other moving bodies. Conducting movement inquiries with skilled movers provides finely nuanced understandings of particular kinds and forms of movement. The focus is on what a particular movement looks like, how it is performed, what happens to the body during the execution of the movement and how it feels in the body. This activity is a precursor to those of describing and documenting movement and visual analysis and representation of moving bodies (see Figure 9.9). The methods and tools presented here include physical demonstration and interrogation, understanding movement from a first-person experiential perspective and understanding how the movement is performed from an observational perspective.

First-person experiential account

I get a lot out of just the sense of weight, so exactly that. So if that's [touching the crown of the head] being pulled up, I've just been strung up then this is an entire weightedness. You really try and get the sense of, like a sack of potatoes, really heavy in the body. This is being kind of hooked up there. And so then that really heavy feeling. Particularly in the fingertips, in the legs and the feet and the thighs and the butt, especially in the pelvis. I tend to work with slightly bent knees. To get a sense of that suspension.

Participant 7, Study of Falling

Figure 9.10 First-person experiential account of the process and felt experience of falling by a skilled mover

Physical demonstration and interrogation

One method of accessing bodily knowledge is through physical demonstration by the mover, coupled with interrogation by the observer. This produces verbal descriptions of their movement processes and felt sensations. Recording this activity on videotape provides raw data of moving bodies for feeding into the tools for analysing, describing and representing movement.

Understanding movement from a first-person experiential perspective

These descriptions preserve the voice of the person describing their understanding of their process and their felt experiences of particular movements. It focuses on their self-perception of their own movements, as well as their perception of the external environment.

First-person experiential accounts are edited transcripts of a person explaining how they perform a particular movement and how it feels in the body. An example from the Study of Falling, Project III (Falling into Dance) is given in Figure 9.10.

These accounts can be analysed into three *characteristic components of movement*: Movement process and technique, Sensing and awareness—internal and external and Felt quality. Each of these characteristic compo-

Characteristic component of movement	Definition	Examples of participant description
Movement process/technique	The process of the movement and the technique for performing the movement are inter-related. Process is the dynamic unfolding of a bodily movement in space and time. The process may be split into distinct stages for a given movement, depending on the complexity of the movement. Technique is an established means for directing or informing the movement process.	*Initiating the fall* Finding pathways into the floor Finding steps to take you off-centre Momentum of dropping down *Controlling the fall* Internal muscular lift to slow down Working in opposite direction to the fall *Contacting the ground* Relax and soften Letting my body roll into the ground
Sensing and awareness – internal and external	What senses are actively engaged and how; the senses include the visual, aural, tactile, and proprioceptive/kinaesthetic; awareness and relating of internal and external environment.	Aware of your body within a larger space You need that visual to know where you are in the space, to remember what plane you are on, especially when you've thrown yourself off-centre
Felt quality	The particular sensation or feeling as experienced in the whole or part of the body.	Sense of weight, like a sack of potatoes Suspension and precariousness

Figure 9.11 Definition and examples of characteristic components of movement for the act of falling by skilled movers

nents of movement is briefly defined in Figure 9.11, along with an example from the Study of Falling, Project III (Falling into Dance).

Understanding how the movement is performed from an observational perspective

Movement sequences are extracted from the video data to enable analysis of how the movement is performed from an observational perspective. Each still in the sequence is annotated with descriptions of the process and technique of performing that particular movement. Movement sequences are also used for visual analysis and representation (see section 9.3.6). Laban movement analysis can be applied to analyse and describe the movements in terms of Effort-Shape from an observational perspective (see also section 9.3.4).

An example of a movement sequence annotated with descriptions of the process and technique of falling, taken from the Study of Falling, Project III is given in Figure 9.12.

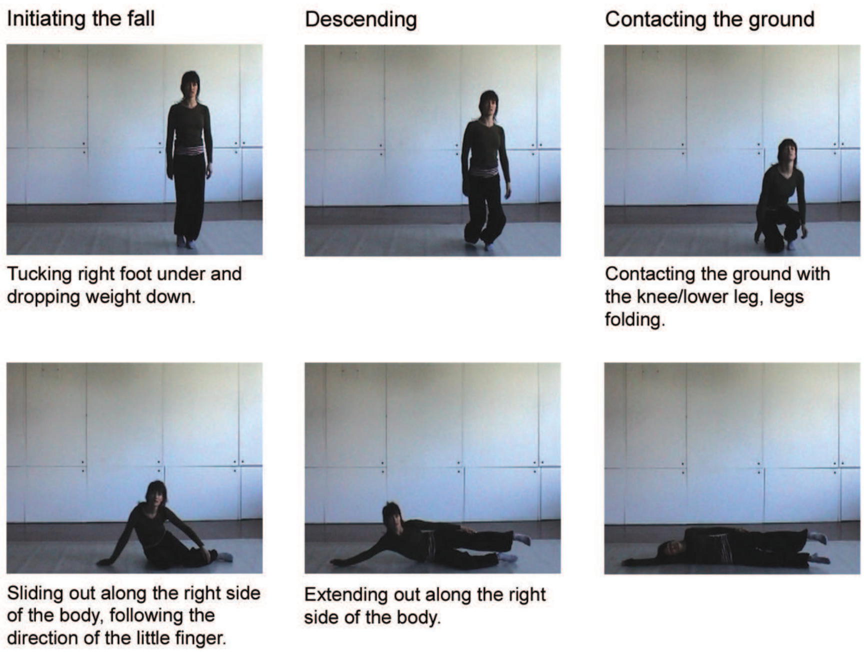

Figure 9.12 Movement sequence for participant 1, annotated with descriptions of the process and technique of falling

Related work

- *Movement analysis*: Bartenieff et al. (1984), Cohen (1993), Daly (1988), Laban (1971), Newlove (1993)

9.3.4 Describing and documenting movement

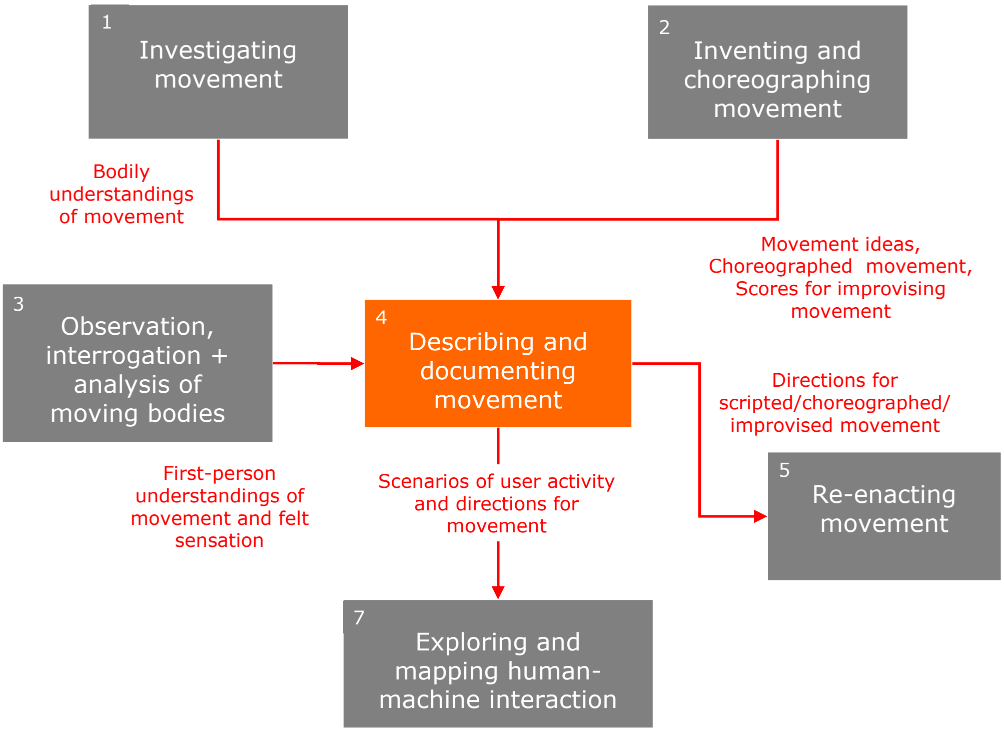

Figure 9.13 The activity of describing and documenting movement and its place in the methodology

We need language to describe movement that captures and evokes the wide range of possible understandings of movement for use in interaction design. The movements of different kinds of users or participants, in interaction with machines, can range from the everyday to highly skilled or choreographed movement. We can focus on the activity of users, the functional character of their movements and actions, the mechanics of their movement, the spatial patterns and organisation or the expressive quality of their movement, for example. Users of interactive, immersive spaces fall roughly into two categories: (1) visitor/spectator and (2) performer/skilled user. Visitors and spectators typically have limited or no prior knowledge of the system. Their interaction is mainly exploratory, learning or in the role of witness. Performers and skilled users typically have rehearsed with the system. Their actions tend to be choreographed or deliberate, governed by knowledge of the system's behaviour.

The primary ways of describing and documenting movement for these different categories of users can be divided into descriptions with a focus on the activity of users (user category 1) and descriptions with a focus on the details and nuances of performing particular kinds of movements (user category 2). These descriptions can be used to re-enact and generate movement for testing and evaluation. They can also be used for exploring and mapping human-machine interaction (see Figure 9.13).

Describing user activity

Scenarios written from a third-person perspective are traditionally used in interaction design to describe the activities of users in specific contexts and settings, either actual observed activities or future imagined activities. These traditional scenarios have been extended here to include *movement-oriented* characteristics. *Movement-oriented* scenarios are textual descriptions of scenarios of user activity and movement based on personas. Here personas represent different kinds of moving users. *Movement-oriented* personas and scenarios can also be used prescriptively to generate or re-enact movement for testing and evaluation.

An example of a *movement-oriented* scenario from Project II (Bystander) is given in Figure 9.14.

Describing skilled or choreographed movement

For skilled or choreographed movement in interaction with the machine, much more detailed and specific description is required to document the movement for later re-enactment during user testing. These descriptions detail the specifics of how the body moves in space and time, the use of timing, repetition, rhythm, the form and phrasing of the movement and the interaction with other movers within the environment. They provide directions for performing the movement for later enactment. They may overlap in part with the scenarios. They can be written in the individual language of the choreographer or the Laban system of movement analysis and description can be

Movement-oriented scenario

This scenario explores the situation where a couple of people enter the Bystander room, which is currently empty. The characters, Val and Betty, are representative of older, retired people with a keen interest in the arts. They embody the fifth type of audience behaviour - *serious, quiet and contemplative engagement*. They enter the space and stand just inside the entry. A key event then occurs where a teenager attempts to enter the room but is blocked by Val and Betty. The teenager embodies the first type of audience behaviour - the *head-poker*. After the head-poker leaves, Val and Betty commence moving around the space, firstly towards the centre of the room and then towards one of the walls. They tend to move slowly with periods of stillness, as they observe the flock circling the room, revealing sets of images and texts. They chat and occasionally point things out to each other.

Figure 9.14 An example of a movement-oriented scenario taken from the Bystander project. It is built on the movement-oriented personas of Val and Betty.

utilised as a standard form of description.

An example of choreographic directions for movement, taken from Project III, is given in Figure 9.15.

Documenting movement ideas and choreography

Tools for documenting the movement ideas and choreography in forms that retain the essence of the movement or motivation for the movement include the use of text, images and sketching. One technique for documenting choreographic ideas is to provide choreographers or designers with a set of images and texts related to the thematic context of the work. They are then able to present their movement/choreographic ideas through a combination of images, text, annotations and sketching. This form of documentation can act as a resource for returning to the original ideas for movement/choreography.

An example of documenting movement ideas and choreography using a mix of text, images and sketching, taken from Project III, is given in Figure 9.16.

Act 2 – Ritualising the Space, Section 2

The four performers shift into treading a figure-of-8 path through the space. Their arms are held in front as if holding a pulsating ball of chi. The gesture changes to shifting side to side and drawing the ball of chi up and down in an arc. Occasionally a performer will stop at the end-point of the figure-of-8, stamp the foot and go into a frenzied form of movement with the arms and head.

These movements with the ball of chi exhibit a flowing, floating, rhythmic quality, that is interrupted every now and then with a very different movement (stamp and frenzied arms and head) to create a different energetic.

Figure 9.15 Directions for choreographed movement in Act 2, section 2

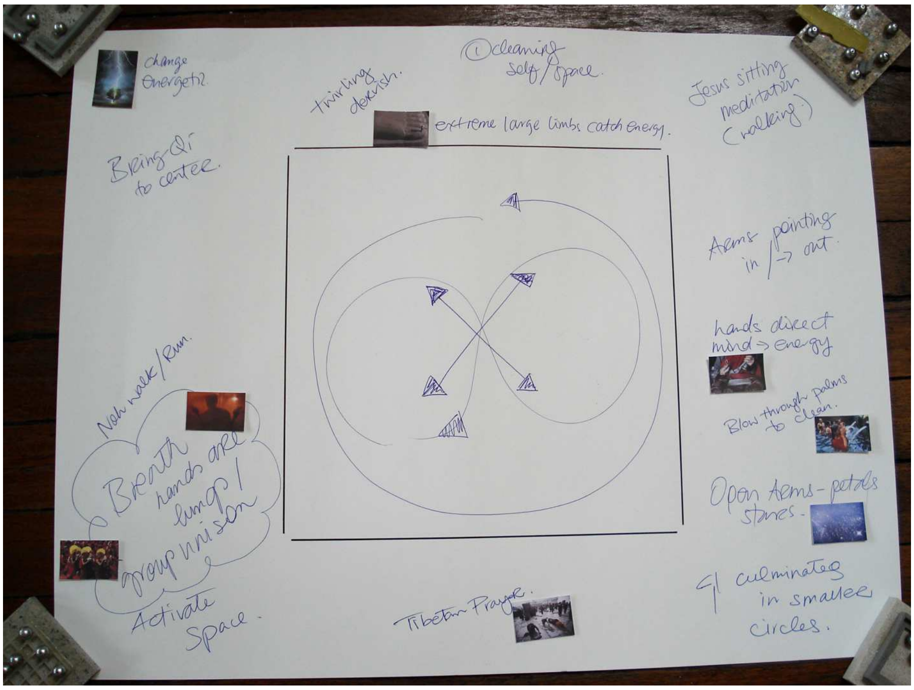

Figure 9.16 Gloria's use of the resource kit for documenting her choreographic and movement ideas

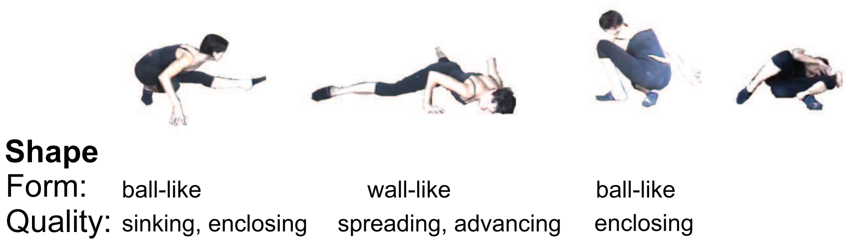

Figure 9.17 Effort-Shape analysis for a choreographed movement sequence

Laban movement analysis and description

In the Laban system of movement analysis, the *structural description* provides a vocabulary for describing the body and its parts, space (direction, level, distance, degree of motion), time (metre and duration) and dynamics (quality or texture, e.g. strong, heavy, elastic, accented, emphasised). The *motivation* for the movement is also described and can come from various sources: directional destination, motion, anatomical change, visual design, relationship, centre of weight and balance, dynamics and rhythmic pattern.

Laban's (1971) *Effort-Shape description* provides a system of analysis and a vocabulary for the qualitative, dynamic character of movement. The energy or Effort expended in a movement can be expressed in dimensions of Space, Time, Weight and Flow. The dynamically changing spatial shaping of a movement can be analysed with Shape categories describing the static form and the changing relation of the body to itself and the environment. Effort-Shape analysis provides a language for mapping from body-based to machine-based descriptions or interpretations. The qualitative, dynamic character of movement can also be described less formally, using evocative and metaphoric language that conveys the essence of the movement (Buur et al., 2004). An example of Effort-Shape analysis applied to choreographed movements from Project III is given in Figure 9.17.

We can use the Laban system to develop shared understandings of human movement, based in a standard vocabulary for describing movement. It is essential to gain an understanding of the Laban system of movement analysis grounded in one's own body. This can happen in tandem with developing one's observational skills using the Laban system of other moving bodies.

An exercise for developing skill in applying the Laban system of movement analysis is give in Figure 9.18.

Related work

- *Scenarios*: Bødker (1998, 2000), Carroll (2000a,b), Ehn and Sjögren (1992), Howard et al. (2002), Kyng (1995), Pedell and Vetere (2005)
- *Designers working with movement*: Brereton et al. (2003), Buur et al. (2000), Buur et al. (2004), Djajadiningrat, Matthews, and Stienstra (2007), Høysniemi and Hämäläinen (2004), Jensen (2007), Jensen et al. (2005), Klooster and Overbeeke (2005)
- *Dance and somatics*: Feldenkrais (1972), Bartenieff and Lewis (1980), Bartenieff et al. (1984), Hanna (1988), Cohen (1993), Hutchinson (1977), Laban (1971), Lamb and Watson (1979)

Developing skill in applying Laban movement analysis

This exercise first explores the basic Effort action of Dabbing. Dabbing is Direct in Space, Sudden in Time and Light in Weight.

First explore Dabbing with free flow. Then with bound flow.

1. This action is clearly felt in the hands as in a painter dabbing at a canvas or in typing. Try dabbing with the right side leading across the body, diagonally backwards, over the opposite shoulder. Repeat with the left side leading.
2. Dab with the feet. It is easy to quickly point the heels or toes. Again, try in all directions and all zones.
3. Try with the knees, hips, shoulders, head, elbows, chin, back and chest. Take plenty of time to experience dabbing in all these parts of the body. Some parts will lend themselves more easily to the effort than others.
4. Try the action with steps. Knees can dab upwards and toes or heels downwards.

Working in pairs, one person leads in a succession of exploratory movements using one of the basic Effort actions. The other person observes and describes the movement in terms of the motion factors of Space, Time and Weight. The mover and the observer compare notes on the experience of performing an action with specific qualitative characteristics and observing and describing the action. The roles are then swapped and the other basic Effort actions are explored until each person has developed confidence in performing and observing movements using Laban Effort analysis. The observer may like to try mirroring the mover to see if this assists in developing observational skills.

Sourced and extended from Laban for Actors and Dancers, Newlove, 1993

Figure 9.18 An exercise for developing skill in applying the Laban system of movement analysis for observation

9.3.5 Re-enacting movement

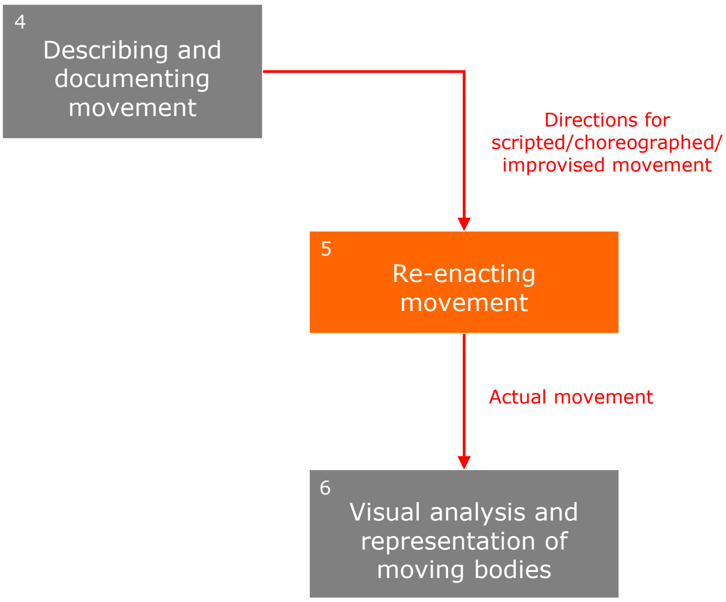

Figure 9.19 The activity of re-enacting movement and its place in the methodology

Re-enactment of scripted , choreographed or improvised movement, from design descriptions and representations of movement including movement-oriented scenarios, spatial movement schemas, movement scores and directions for choreographed movement, provides actual movement for use in testing and evaluation of the design of interactive systems. It feeds into the activity of visual analysis and representation of moving bodies (see Figure 9.19).

Enactment enables design reflection and refinement that is anchored in a bodily understanding of what it is like to act, move, perceive and respond in interaction with such systems. It provides designers with first-hand experiential data on the interactional viability of particular forms and patterns of movement. Felt, bodily experience can be garnered of architectural qualities of the interactive space such as the sense of scale, enclosure and spatial arrangement. The visual and sonic outputs of the system can be experienced kinaesthetically as well as visually and aurally. The effects of interaction between people on their actions, movements and perception can be gauged.

Time Min:Sec	Scenario and Key Events	Activity: Movement/Stillness	Spatiality: Path/Position/Orientation
01:00	*Slow-moving, contemplative visitors*. Betty and Val about to enter empty room.	Betty and Val enter room together and stand fairly still looking around with heads turning.	Stand just inside entrance.
01:30	*Head-poker*. Young teenager enters, blocked by Betty and Val, so leaves.	Young teenager enters room, then exits.	Just inside entrance.
02:00	Betty and Val decide to stay and watch more.	Betty and Val walk towards centre.	Straight path towards centre.
02:30 - 04:00	They watch the flock.	Slowly turning to watch flock, taking 1 or 2 steps each way.	Stand in centre facing wall w2.

Figure 9.20 Scripted movement corresponding to a movement-oriented scenario

Enactment of scripted, choreographed or improvised movement grounds the imaginings of user behaviour and experience in actual bodies.

An example of scripted movement corresponding to a movement-oriented scenario is given in Figure 9.20. It is from Project II (Bystander). For this particular system, it was important to distinguish the activity and movements of the users and their spatial paths, position and orientation. Links to the spatial movement schemas are normally included, although not shown in this example. The spatial movement schemas provide a visual representation of the spatial characteristics of the user activity—more detail is provided in section 9.3.6.

Three examples of movement scores for generating movement in user testing of an interactive, immersive space like Bystander are given in Figure 9.21. The order and timing of these elements is not prescribed and is improvised during actual performance of the score. More complex scores can be devised incorporating more parameters and constraints on the movement, as well as interactions with other people.

Movement scores

A simple score for a user persona representing an older woman, Val, may consist of three elements:

1. standing still
2. walking slowly to another location
3. slowly turning around to follow the visual effects of the system

A score for a user persona representing a young child may consist of elements, where parameters of time, relating and direction are implied.

1. running around in all directions
2. sudden plonking onto the ground
3. grabbing onto a person they know
4. dragging the companion around

A score for a user persona representing the kind of visitor that prefers to find a comfortable position and remain there may consist of elements like:

1. stand on spot
2. turn head then body to follow visual effects
3. minimal shifting of position to accommodate the infringement of another person

Figure 9.21 Examples of three movement scores for an interactive, immersive space like Bystander

Related work

- *Role-playing and acting out*: Brandt and Grunnet (2000), Buchenau and Suri (2000), Burns et al. (1994), Ehn and Sjögren (1992), Howard et al. (2002), Iacucci et al. (2002), Iacucci and Kuutti (2002), Jacucci et al. (2005), Kuutti et al. (2002), Oulasvirta et al. (2003), Sato and Salvador (1999), Svanæs and Seland (2004)

9.3.6 Visual analysis and representation of moving bodies

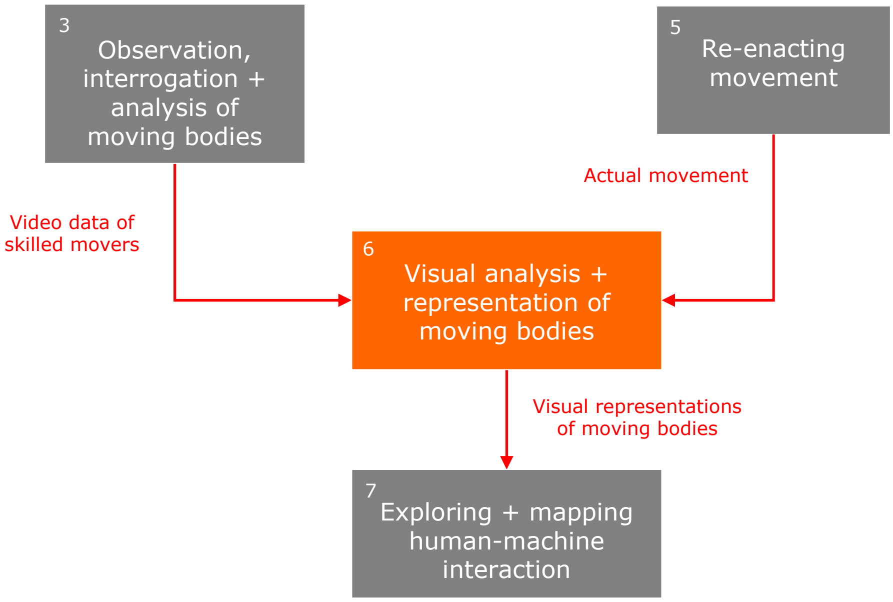

Figure 9.22 The activity of visual analysis and representation of moving bodies and its place in the methodology

Visual representations of the moving body enable closer examination of the moving body from an external or machine perspective. The data gained from this kind of inspection can assist with the design of machine interpretations of the input and bridge the interface between human-centred design approaches and technologically-driven implementations (see Figure 9.22).

The assumption here is that video sensor technology is used for input of human movement. The visual data can be analysed to identify the changing spatial shapes, positions and trajectories of moving bodies and the relation to other bodies and the external environment. The tools presented here include movement sequences, silhouettes, shape analysis using Laban Shape categories and spatial movement schemas in Labanotation.

These tools provide a rudimentary baseline of visual representations of the moving body. These visual representations can be transformed in many ways to bring out different aspects of the moving body in space and time.

They can be used as resources for the design of machine interpretations of the moving body and for computerised motion analysis.

Movement sequences and silhouettes

Movement sequences extracted from video data focus on the key postures and organisation of the body through its trajectory in space and time. The movement sequence can be presented in a number of formats to provide different kinds of information and emphasis. They assist in analysing the mechanics of the body movement in relation to the environment. The movement sequence can be transformed into a sequence of silhouettes of the body. These silhouettes highlight the changing spatial shapes made by the body as it moves through a trajectory. The dynamically changing spatial shaping of a movement can be analysed with Laban Shape categories, describing the static form and the changing relation of the body to itself and the environment. From these movement sequences, a range of other data can be derived such as the changing position of the body and its parts, the trajectory of the moving body, the use of space, timing and rhythm.

An example of a series of silhouettes for the moving body in the act of falling, taken from Project III, is given in Figure 9.23. It shows the mapping or tracking of body parts over the trajectory of the fall. The changing positions of the head, centre of torso and feet are shown for participant 4. In this representation, each snapshot in time is spread out spatially so the body and any overlaid data can be clearly seen at that instant. The shade of grey deepens over time to indicate the progression of the movement. In Figure 9.24, the Laban Effort-Shape description for the movement sequence is depicted.

Spatial movement schemas

Spatial movement schemas are visual representations of spatial paths of individual or multiple people moving through a space. They can be drawn informally or using Labanotation symbols for group choreography (Hutchinson, 1977). Using Labanotation symbols, the position, direction, path and

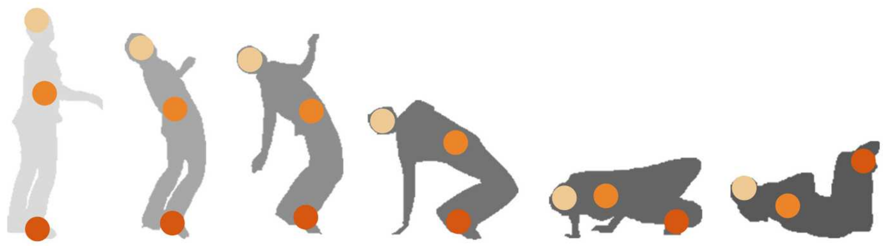

Figure 9.23 Mapping of changing positions of the head, centre of torso and feet for participant 4. The changing spatial shaping of the body is presented in its trajectory through space and time.

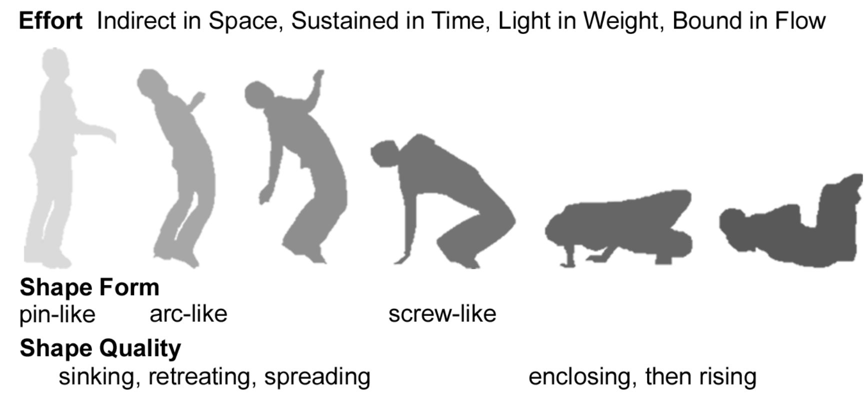

Figure 9.24 Effort-Shape description for participant 4

sequencing of multiple bodies can be visually represented.

An example of a spatial movement schema from Project II (Bystander) is given in Figure 9.25. A detailed explanation of the schema is given in section 6.2.4.

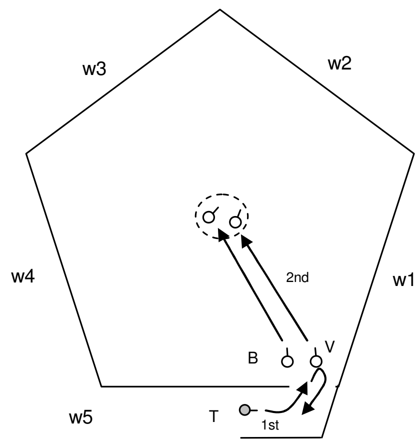

Figure 9.25 Spatial movement schema 2

Related work

- *Visual representations of moving bodies*: Badler and Smoliar (1979), Buur and Soendergaard (2000), Buur et al. (2000), Camurri et al. (2000, 2003a,b), Chi et al. (2000), Hachimura et al. (2005), Høysniemi and Hämäläinen (2004), Muybridge (1984), Zhao (2001)
- *Movement notations*: Guest (1984, 1989), Hutchinson (1977)

9.3.7 Exploring and mapping human-machine interaction

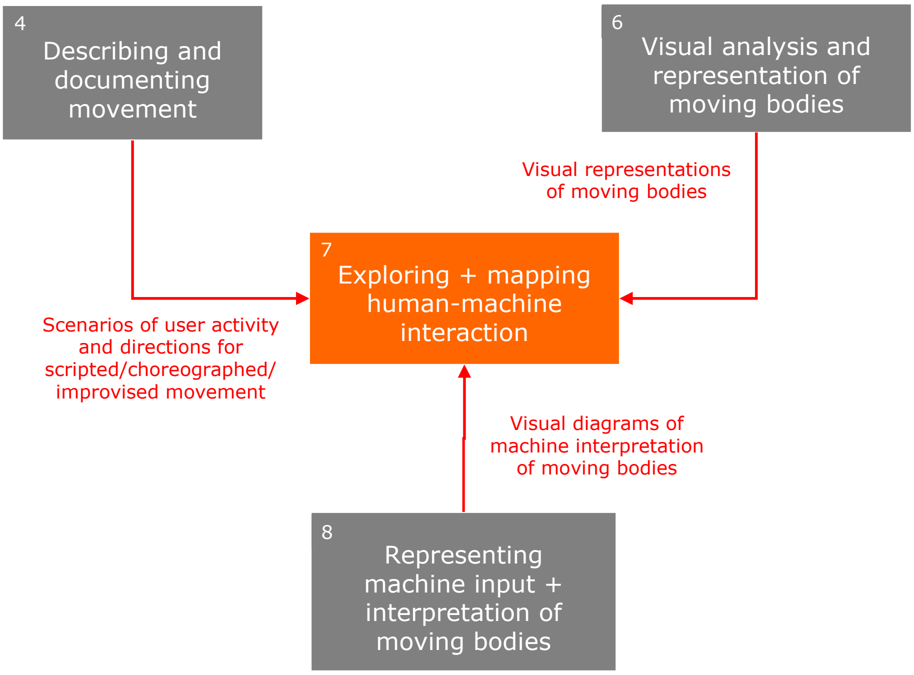

Figure 9.26 The activity of exploring and mapping human-machine interaction and its place in the methodology

When designing an interactive system, one of the core activities is exploring and mapping the interaction between humans and machine (see Figure 9.26). For movement-based interactive, immersive spaces, the focus is on mapping between human movements and the sensing of those movements by the machine and its subsequent response. This is the essence of HCI, originally referred to in the Introduction as an input-processing-output loop. A model of action and perception for both human and machine in the interaction is utilised here, as illustrated in Figure 9.27. This model is embodied in the design tool known as the *Moving-Sensing schema*.

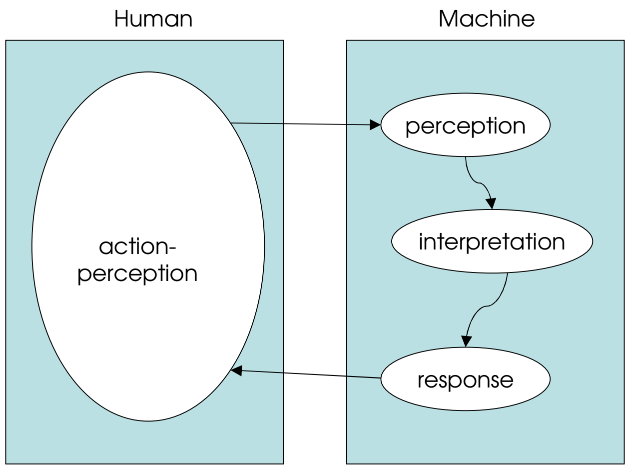

Figure 9.27 Diagram of model of action and perception for human and machine

Moving-Sensing schema

The *Moving-Sensing schema* presents the interaction between user and machine from the perspectives of the user and the machine. It is an integrating representation, as it brings together the various activities and tools that are more or less human or machine focused—this is illustrated in Figure 9.28.

Tools for representing human activity and movement include movement-oriented scenarios, movement scores and choreographic directions. Tools for representing machine behaviour include the breakdown of machine behaviour into input, output and processing. Machine input schemas are used to visually represent the input mechanisms and corresponding interpretation of the input (see also section 9.3.8). The machine input schemas rely on the visual analysis and representation of moving bodies, where actual movement is provided by enactment of scripted movement.

The *Moving-Sensing schema* is an adaptation of Suchman's (1987) analytic framework, which hinges on the notion of resources available for perception and action by human and machine. The *Moving-Sensing schema* can be organised in a flexible way to enable documentation of user activity in terms of action/movement and perception (internal/external), alongside machine interpretation and response. It makes explicit the links between particular human actions or patterns of activity in an interactive space and

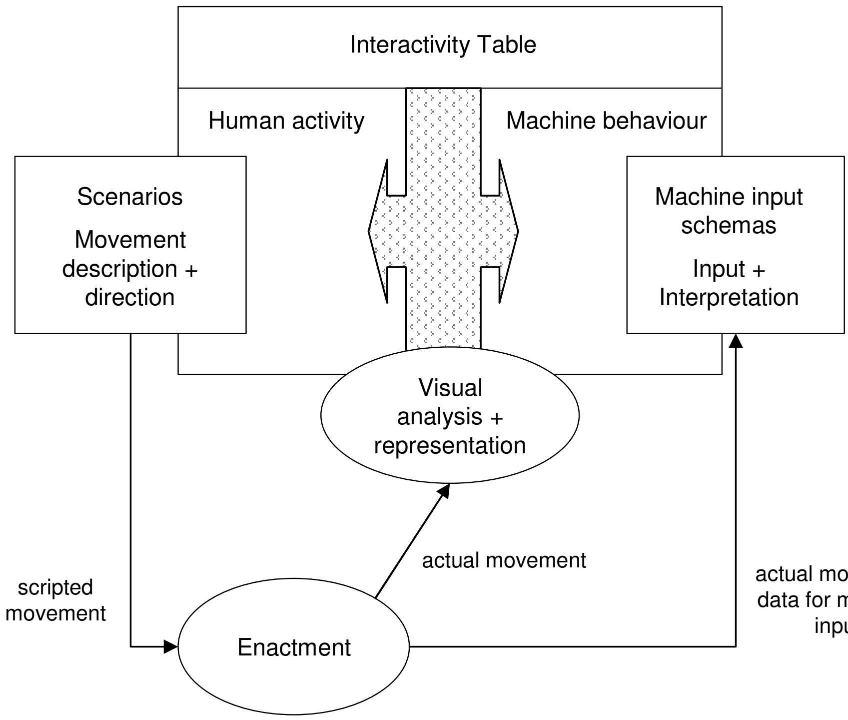

Figure 9.28 Diagram illustrating how the Moving-Sensing schema brings together various activities and tools. The ovals represent activities and the rectangles represent design tools or representations.

The User			The Machine	
Actions not available to the machine		Actions available to the machine	Effects available to the user	Design rationale
User activity/action	Movement description	Motion detection via video camera	Output: Visual display and audio	Game context

Figure 9.29 Suchman's analytic framework adapted specifically for Project I (Eyetoy)

the corresponding machine behaviour. It enables designers to explore, reason about, evaluate and refine the design of the interactivity between the active, moving bodies of human users and computer-based interactive systems using human movement as direct input. It makes explicit any design assumptions about user behaviour that become embedded in computer-based interactive systems. In this research, the focus has been on interactive, immersive spaces that have visual and sonic outputs to manifest the behaviour of the system. However the design tool can be applied to other kinds of interactive systems such as robots, which may use computer vision to sense human movement and respond with their own programmed movements (Davis and Horaud, 2003; Hachimura et al., 2005).

Examples of Suchman's analytic framework adapted specifically for Project I (Eyetoy) and as the *Interactivity table* for Project II (Bystander) are provided in Figure 9.29 and Figure 9.30, respectively. In Eyetoy, the framework was used to analyse the movements of the player interacting with the Eyetoy games. In Bystander, the framework was adapted and used as a design tool to explore and map the movements of the audience in relation to the machine behaviour.

Related work

- *Frameworks for interaction analysis and design*: Bellotti et al. (2002), Benford et al. (2005), Bongers and van der Veer (2007), Eriksson et al. (2007), Hornecker and Buur (2006), Rogers and Muller (2003), Suchman (1987)

The User			The Machine		
Actions not available to the machine		Actions available to the machine	Effects available to the user	Internal machine behaviour not available to the user	
Scenario and Key Events	User Perception	User Activity: Movement/Stillness	Machine Effects (Audiovisual)	Machine State	Machine Perception

Figure 9.30 Suchman's analytic framework adapted as the *interactivity table* specifically for Project II (Bystander)

9.3.8 Representing machine input and interpretation of moving bodies

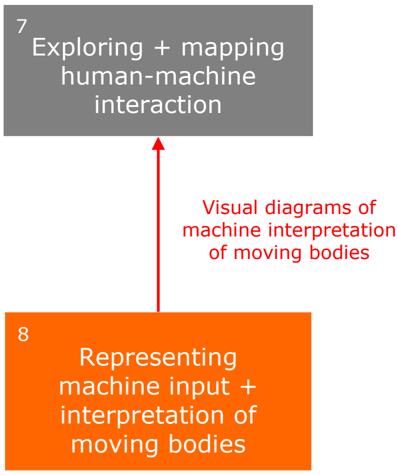

Figure 9.31 The activity of representing machine input and interpretation of moving bodies and its place in the methodology

The machine interpretation of the input depends on the specific application and the sensor technology employed. For video-based sensors, the input is dynamic visual data of moving bodies, which can be broken down frame by frame. Designing the machine interpretation of the input rests on conceptual decisions about how to interpret moving bodies in the system under design. Visual representations of the machine input and interpretation can be constructed to assist in the mapping of human activity/movement in relation to machine behaviour (see Figure 9.31). One specific representation used in this research is the *machine input schema*.

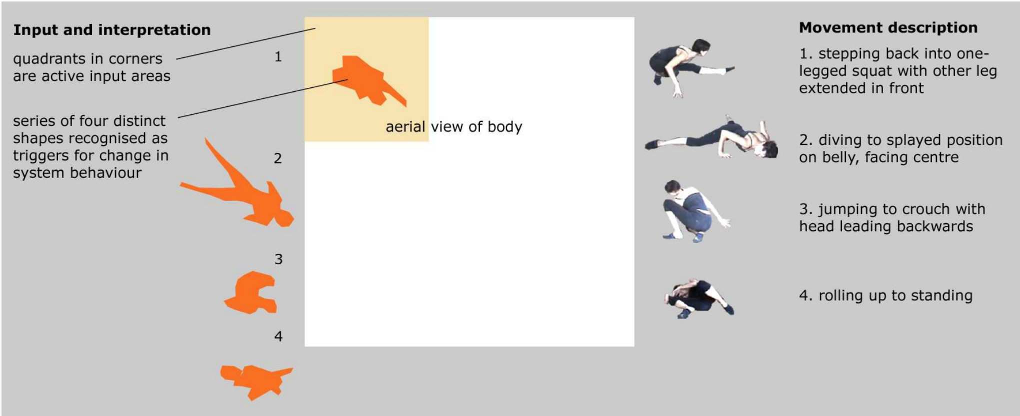

Figure 9.32 Machine input schema from Project III showing the choice of machine input and interpretation for a sequence of choreographed movements

Machine input schemas

Diagrams documenting the movements of users, such as the spatial movement schema diagrams or movement sequences, can be annotated or overlaid with interactive options, detailing the choice of input mechanism, interpretation of the input and corresponding system response. A series of these machine input schemas may be required if longer temporal and dynamic patterns of movement are to be recognised. For example, identifiable patterns of movement could be clustering and dispersion of bodies, periods of relative stillness, straight-line trajectories, slow-moving or fast-moving bodies, textures and rhythms.

An example of a machine input schema from Project III is given in Figure 9.32. The choice of machine input and interpretation of moving bodies in this case is the recognition of a series of four distinct spatial shapes of the body-in-motion within a nominated quadrant of the physical space, which then triggers certain effects such as changing visual imagery.

Related work

- *Digital representations of human motion*: Aggarwal and Cai (1999), Badler and Smoliar (1979), Camurri et al. (2000, 2003a,b), Davis and Horaud (2003), Gavrila (1997), Pers et al. (2003), Pinhanez (1999), Wang et al. (2003)

- *Sensors*: Bellotti et al. (2002), Michahelles and Schiele (2003), Rogers and Muller (2003)

9.4 Summary—A Design Methodology of Moving and Making Strange

The design methodology of Moving and Making Strange is motivated by a spirit of inquiry into the experiential, moving body. In the design of interactive, immersive spaces and other movement-based interactive technologies, the design methodology offers methods and tools for use at different stages of the design process. There are methods and tools for investigating movement through practices of *making strange* with the moving body and for inventing and choreographing movement. There are methods and tools for observing and analysing human movement from an experiential perspective and an observational perspective. There are methods and tools for describing and documenting movement and re-enacting movement. There are methods and tools for visually analysing and representing movement, exploring and mapping human-machine interactivity and representing machine input and interpretation of moving bodies.

The methodology includes the two major strands of investigation running through this thesis—the Laban system of movement analysis and Labanotation and Suchman's analytic framework adapted as a design tool. The part of the methodology for *representing* movement is contingent on the specific sensor technologies employed for sensing movement. The kinds of visual representations of moving bodies depicted in the methodology are strongly related to the use of video-based motion-sensing technologies for input of human movement. The use of other kinds of sensors such as pressure mats, lasers, ultrasound, etc. would require different forms of visual representation.

This methodology enables designers to shift between the different, multiple perspectives of the first-person experiential, the observational and the machine, depending on which method/tool is being employed. The first-person experiential perspective ensures designers are accountable to the lived experience of the mover and to potential users of technology. It develops a designer's abilities and sensibilities to work with the moving body as a design material and to access the creative potential of the moving body. It contributes to a designer's embodied intuitions for working with movement and its felt experience in the generation and evaluation of design concepts, prototypes and final systems.

The observational perspective ensures accountability to the external point of view of the observer, to what the moving body presents to the outside. Three of the five conceptions of movement presented in Chapter 3 offer various interpretations of the moving body. Movements of the body can be interpreted from the outside as physical movements, as individual or cultural expression or as communicative acts. The moving body can be considered in the sociocultural frame of patterns of social and spatial interaction between people and the patterns of meaning in structured movement systems.

The machine perspective ensures designers are accountable to the machine view of the movements of users and that appropriate mappings are made between user activity and machine interpretation and response. The representations constructed from both the observational and machine perspectives can act as boundary objects (Star, 1990) or bridging representations between the movements of users and the input and interpretation of those movements by the machine.

Chapter 10

Conclusions and Future Work

> We can begin any exploration from a conceptual framework and discover its inherent origins through creative awakening. Or conversely, we can begin any exploration from the roots of our unknowing and discover the pattern as it manifests in expressed form. It is the dialogue and weave between the two that creates the full fabric of our individual, creative, and cognizant self.
>
> Bonnie Bainbridge Cohen (1993, p.13)

This chapter summarises the results of the thesis in relation to the research questions. It also offers suggestions for future work and the extension of the design methodology of Moving and Making Strange to other kinds of interactive technologies and to phenomenologically-inspired and ethnographically-inspired approaches to technology design.

The wider implications of design for the kinds of lives we lead and the experiences made possible by engaging with interactive technologies, are at the heart of my thesis. Prioritising the lived, experiential moving body and understanding human movement as not just purely functional, but a source of qualitative, aesthetic (or even transcendental) experience, require that we look more closely at the relations between interactive technologies and the kinds of movement-related experiences and interactions they make possible.

The design methodology of Moving and Making Strange, developed in this thesis, offers an approach to the design of movement-based interactive technologies which recognises this intimate relationship between the technologies we develop and the qualities of human experience engendered. It enables a specific focus on movement and its felt experience, which can then inform the design of new movement-based systems and ensure the accountability of future systems to the lived experience of potential users of technology.

10.1 Research questions revisited

Within the context of movement-based interaction design, the research questions explored in this thesis were:

1. What understandings of human movement are relevant?
2. How and in what ways can the experiential nature of the moving body be accessed and understood?
3. How and in what ways can the moving body be described and represented?

Each question is addressed in turn, in the following sections.

10.1.1 Question 1: What understandings of human movement are relevant?

In regard to the first question, ways of understanding human movement for use in the discourse and practice of movement-based interaction design were sourced from other disciplines with a focus on movement, in particular, dance, somatics, physiotherapy, anthropology and phenomenology. Five conceptions of movement were drawn from the literature to provide a multiplicity of perspectives for designers working with the moving body as input to interactive, immersive spaces and other movement-based interactive technologies. The manifold perspectives on movement include movement as anatomical, mechanical function, movement as perception, movement as expression and transformation, movement as felt, kinaesthetic experience and movement as a communicative act. This set was chosen specifically to support the proposed design methodology with its emphasis on understanding movement from both the first-person experiential and the observational perspectives. The first-person experiential perspective deals primarily with movement as anatomical, mechanical function, movement as perception and movement as felt, kinaesthetic experience. The observational perspective deals primarily with movement as anatomical, mechanical function, movement as expression and movement as a communicative act. The five different, yet complementary, conceptions of movement enable designers to understand the moving body in interaction with machines and other people within various contextual frames, ranging from the individual performance and perception of movement to the social and cultural.

I worked with different kinds of movements in each of the three projects. The movements examined for potential input to interactive technologies included physical actions in the context of single user game-play, the patterns of movement and stillness of multiple users in social contexts and heightened and choreographed forms of movement, including the act of falling, within a hypothetical interactive space for public performance. The range of movements covered enabled a focus on the relations between the performance and experience of different aspects of movement treated as input and machine interpretations of the input.

10.1.2 Question 2: How and in what ways can the experiential nature of the moving body be accessed and understood?

In regard to the second question, the experiential nature of the moving body can be accessed and understood through first-person perspectives and methods that focus on the attention to, and articulation of, the sensing, feeling and moving body and the felt experience of movement. This was initially explored in the second project, Bystander through the use of experiential methods of design reflection-in-action (Schön, 1983), such as enactment and physical immersion. These experiential methods enabled the designers to experience first-hand the movements and felt experience of potential users of interactive technologies and to ground their understandings of the design in the actual movements arising from interaction with specific interactive technologies. Movement-oriented personas and scenarios were developed and used in this thesis to orient designers to the user experience and to provide structure for scenario enactment.

This question was further explored in the third project, Falling into Dance by working with trained dancers and physical performers. Methods and techniques were identified from dance and movement improvisation practices as potential tools for designers to access the experiential nature of the moving body and to make strange with the moving body. These methods and techniques then formed a critical part of the design methodology of Moving and Making Strange. The application of these methods and techniques will provide designers with a vibrant ground for working with movement in the design process and for finding new ways to use movement as input to interactive technologies.

10.1.3 Question 3: How and in what ways can the moving body be described and represented?

In regard to the third question, a continual thread running through the thesis was the exploration of ways of describing and representing moving bodies. A range of representations of human movement was trialled throughout the three projects as potential design tools. The design representations of movement needed to have the following characteristics in order for them to function adequately as tools for exploring movement as input. First, the design representations of movement must retain adequate references to the lived experience of movement in order to re-enact and re-generate the process and quality of the movement. Second, the design representations are produced from the perspective of being able to think through possible translations or mappings from the execution of movement by people to the detection and interpretation of those movements by a computer system. A set of design representations of moving bodies was developed in this thesis with these characteristics and includes movement-oriented personas and scenarios, spatial movement schemas in Labanotation floorplans and visual movement sequences analysed and annotated with Laban Effort-Shape description.

Language for describing movement was explored through the application of the Laban system of movement analysis and description and an examination of the language used by dancers for describing the experiential aspects of movement and for devising or choreographing movement. The Laban system was trialled in all three projects and provides a common language for describing the structural, spatial and temporal aspects of movement and the qualitative, dynamic aspects of movement in terms of Effort-Shape. The language of individual dancers was investigated in the third project. Their descriptions of movement tended to reflect their training and did not necessarily employ the same terms as the Laban system, particularly with regard to Effort-Shape. This resulted in the adoption of terminology from both the Laban system and the language of individual dancers in the design methodology of Moving and Making Strange.

The questioning of the relations between conceptions of movement and assumptions built into machine interpretations of moving bodies lies at the heart of the design of movement-based interaction. This thesis offers the adaptation of Suchman's analytic framework as a design tool to facilitate this inquiry. This new design tool is called the *Moving-Sensing schema*. The adaptation of Suchman's analytic framework as a design tool was successfully trialled in the projects, Eyetoy and Bystander. It provides a frame for exploring, interrogating and evaluating the interactions between the movements of people and the sensing and interpretations of those movements by the machine. It emphasises the resources available to both user and machine for perception and action. It is also valuable for making explicit the inherent ambiguity in interpretations of human actions from purely visual means and highlights the challenges in using human movement as direct input to interactive systems built on video-based, motion-sensing technologies.

In summary, the contributions of this research include:

- Design Methodology of Moving and Making Strange: a design approach to movement-based interaction that prioritises the experiential, moving body and consists of methods and tools for exploring, experiencing, describing, representing and generating movement.
- Laban movement analysis and Labanotation as a design tool.
- Moving-Sensing schema: Suchman's analytic framework adapted as a design tool.
- Extension of existing human-centred design tools to explicitly represent moving bodies, in the form of movement-oriented personas and scenarios.
- Patterns of watching: a catalogue of audience behaviour in terms of movements and stillness in relation to engagement with a specific interactive, immersive artwork.
- New methods for generating, enacting and experiencing movement, sourced from dance and movement improvisation practices and incorporating the principle of making strange.

10.2 Future Work and Applications

A number of possible avenues exists for future work. These include validating the utility of the methodology in actual practice; exploring movement improvisation scores for enactment and evaluation; choreographing new movements; investigating Body-Mind Centering and Bodyweather as sources of making strange; extending the methodology to other kinds of movement-based interactive technologies; and the applicability of the methodology to phenomenologically- and ethnographically-inspired approaches to technology design.

10.2.1 Validating the methodology in actual practice

The first avenue is the application of the design methodology to a concrete design situation. This would serve to validate the utility of the methodology as well as to further develop the methodology in actual practice.

10.2.2 Movement improvisation scores for enactment and evaluation

An interesting avenue of exploration is the use of scoring and other improvisational techniques for directing and improvising the movements of users in enactment and evaluation of interactive systems. In the development of Bystander, movement-oriented scenarios were used to direct the activities of people representing users during user testing. However, movement improvisation scores could be a useful technique for generating the relevant kinds of movement for other specific interactive systems.

10.2.3 Choreographing new movements

One still embryonic area of the design methodology of Moving and Making Strange is that of inventing and choreographing new movements for use in interactive, immersive spaces and with other interactive systems. This area could be expanded and developed further by continuing to work with dance choreographers and movement improvisation practitioners. The development of design methods for working with the moving body as a design material and design sensibility is an emerging area to which this thesis has contributed and seeks to further. The specific relations between the choreographing of movements for interaction, the potential interactive treatments of the movements and user experiences and meaning-making are open for further investigation.

10.2.4 Body-Mind Centering and Bodyweather

Potential sources of techniques for making strange include dance, movement improvisation and somatics as these disciplines provide attentional strategies and movement techniques based in the experiential, moving body. Two specific practices, of which I have personal experience, Body-Mind Centering (Cohen, 1993) and the Bodyweather School of Butoh, offer opportunities for further research into practices of making strange with the moving body.

Body-Mind Centering (BMC) is an experiential exploration of the relationship between the body and mind. It involves "direct experience of anatomical body systems and developmental movement patterns, using techniques of touch and movement repatterning." (Hartley, 1995, p.xxix, Introduction) It draws on Western and Eastern scientific knowledge and was developed by Bonnie Bainbridge-Cohen in the 1970s. The fundamental premise is that "the qualities of any movement are a manifestation of how mind is expressing through the body at that moment. [...] Conversely, when we direct the mind or attention to different areas of the body and initiate movement from those areas, we change the quality of our movement." (Cohen, 1993, p.1) One example from BMC is the exploration of the head-as-a-limb for accessing the imagination. This could potentially offer an entry point for designers to access the creative potential of the moving body. Another line of investigation is a further analysis of the act of falling using Body-Mind Centering righting reactions and equilibrium responses to see if it yields useful perspectives and data for movement-based interaction design.

Bodyweather is an open investigation into the moving body and a broad-based physical training drawing from both eastern and western dance, sports training, martial arts and theatre practice (de Quincey, 1988). It was originated by Min Tanaka in Japan and introduced to Australia by Tess de Quincey in 1988. The training is fundamentally concerned with making strange, with breaking habits of perception and the social mask through movement techniques grounded in sensorial focus and generative imagery. It is a potentially interesting area for interdisciplinary work.

10.2.5 Extension to other kinds of movement-based interactive technologies

The design methodology of Moving and Making Strange can also be extended to the design of other kinds of movement-based interactive technologies, not just interactive, immersive spaces built on video-based, motion-sensing technologies. Some possible areas of application include interactive entertainment, tangible and embedded computing, mobile and ubiquitous computing and robotics. The choice of sensors and input devices for detecting and recognising various aspects of movement is easily accommodated in the methodology and influences the forms of representation required in the design process.

The contemporary use of the Nintendo© Wii™ (a handheld, motion-sensing interactive device) as a rehabilitation tool for people suffering from impaired movement function as a result of stroke or burns suggests a potential application area for the methodology. The methodology's emphasis on the lived experience of movement and ways of accessing the creative potential of the moving body suggest interesting ways of understanding and extending the movement possibilities of people with impaired movement function.

10.2.6 Applicability to phenomenologically-inspired and ethnographically-inspired approaches to technology design

This thesis contributes to a long history of phenomenologically-inspired and ethnographically-inspired approaches to technology design. These approaches share a commitment to understanding the lived experience of potential users of technology. Ethnographically-inspired approaches to technology design typically utilise ethnographic fieldwork to obtain understandings of the practices of potential users of technology as a precursor to design. Both approaches to technology design imply an openness to phenomena and to developing understandings of phenomena and practices beyond what is given. This openness is reflected in the principle of making strange that pervades the design methodology of Moving and Making Strange developed in this thesis.

Given the phenomenological foundations of the design methodology, it lends itself to design from fieldwork. The general principles of the methodology include making strange, investigation of lived bodies, different, multiple perspectives and different kinds of representations. These principles motivate a design approach that can easily be extended into other kinds of technologies, not just movement-based interactive technologies. The methodology has great potential for providing a general framework for conducting technology design and research where the multiple perspectives of the first-person experiential, the observer and the machine are equally valued.

The motivating hope is that the application of the design methodology of Moving and Making Strange to the design of future interactive technologies will create new environments, new forms of engagement and new realms of experience that support and extend the experiential, moving body in its fullness of being.

To date, the work in this thesis has contributed to the wider research community by being published in two international journals and seven peer-reviewed conferences, as listed below.

1. L. Loke and T. Robertson. Design representations of moving bodies for interactive, motion-sensing spaces. International Journal of Human Computer Studies, 2009.

2. L. Loke and T. Robertson. Inventing and devising movement in the design of movement-based interactive systems. In Proceedings of OZCHI2008, December 2008.

3. L. Loke and T. Robertson. Making strange with the falling body in interactive technology design. In Proceedings of the 3rd European Con-

ference on Design and Semantics of Form and Movement (DeSForM), December 12–13 2007.

4. L. Loke, A. T. Larssen, T. Robertson, and J. Edwards. Understanding movement for interaction design: Frameworks and approaches. Journal of Personal and Ubiquitous Computing, Special Issue on Movement-based Interaction, 11(8), 2007.

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