Understanding Movement as Input for Interaction – A Study of Two Eyetoy™ Games

Astrid Twenebowa Larssen
Lian Loke
Toni Robertson
Jenny Edwards

Faculty of Information Technology, University of Technology, Sydney
Sydney, Australia
Email: {Astrid.T.Larssen; Lian.Loke; Toni.Robertson; Jenny.Edwards}@uts.edu.au

Abstract

Interaction between people and computers can now be driven by movements of the human body without the need for mediation by other input devices. We present a way of conceptualising movement-based interaction. Our approach uses two existing frameworks for investigation of the relationship between bodily actions and the corresponding response from technology. The first framework examines characteristics of an interface in terms of "Sensible, Sensable, and Desirable" movement properties. In the second framework movement is seen as a form of "communication" between the user and technology, and the analysis looks at the implications this has for realising the interaction.

Keywords

Design framework, embodiment, embodied interaction, human body, human movement, input, physical interaction, human-centred design.

INTRODUCTION

There is increasing interest in the physicality of the user within the field of Human-Computer Interaction (HCI). This is manifested in the variety of ways new concepts and technologies draw on this physicality for example for input and interaction control (Chua et al. 2003), as an interface (Ängeslevä et al. 2003), and for interaction metaphors (Mine et al. 1997). The benefits of direct manipulation were established early (Hutchins et al. 1986, Shneiderman 1998). Now, there are claims being made that increased physicality enriches the user experience (Camarata et al. 2002, Schnadelbach et al., 2002) in relation to tangible and augmented environments. However, there is little established knowledge as to why increased physicality in relation to technology produces such effects.

Using our abilities to act in physical spaces and to manipulate familiar physical objects when interacting with technology allows interaction that fits more naturally with the way we are accustomed to moving our bodies in the physical world. Such interaction can be driven by the physical makeup of the human body and also by the ways in which the body is involved in meaningful actions in a physical and social world.

This paper draws upon a study of movements produced by interaction with the Sony Playstation2® and Eyetoy™ as an exploration of how interaction can be driven by movements of the body. We describe the application of two frameworks, *Sensible, Sensable, Desirable: a framework for designing physical interfaces* (Benford et al. 2003) and *Making Sense of Sensing Systems: Five Questions for Designers and Researchers* (Bellotti et al. 2002) as a way of conceptualising movement-based interaction. The study serves as a starting point for developing an understanding of movement as input for interaction in order to inform interaction design. Using findings from the study to populate two existing conceptual frameworks then provides us with tools to further this understanding.

BACKGROUND

In human-computer interaction (HCI), the interaction between humans and computers depends on humans communicating intentions to the computer in such a way that the computer can interpret them (Preece et al. 2002). The different possibilities for communication with technology are governed by human anatomy and physiology, meaning the options for input are speech, anatomical and physiological measures, sensed movement or a combination of these modes.

For an understanding of the role of the body and movement in relation to technology, we first look to anatomy, physiology and biomechanics for information about the physical makeup and movement potential of the human body. Equally important is an understanding of the role of the body in the world and consequently to technology; here we look to Merleau-Ponty's phenomenology (1962). These accounts can inform our pursuit through their description of the human body, its possible movements and potential for action.

Movement takes place through the body's musculoskeletal system. The use of movement as input for interaction then relies on the natural paths of movement determined by the mechanics of the joints and flexion and extension of muscles and tendons. As such the human body provides both constraints and resources in the determination of possible movement profiles, as well as an indication of which parts of the body could be suitable for different types of interaction (Barfield et al. 2001).

When people interact with other people, physical, digital or hybrid environments, human movement is manifested as purposeful actions reliant on the "essential corporeality of human cognition" (Robertson 2000, p.122). This embodied nature of cognition shapes the way we can think about movement as input for interaction. For example, by learning to use a stylus we incorporate the stylus into our bodily space for the task of inputting. In contrast, when using movement as input for interaction we do not have to learn to use a new device, but we are reliant on the *potential for action* that the technology creates for us. This is to be taken in the sense that the technology poses certain constraints on and/or opportunities for our actions as natural movement, but also in the sense that what an action means depends on the intentions of the user (Svanæs 2001). In our study this means that the application, a game, creates the spaces within which the player can perform movements that are meaningful.

EXISTING FRAMEWORKS FOR CONCEPTUALISING MOVEMENTS AS INPUT

The *Sensible, Sensable, Desirable: a Framework for Designing Physical Interfaces* (Benford et al. 2003) and *Making Sense of Sensing Systems: Five Questions for Designers and Researchers* (Bellotti et al. 2002) are two frameworks that have emerged to assist researchers and designers in designing and evaluating such novel systems.

Sensible, Sensable, Desirable: a Framework for Designing Physical Interfaces

This framework is based on the analysis and comparison of characteristics of a technology in terms of *sensible, sensable* and *desirable* movement properties.

- **Sensible** being natural movements for a combination of user, technology and environment
  Consider: *"the likely effect of physical form, envisaged users and environments"* (p. 5) for degree of freedom of movement, range, speed, accuracy and stability.
  Example: Mouseclick to select in a GUI.
- **Sensable** being movements that a computer can measure determined by the sensing technologies used
  Consider: degree of freedom of movement, range, speed, accuracy and stability, as well as how one could *fool* the technology's sensing system.
  Example: Invert the mouse and select by pressing the mouse into a surface rather than using a finger on the button.
- **Desirable** being movements that are required by a given application
  Consider: how the technology would move if unconstrained by the limitations of the physical world or available sensing technologies.
  Example: Use mouse to move a scrollbar in a GUI.

Key aspects of this framework are that sensible, sensable and desirable movements only partially overlap and that an evaluation of the overlapping areas can reveal potential problems as well as opportunities to be exploited in design solutions. The framework can be related to existing taxonomies for input and input devices (e.g. Buxton 1986, Jacob et al. 1994) that explore how to analyse sensable movements in relation to sensible ones. Benford et al.'s focus on the overlaps and less sensible or non-sensable movements differentiates this framework from these earlier once.

Making Sense of Sensing Systems: Five Questions for Designers and Researchers

Using research in the social sciences that explores human-human interaction (HHI), Bellotti et al. posed a set of questions for the design of sensor-based systems. Basing the framework on HHI invites us to consider interaction as *communication* between the user and technology and how to achieve *joint* *accomplishment* (Bellotti et al. 2002, p. 416) to realise the interaction. Bellotti et al.'s framework is informed by Norman's *seven stages of action* (Norman 1998).

The basic concepts of this framework:

- **Address**: Directing communication to a system
- **Attention**: Establishing that the system is attending
- **Action**: Defining what is to be done with the system
- **Alignment**: Monitoring system response
- **Accident**: Avoiding or recovering from errors or misunderstandings.

Drawing on comparisons with GUIs, their subsequent exploration focuses on how to handle input and output issues in systems where the user interface might or might not be graphical.

STUDY

To explore movement as input for interaction with technology, we carried out a study with two games using the Sony Playstation2® Eyetoy™. We applied each framework as a way of sorting and categorising actions and movements we identified, as a tool for thinking.

We emphasize that we are not evaluating the games as such. We are using the games as a cheap and available prototype in order to study the movements produced in the interaction with the games. See Demming (2004) for a study that focuses more specifically on the usability of the games.

Eyetoy™

Eyetoy™ is a motion recognition camera that plugs into a Playstation2® game console with USB. 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. The player has no direct physical contact with the technology; rather their movements are used to drive the interaction by coinciding spatially and temporally with buttons and game events that the player can see in a projected image of their body in the middle of the screen, together with the gamescape.

Accuracy is determined by the camera's resolution and processing of frame rates. The camera is tailored to recognise specific objects in particular environments and is unable to cope with different objects, multiple objects, occlusion and changes in lighting. In terms of the technology and application, the Eyetoy™ camera functions successfully as long as sufficient coverage of the active area of the screen is achieved by the user within spatial and temporal constraints. During game play, only delimited areas of the screen are active (able to register input motion) at any point in time depending on the game context. The technology is constrained to detect movements only in the x-y plane and does not register depth as movement in the z-plane. There is an optimal distance for motion recognition given by a certain calibrated distance from the camera.

The technology is a GUI/movement hybrid, relying on movement for input and providing the players with feedback through graphical/visual and aural means. This positions the movements produced in the interactions with this technology amongst the intended candidates for evaluation with both frameworks being studied.

Method

An examination of the available games was undertaken to identify the most suitable games for this study. By a *suitable* game we mean games that were seen to elicit a range of movements while at the same time being fairly quick and easy to learn. Two games *Beat Freak* and *Kung Foo*, were selected.

Beat Freak requires the player to move their hands 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 in time with the music. The active area in this game is the circular zone designated by the top half of the speaker, which is positioned in one of the four corners of the screen. For a given event such as a CD flying out from the centre to the upper right corner, the target area becomes active for a specific time period in which the user's movement can be registered.

In Kung Foo the player needs to intersect with Wonton's henchmen to prevent them from reaching the middle of the screen. The henchmen appear randomly from both vertical edges of the screen. Extra points are gained by breaking wooden boards and hitting Wonton himself.

Eight participants, 4 female and 4 male, were recruited to play the two games. Before playing, data on demographics and previous experience with the games were collected. To avoid injury, the participants were warmed up through a series of light moves and stretches by an experienced aerobics and yoga instructor. 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 on the screen; the other view captured the participant's full body whilst playing. After playing, the participants were interviewed about their experience with the game and given a questionnaire with usability related questions. See Figure 1 for a setup of the technology.

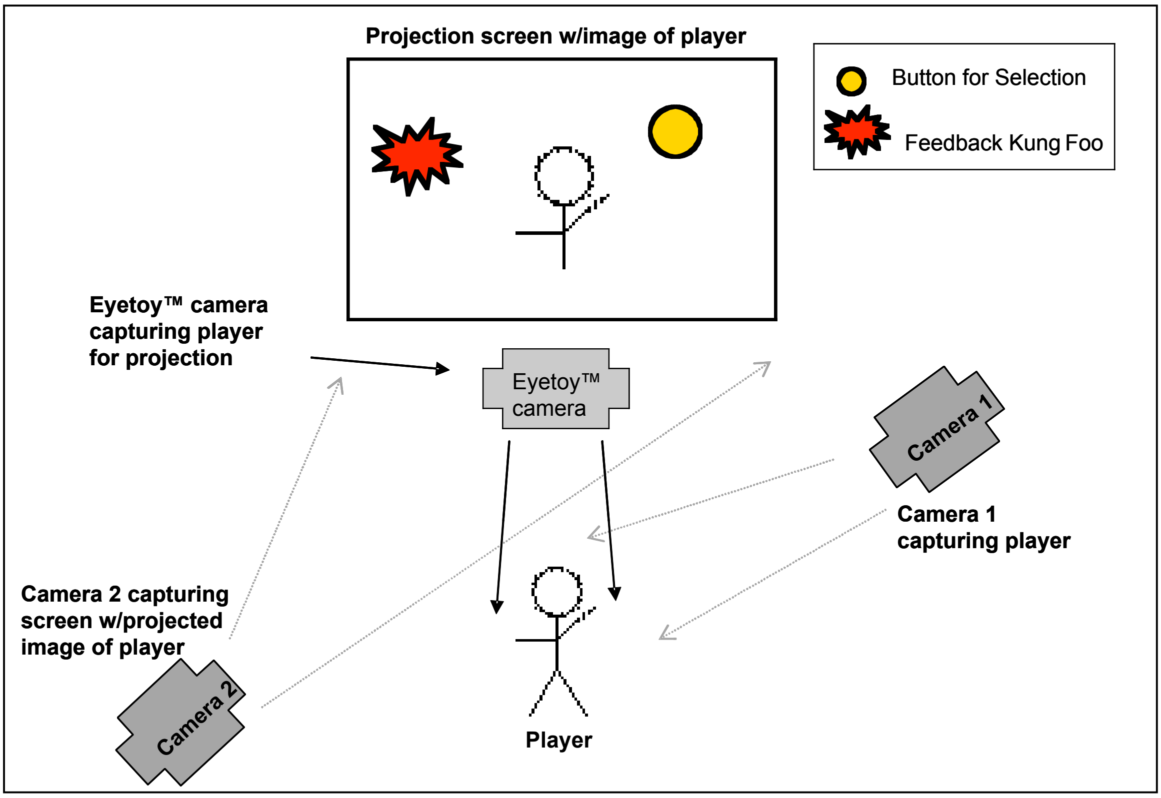

Figure 1: Experimental Setup

Analysis

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

- The actions taking place in each game; and
- The specific movements used to perform these actions.

Three of the eight participants were initially selected for analysis. The three were selected on the basis of variation between their movement styles. The actions and movements were first identified from these three, and then evaluated against the remaining five participants.

The actions used to drive the interaction in the two games are outlined in Table 1 below.

Table 1: Actions for game play

Action	Description	Game
Selection	Selection of game choices and settings	Both
Strike Moving Object at Fixed Target	Coincide with object at target location	Beat Freak
Strike Fixed Target	Strike as soon as object appears	Kung Foo
Strike Moving Target	Strike as soon as object appears	Kung Foo

The actions in table 1 were then further examined to determine the specific movements used to perform these actions. We identified an initial set of movements; these were further checked and performed with the games to ensure that they would drive interaction, eventually settling into a set of seven movements. See Table 2 for the seven movements, a description and illustrative examples.

Table 2: Movements identified during game play

Movements	Description	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	Boxing
Flick	To deliver a light, sharp, quickly retracted blow	Flicking away a piece of dust on one's coat

Table 3 shows how the actions identified in Table 1 correspond to the movements in Table 2.

Table 3: Action and corresponding movements for game play

Action	Movement	Game
Selection	Wave	Both
Strike Moving Object at Fixed Target	Reach, flick	Beat Freak
Strike Fixed Target	Slash, punch	Kung Foo
Strike Moving Target	Slash, punch, slap, swat	Kung Foo

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 Table 2.

The actions and movements listed in Table 3 were further analysed within the two frameworks.

USING THE FRAMEWORKS TO EXPLORE MOVEMENT AND ACTION

In order to study the interaction we looked at the combination of the user, the technology and the environment within both frameworks.

Sensible, Sensable, Desirable

We approached the investigation of the movements in the games using the Benford et al. framework solely with regards to the movements of the user. We disregarded the movements of the technology itself.

First the possible user interactions with the games were studied using the *sensible* and *sensable* categories of movement, without regard to the particular application (addressed by the *desirable* category). See Table 4.

Table 4: Sensible and Sensable movements

Sensible (but not sensable)	Sensible & Sensable	Sensable (but not sensible)
Natural movements that cannot be sensed	*Natural movements that can be sensed*	*Movements can be sensed but are not natural*
Any movement that takes place outside the sensing areas and capabilities of the technology: - Moving outside the area of motion recognition. - Moving too quickly or too slowly for the sensing technology. - Movements not detected due to inadequate ambient lighting.	Movements of the body, mainly arms and legs, within the area of the screen that can be registered by the motion sensing technology. The body movements should be appropriate to the spatial and temporal demands of the technology. In this case, movements of the user in the x-y or lateral plane can be sensed. Users can move in the sagittal plane but depth in the z-direction cannot be sensed. Movements of the user in the lateral plane are constrained by dimensions of the screen and physical capabilities of the body. Accuracy of timing and spatial positioning becomes more demanding as the level of difficulty increases. There is a 1-2 second timeframe for successful action during game play.	Any part of the body that moves can be sensed. It depends on the particular application as to whether a movement is considered sensible or not. It may be sensible to stand on your hands and move your legs in an acrobatic game, but not for one where it is more natural to be standing on your feet. Though such a movement can be sensed.

Secondly the set of *desirable* movements was evaluated for the particular application of the two Eyetoy™ games. *Desirable* movements were taken to be those corresponding to successful actions performed during actual game play, and thus could also be classified as *sensible* and *sensable*. In this case, the actions are for selection of game settings and game-specific movements. Thirdly the set of *desirable* movements was then considered in the light of the set of *sensible* and *sensable* movements. Unsuccessful actions were also considered as part of this analysis. Figure 2 summarises the findings of the evaluation and shows the combinations of movement categories that were considered relevant and those that were omitted. This comparison clarified the relationship between the user, the technology and the game application. It also suggested areas of potential redesign.

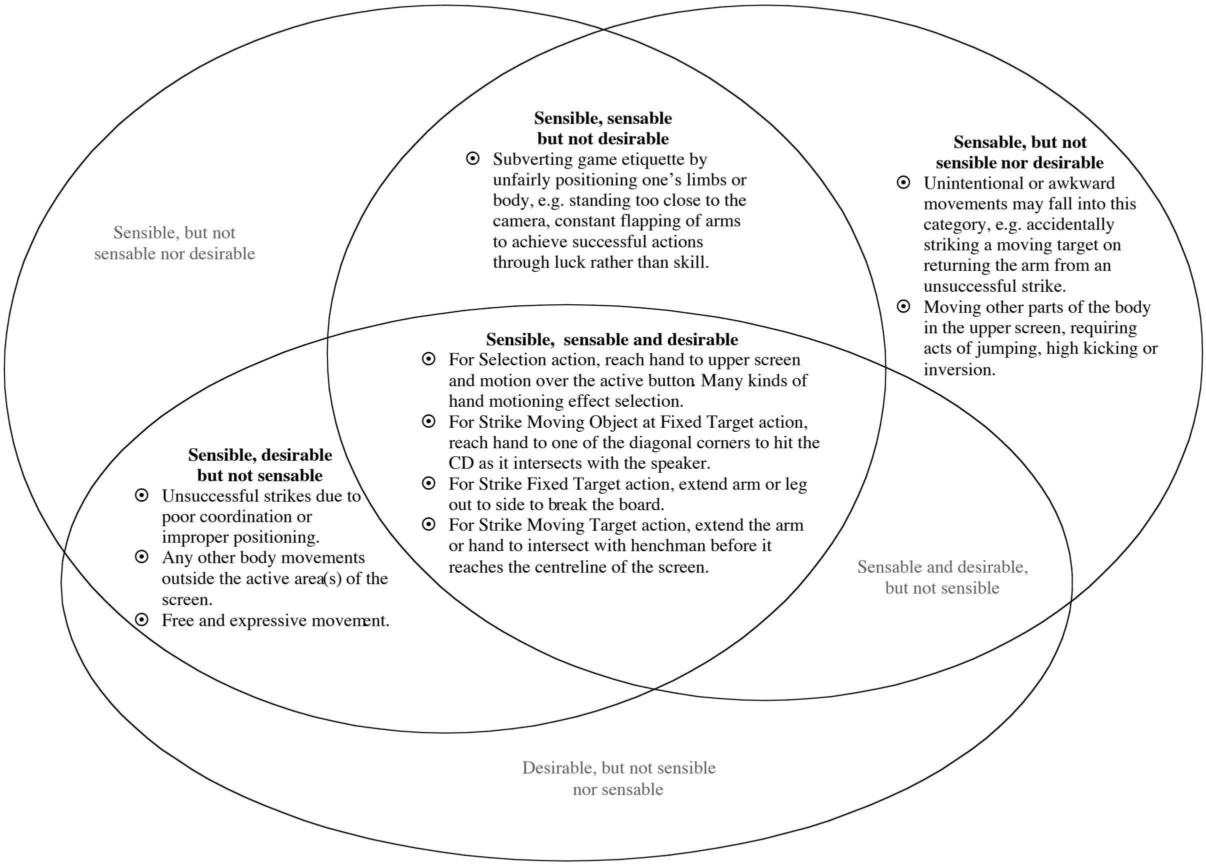

Figure 2: Combinations of Sensible, Sensable and Desirable Movements

The evaluation illustrates that the movements that fall into the *sensible*, *sensable* and *desirable* categories are probably the movements intended for natural operation of the technology. Movements outside this category were physically unlikely, technically not sensable or undesirable in this particular game. The evaluation clearly shows what constraints the technology places on the movements of the user, in other words what movements the technology *affords*.

The *desirable* category, initially taken to correspond to successful actions performed during game play and then extended to include unsuccessful actions, was found to be the trickiest to apply. If the framework was being used for design rather than evaluation, the designers' intentions would be known and this would not be an issue. Nevertheless, the *desirable* category could potentially be a useful source of reflection during design. For example, thinking in terms of *sensible* and *desirable*, but not *sensable* movements allows for movements that are free and expressive and it allows for periods of rest. It also encourages consideration of the ideal movements for the interaction. Basing design on these movement categories determines the characteristics of the sensors, rather than limiting the movements of the user to fit with the capabilities of the sensor.

Making Sense of Sensing Systems

Evaluation using the Bellotti et al. framework was conducted by looking at how movement as input would hold as communication in the interaction. We did this by considering how the games address the five questions posed by Bellotti et al. Table 5 presents the evaluation with GUI examples for comparison.

Table 5: Application of Bellotti et al.'s framework

Questions (GUI example)	**Eyetoy™ "Answers"**
Address: How do I address one (or more) of many possible devices? (Keyboard, mouse, social control over physical access)	- Only one device to *address*, but the player has to be positioned, i.e. calibrated with system. Player chooses to step into position to initiate interaction, although interaction is possible when not optimally positioned. - Interface elements designate areas to *address*. Motioning over the spot corresponding to the 'button' or intersecting with game objects *address* the system. - The system can also be addressed by other moving objects passing through sensing range, e.g. another person. - No means of *not addressing* the system other than quitting the game. *Pause* not possible.
Attention: How do I know the system is ready and attending to my actions? (Flashing cursor, cursor moves with mouse)	- Player sees their image in the projection - this is a constant reminder of the system's *attention*. System *attention* is signalled with request for command/input or game events. - Feedback is in the form of text, images, animation, audio, e.g. animation of circle closing when "selected", and visual and audio feedback when intersecting successfully with object.
Action: How do I effect a meaningful action, control its extent and possibly specify a target or targets for my action? (Click on objects, drag cursor over area around objects, select objects from menu.)	- User interface with button and game objects that designate areas to effect *action*. - Game directs the *sequence of action*. Player responds to events by moving limbs to intersect with target. Issue command by waving in a defined area in time-space, i.e. interface specifies targets. - Limited number of objects in the interface to manipulate to effect *action*.
Alignment: How do I know the system is doing (has done) the right thing? (Characters appear as you type, icon appears in a new position.)	- GUI presents text (e.g. score, stats), graphics (e.g. smashed enemies), audio (e.g. cheering).
Accident: How do I avoid mistakes? (Stop/cancel, undo, delete.)	- Not possible to *undo* action during game play, given that this is a game this would be cheating. You can change selections only by using *cancel* which takes you "back" one step. - *Mistake* in terms of game play would be failure to intersect with object, resulting in loss of a life, lower score or end of game. - Unintentionally intersecting with game objects during game, resulting in a lucky strike with visual and audio feedback, but no disadvantage in the form of lost points.

Since the Eyetoy™ operates with a GUI, some of the challenges that Bellotti et al. set out to tackle are solved in conventional GUI ways. This highlights how challenging it would be to facilitate this interaction without a GUI, i.e. how to display/output state information without a GUI, and the potential usefulness of considering these questions.

Comparison of the two frameworks

Both frameworks lead to an examination of the relationship between the user and the technology, but from different perspectives. Benford et al. consider the relationships between movements of the technology in our case taken to be the user's movements, and the environment. Bellotti et al. on the other hand focus on what happens when the technology moves into the environment around us and the challenges this poses to the interaction between people and computers. Benford et al.'s framework overlaps with Bellotti et al.'s first two questions, *address* and *attention*, in determining the relationship between the user's movements and the capabilities of the sensor technology.

From both frameworks we gained insights that we would not have gained from an evaluation using standard usability principles. The evaluation using the Benford et al. framework clearly shows what constraints technology places on the movements of the user. In contrast, the evaluation using the Bellotti et al. framework demonstrates that interaction in terms of simplistic movement profiles is possible, but it does not focus on the movements themselves in the interaction.

In HCI, design principles suggest maximising the ease of use in the interaction between people and technology. However, non-task based applications such as games would not have the same interaction design objective. In Eyetoy™ the aim of the games is for the player to make as many successful strikes as possible. The technology would not be designed to maximise the ease of striking as there must be a measure of skill in the performance of such actions. An examination of the Benford et al. *desirable* category of movement during evaluation highlighted this gap between traditional task-oriented interactions and more novel forms of interaction such as games.

Another objective in design for usability is to cater for a diversity of user ability and experience. The question of *action* in the Bellotti et al. framework revealed that the set of possible actions from the human point of view is large, but only a few (determined by the sensitivity and range of the sensors in time and space) are possible from a machine point of view. This is good for novices, but could be limiting for more experienced users. However limited variety in movements that effect action can also be an advantage.

UNDERSTANDING MOVEMENT AS INPUT FOR INTERACTION

People organise their bodily movement and expression according to their intentions as they inhabit the space provided by the game. This bodily organisation is crucial for performance of movements that are meaningful and intentional actions. Within the Eyetoy™ games, we identified four basic actions that were performed with a variety of movements reflecting the individual movement preferences of the participants. The two games studied produced quite different movements. Kung Foo produced a variety of strong, fast movements in all lateral directions in space. The expressive force applied by players whilst defending themselves from attacking henchmen suggests that a movement needs to be considered within the context of its performance, particularly its underlying intention. When designing systems that rely on movement as input for interaction, it may be useful to examine, not just the communicative intent of the movement, but the effort required for performance of that movement as well. Our earlier work on the usefulness of Labanotation for the design of movement-driven interaction proposed that an understanding of human movement as described by Laban (1980) would provide designers with a tool for explicitly considering the types and qualities of human movement for their area of application. Apart from the structural aspects of movement dictated by the anatomy and mechanics of the human body, Labanotation also provides a way of describing the effort or energy expended in a movement in terms of its relation to weight, space and time.

What happens to the rest of the body? A movement of the body does not happen in isolation. As Benford et al. so aptly put it, “the moment of interaction is embedded in an entire gesture that determines its timing and feel” (p. 4). The players were observed bracing themselves when hitting the virtual wooden boards in Kung Foo and literally dancing along in Beat Freak, even though the only thing the sensor would pick up was whether the player’s arm was in the right position to intersect with an object in space-time. The dancing and bracing movements are *sensible* movements; should they also be *sensable?* Making them sensable pushes more responsibility and complexity onto the technology in terms of sensing and interpreting the input; making them non-sensable can allow for movement that is free and expressive and it also allows for periods of rest. Bowers and Hellström (2000) refer to this as designs that allow *expressive latitude*, leaving room for physical performance and individual movement styles. In the Eyetoy™ games non-sensable movements occurred whenever the player stepped outside the area of the screen or was not interacting with the active areas of the screen. This could have been exploited in design as the desirable action of pausing the game by stepping outside the sensing area of the camera – something not currently possible. Beat Freak was played in an almost semaphore-like way; an observation that can be potentially useful for interactions that require a limited set of stylised movements. This could further be exploited in design by varying the degree of expressive latitude sensed by the technology. If the technology is designed for coarse-grained recognition of movement then it allows greater expressive latitude in the performance of these movements.

An interesting but different issue related to the use of movement as input for interaction was observed as well as articulated by several of the participants; the type of movement or effort used for the S*election* action may be inappropriate to the required function. Waving to activate a button was found by some participants to be an inappropriate movement in terms of effort expended and expectation. The expectation of a user familiar with buttons, be they physical or virtual, is to press or push the button.

However, the S*election* action may have been designed this way due to the limitations of the motion sensing technology which cannot register depth.

CONCLUSION

Our objective for this investigation was to further our understanding of interaction driven by movements of the body. Our analysis suggests that both frameworks are valuable tools that will aid researchers and designers in understanding some of the specific challenges that new interaction and input options present and how they might be evaluated.

When movement is the primary means of interaction, the forms of movement as enabled or constrained by the human body together with the affordances of the technology need to be considered as a primary focus of design. The particular application supplies the context within which users can perform movements that are meaningful and purposeful acts. It is important to consider any movement that is input for interaction within the context of its performance and the underlying intention of the user. It is also vital to respect the natural paths of movement of the human body and the effort expended in performance of movements intended for interaction.

For intuitive and natural interaction through movement an appropriate mapping between movement and function is also important. This is the point made by Benford et al.'s *sensible* and *sensable* categories as well as Buxton (1986), who argued that the form of an input device is as important as the dimensions of sensing it affords. Underlying all of this is the fact that we have to address Norman's (1988) *gulfs of execution and evaluation* in a very different arena. An understanding of movement from these many and varied perspectives can only improve the design and evaluation of systems that rely on movement as input for interaction. Future work includes extending the frameworks or creating methods of evaluation that more explicitly consider human movements as input for interaction.

REFERENCES

Ängeslevä, J., Oakley, I., Hughes, S. & O'Modhrain, S. (2003), 'Body Mnemonics: Portable Device Interaction Design Concept', *UIST'03*, Vancouver, Canada.

Barfield, W., Mann, S., Baird, K., Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., Martin, R. & Cho, G. (2001), 'Computational Clothing and Accessories', in W. Barfield & T. Caudell (eds), *Fundamentals of Wearable Computers and Augmented Reality*, Lawrence Erlbaum Associates, Mahwah, New Jersey, pp. 471-509.

Bellotti, V., Back, M., Edwards, W.K., E., G.R., Henderson, A. & Lopes, C. (2002), 'Making Sense of Sensing Systems: Five Questions for Designers and Researchers', *CHI'02*, ACM Press, Minneapolis, USA, pp. 415 - 422.

Benford, S., Schnadelbach, H., Koleva, B., Gaver, B., Schmidt, A., Boucher, A., Steed, A., Anastasi, R., Greenhalgh, C., Rodden, T. & Gellersen, H. (2003), *Sensible, Sensable and Desirable: a Framework for Designing Physical Interfaces*, Accessed 5 Nov 2003, Available: http://machen.mrl.nott.ac.uk/PublicationStore/2003-benford.pdf.

Bowers, J. & Hellström, S. O. (2000), 'Simple Interfaces to Complex Sound Improved Music', *CHI'00 extended abstracts on Human factors in computing systems*, ACM Press, The Hague, The Netherlands, pp. 125-126.

Buxton, W. (1986), 'There's More to Interaction Than Meets the Eye: Some Issues in Manual Input', in D. A. Borman & S. W. Draper (eds), *User Centered System Design: New Perspectives on Human Computer Interaction*, Lawrence Erlbaum, Hillsdale, N.J., pp. 319-337.

Camarata, K., Yi-Luen Do, E., Gross, M. D. & Johnson, B. R. (2002), 'Navigational Blocks: Tangible Navigation of Digital Information', *CHI'02*, ACM Press, Minneapolis, USA, p. 752–753.

Chua, P. T., Crivella, R., Daly, B., Hu, N., Schaaf, R., Ventura, D., Camill, T., Hodgins, J. & Pausch, R. (2003), 'Training for Physical Tasks in Virtual Reality Environments: Tai Chi', *VR '03*, pp. 87- 94.

Demming, G. (2004), 'Sony Eyetoy(TM): Developing Mental Models fpr 3-D Interaction in a Gaming Environment', *APCHI'04*, vol. LNCS 3101, eds. M Masoodian, S. Jones & B. Rogers, Springer, Rotorua, New Zealand, pp. 575-82.

Hutchins, E. L., Hollan, J.D. & Norman, D. (1986), 'Direct Manipulation Interfaces', in D. Norman & S. Draper (eds), *User-Centred System Design*, Lawrence Erlbaum Associates, Hillsdale, pp. 87-124.

Jacob, R. J. K., Sibert, L. E., McFarlane, D. C. & Mullen, M. P. J. (1994), 'Integrality and Separability of Input Devices,' *ACM Transactions on Computer-Human Interaction*, vol. 1, no. 1, pp. 3-26.

Laban, R. (1980), *The Mastery of Movement*, 3rd revised and enlarged by Lisa Ullmann edn, Plays, Inc., Boston.

Merleau-Ponty, M. (1962), *Phenomenology of Perception*, trans. C. Smith, Routledge, London.

Mine, M.R., Brooks Jr., F.P. & Sequin, C. (1997), 'Moving Objects in Space: Exploiting Proprioception in Virtual-Environment Interaction', *SIGGRAPH'97*, ACM Press/Addison-Wesley Publishing Co, pp. 19-26.

Norman, D. A. (1988), *The Design of Everyday Things*, Basic Books, New York.

Preece, J., Rogers, Y. & Sharp, H. (2002), *Interaction Design: Beyond Human-Computer Interaction*, John Wiley & Sons, New York.

Robertson, T. (2000), 'Building bridges: negotiating the gap between work practice and technology design', *International Journal of Human-Computer Interaction*, vol. 53, pp. 121-146.

Schnadelbach, H., Koleva, B., Flintham, M., Fraser, M., Izadi, S., Chandler, P., Foster, M., Benford, S., Greenhalgh, C. & Rodden, T. (2002), 'The Augerscope: A Mixed Reality Interface for Outdoors', *CHI'02*, ACM Press, Minneapolis, USA, p. 9–16.

Shneiderman, B. (1998), *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 3rd edn., Addison-Wesley Longman, Inc., Reading, Massachusetts.

SONY, *Eyetoy ™ website*, Accessed 16 July 2003, Available: http://www.eyetoy.com/.

Svanæs, D. (2001), 'Context-Aware Technology: A Phenomenological Perspective', *HCI Journal, special issue on context-aware computing*, pp. 379-400.

COPYRIGHT