Labanotation for Design of Movement-Based Interaction

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ABSTRACT
This paper reports findings from a study of Labanotation, an already established movement notation, as a design tool for movement-based interaction where movements of the human body are direct input to technology. Using Labanotation, we transcribed movements performed by players of two different Eyetoy™ games. Our analysis identified a range of advantages and disadvantages of the potential use of Labanotation in design. Its major disadvantage is the effort required to learn how to use it. But it supports a representation of movement that can be easily linked into the context and point of interaction. This provides a valuable foundation for design of movement-based interaction.

Keywords
Design tool, human movement, Labanotation, movement analysis, movement notation, physical interaction.

1. INTRODUCTION
The design of movement-based interaction with technology is an emerging area that calls for a renewed focus on the active human body and its capacity for movement. Opening up input possibilities to involve the moving body promises richer forms of interaction than those offered solely by the traditional keyboard, mouse or joystick. Fertile areas of research and development include the burgeoning games industry, interactive entertainment and interactive art, as well as physical training and rehabilitation.

We present in this paper our findings from an investigation into the potential usefulness of Labanotation, an already established movement notation, as a design tool for movement-based interaction. Our primary aim was to examine the ways in which this notation, for representing and recording human movement, might provide designers with a useful tool when designing interaction that involves 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 analysis is based on a study of people's movements when playing two Sony Playstation2® Eyetoy™ (hereafter referred to as Eyetoy) games. The Eyetoy games utilise free body movements performed by players as input and very basic computer vision to sense that input.

A secondary aim was to make the use of Labanotation accessible to designers of movement-based interaction, who may not necessarily be skilled observers or performers of movement, nor familiar with this notation. In the following section, we provide some context for later discussion including existing approaches to representing and analysing movement, an introduction to Labanotation and an overview of how it is being used to date in technology design and development. We then present our analysis of, and reflection on, the transcription of movements using Labanotation. We conclude the paper with a discussion of the potential contribution of Labanotation as a reflective design tool.

2. BACKGROUND
We can describe human movement from many perspectives - the mechanics of the moving body in space and time, the expressive qualities of movement, the paths of movement through space, the rhythm and timing of movement, and the moving body involved in acts of perception as part of human action and activity, to name but a few (Bartenieff, 1980; Farnell, 1999). Each discipline has differing models and approaches to understanding and representing the moving body. The areas that are pertinent to this study include dance choreography, movement observation, computerised human motion analysis, computer vision and recognition of human movement, and computer simulation of human movement. The major, established movement notations have arisen out of dance choreography and include, as well as Labanotation, Benesh - a system for ballet based on an abstract stick figure representation on a music stave and Eshkol-Wachmann - a more general system, not specifically tailored to the human form (Hutchinson, 1977).

An early form of movement analysis developed by Muybridge (1984) in the 1890's 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. His work was the forerunner for contemporary methods of movement analysis dominated by use of the video camera (Farnell, 1999) and computerised motion analysis (Aggarwal & Cai, 1999). This technique of presenting a sequence of stills to represent a phrase of movement is being used today within the fields of human-computer interaction and game design. Some researchers have found video-based analysis and representation of human movement to be more efficacious for game design than graphical notation systems such as Labanotation (Höysniemi & Hämäläinen, 2004). Contemporary movement analysis is the domain of biomechanics, sports science, sports performance and physical rehabilitation. These fields typically use computerised motion analysis systems that are based on a biomechanical understanding of the moving body. 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 statistical models of human movement (Gavrila, 1997; Aggarwal

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& Cai, 1999). Computer vision, for instance, is rooted in algorithmic and computational approaches for the visual analysis of human movement; this analysis aims to recognise human motion at three distinct levels - body parts, tracking of the whole body, and recognising human activities.

Existing work in human-computer interaction, computer animation and artificial intelligence that uses Labanotation and Laban's theory of movement falls into two main categories – *recognition* and *simulation* 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). This has been continued with the development of the EMOTE model – a 3D character animation system that incorporates other elements of Laban's theory in order to produce simulated movement that is more natural and expressive (Chi et al., 2000). Further examples include animation systems for visualising dance choreography from written notation scores, such as Life Forms, NUDES and Virtual Ballet Dancer (Neagle et al., 2003). Aspects of Laban's theory are also being used in attempts to extract emotive qualities from human movement – as part of computerised motion recognition systems such as EyesWeb, a system that recognises gesture and affect from dance movement (Camurri et al., 2000); the design of gestures for affective input (Fagerberg et al., 2003); and the gestural semantics of caress (Schiphorst et al., 2002).

Most of this work focuses on *digital* representations of human movement within the computer. We are interested in *design* representations of human movement for movement that is used as *input* to technology. Our interest in a movement notation for the design of movement-based interaction is complementary to the methods mentioned above.

2.1 Labanotation

Labanotation is a system of analysing and recording movement, originally devised by Rudolf Laban in the 1920's and further developed by Hutchinson and others at the Dance Notation Bureau, New York (Hutchinson, 1977). It continues to be used in fields traditionally associated with the physical body, such as dance choreography, physical therapy and drama. It has also been applied in anthropology and industrial production. It can be used for analysis and choreography of all forms of human movement. It comprises a symbolic notation, related to music notation, where symbols for body movements are written on a vertical 'body' staff. The symbols represent change; that is, movement. 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 a transfer of weight. A gesture is a movement of a part of the body that does not involve a transfer of weight.

There are three essential forms of movement description in Labanotation - *Motif*, *Effort-Shape* and *Structural*.

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 just describe 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. For example, in dance choreography this form of description conveys the aesthetic, emotional and expressive qualities of the dance, not just where the feet are. *Effort* (or the energy content) of a movement is described in dimensions of Weight, Space, Time and Flow; together with how a person engages with or resists each dimension. Each dimension 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 dimensions 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 1. For example, a *Glide*, which is Light in Weight, Direct in Space and Sustained (i.e., slow) in Time (see top, back, left corner of cube in Figure 1). 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 1).

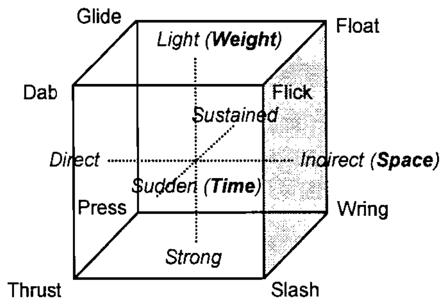

Figure 1. Effort cube

Shape describes the spatial shaping of form – growing, shrinking or carving patterns in space. 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 along the path dictated by the spatial intent as the person repeatedly pulls the net in towards the body (Bartenieff, 1980).

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 (meter 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 at in space.

We have provided here a broad overview of the range of description available in Labanotation. We found in our study 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. But this is not to imply that other kinds of systems would not exploit more of the options available within Labanotation.

3. THE STUDY

The aim of this study was to gain an understanding of the potential usefulness of Labanotation for the design of physical or movement-based interaction with computer technology. It involved the use of Labanotation for analysing and transcribing movements produced by interaction with the Eyetoy interface. We were using the Eyetoy games as a prototype of future systems that are based on human movement and computer vision. It should be noted that although we did not undertake an actual design activity using this notation, the kind of analytical work we performed would appear in any rigorous iterative and user-centred design process, that is grounded in observation of actual practice.

3.1 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. 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 we use the terms *virtual space* 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 player's movements are able to be sensed by the camera and registered as input. 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 of the player, given by a certain calibrated distance from the camera.

3.2 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 (see Figure 2) 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 2. Beat Freak game

In Kung Foo (see Figure 3) the player has to strike Wonton's henchmen by moving their limbs. 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.

Figure 3. Kung Foo game

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 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. After playing, the participants were interviewed about their experience with the game and given a questionnaire with usability related questions.

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 evaluated against the remaining five participants. 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 the movements of individual participants. 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.

3.3 Actions and movements

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.

Table 1. Actions and characteristic movements for game play

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

The actions in Table 1 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 Table 2).

Table 2. Characteristic movements of game play

Movement	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

For each of these actions the mechanics of each participant's movement were transcribed into a movement script using the 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 embodied understanding of Laban's theory (after Newlove, 1993), while refining our 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*.

3.4 Examples of Labanotating

In this section we present detailed explanation of two out 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 our application of Labanotation in this study.

Before describing the notated movements, 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. When notating, a *normal carriage* of the body is understood 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*. For our purposes here, we have deviated from the standard Laban convention for normal position of the feet being in ballet first position, instead, we are assuming a more natural position for our context is feet about hip width apart. 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.

For the *Strike Moving Object at Fixed Target* action the notated movements for participant 2 are presented in Figure 4 below. 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. We suggest that Figure 4 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 top, with time in the vertical axis. Time can be split into measures (rows in the diagram), just like in musical scores. We have numbered each measure 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 contraction of the hand. See the legend in Figure 5 for symbols used in this paper.

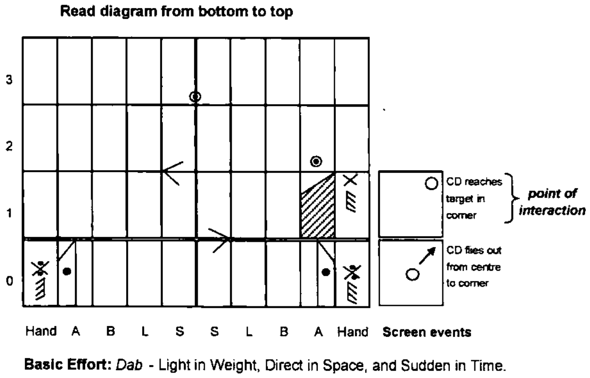

Figure 4. Labanotation for Beat Freak action by participant 2

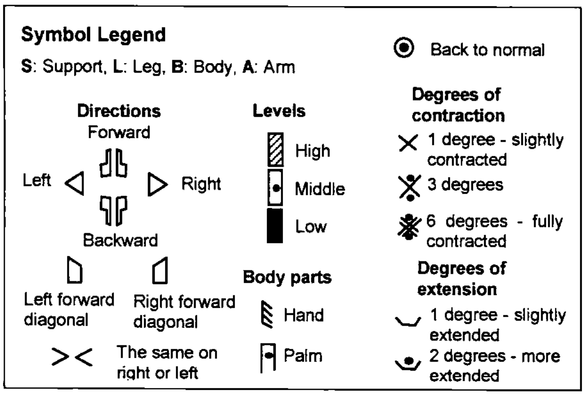

Figure 5. Legend for Labanotation

The notated movement for *Strike Moving Object at Fixed Target* action of participant 2 in Figure 4 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. We have indicated the game events 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' symbol), they shift their weight to the left and then in measure 3, they return to centre. Here we have taken liberty with the use of the 'back to normal' symbol and redefined it 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.

For the *Strike Moving Target* action in the Kung Foo game the notated movements for participant 5 are presented in Figure 6 below.

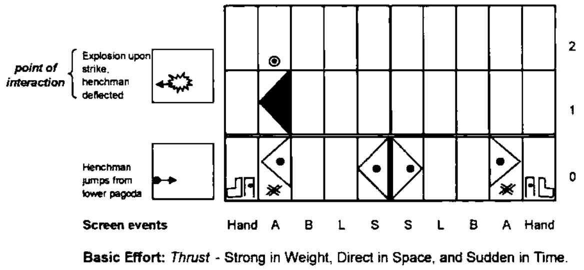

Figure 6. Labanotation for Kung Foo action by participant 5

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 7 below portrays the corresponding performance of the *Strike Moving Target* action for participant 5.

Figure 7. Performed movements for participant 5, Kung Foo

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 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 Table 2. These variations and subtle nuances in performance could be suppressed on the functional movement script (see Figure 8) if they were incidental to the functioning of the interface. If it was important to explicitly describe allowable variations, then this could be included on the diagram in some form.

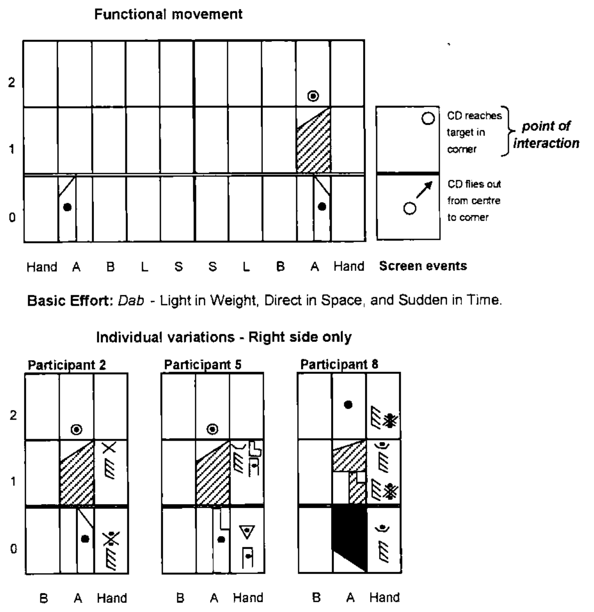

Figure 8. Functional movement and individual variations

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. Typical physical actions would be lightly and quickly reaching to a point in space and retracting - these would tend to exhibit 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 would be typical and would tend to exhibit 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 1), 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.

These two Eyetoy games did not encourage people to move around the space as the optimum position for play was in the centre where initial calibration took place. Most participants stayed rooted to the spot, moving only their arms and acting within the lateral plane. Perhaps more experienced players would be more adventurous in how they moved their bodies in the space, although this form of single-camera, computer vision input technology does place spatial restrictions on the player. We observed that some of the participants engaged in experimentation with how their movements resulted in a higher ratio of successful strikes. Two common strategies included holding their arms further out to the periphery which was then closer to the point of interaction with the target event, or using a sweeping gesture. However they usually tired of these strategies and reverted to a more natural posture with their arms closer to their upper body whilst readying for the next game event.

4. DISCUSSION

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. Our 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 we describe these advantages and disadvantages through the concepts of functional and performed movement, simplicity and specificity, context of movement, and ease of reading and writing, presented below.

4.1 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.

4.2 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 study, 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, 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™ Me2Cam, that is 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, or alternatively, more sophistication of the input technology 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 Höysniemi and Hämäläinen (2004). Höysniemi and Hämäläinen's concern 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.

4.3 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, and 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 6).

In other work involving the design of an interactive, immersive environment, we have investigated the use of Labanotation intended for group choreography (Loke et al., 2005). We found it to be very valuable for representing the social and contextual aspects of interaction that influence how and where people move and locate themselves in space in relation to others. Spatial trajectories can be mapped onto floor plans indicating the position, orientation, direction and path taken through space and time of individual and multiple people.

4.4 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 8).

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" (Suchman, 1994). 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 lifelike human figure that dynamically performs the notated movements. Computerised Laban editors are also available to facilitate the recording of notated movements (Neagle et al., 2003).

Höysniemi 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. CONCLUSION

The findings from our study suggest that Labanotation is a potentially useful tool to support the design of movement-based interaction, particularly for systems where physical actions of the user constitute the actions in the system, such as the Eyetoy games. Labanotation and its underlying movement analysis system offer an understanding of the moving body and its movement potential that can act as a foundation for the design of movement-based interaction. It provides a common vocabulary and ensures a common understanding of movement principles that are valuable for designers of physical or movement-based interaction, who may not be well-versed in movement observation. The visual representation of movement in Labanotation can easily be linked to the points of interaction within a particular game context by depicting the interface elements alongside the scripted sequence of movements. The essential features or the general form of the movement required for successful functioning of the interface can be represented as a *functional movement* script in Labanotation. The functional movement script can then be used to reason in a more informed, robust and flexible way about possible input design options.

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