Evaluation of User's Physical Experience in Full Body Interactive Games

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Abstract. This paper is an evaluation of full body interactive games using Kroflič's and Laban's framework of Body, Space, Time and Relationship. An experiment with 8 participants playing 10 games for 20 minutes was conducted and recorded to digital video. Body, Space and Time elements have been measured using observation, motion tracking and Quantity of Motion (QoM). The results from the experiment informed the designer about the participants' physical experience through the analysis of postures used in each game, the quality of the movement, the body parts used in the interaction, the playing area, the direction of movement, direction of gaze, tempo, dynamics and QoM. The experiment informed the designer about important issues of the user's physical experience and proved that the method can provide useful information in the development and evaluation of full body interactive games. The theoretical work of Laban and Kroflič also proved useful for interaction and games design in the transition from desktop to full body interactive games.

1 Introduction

Although the start of full body interaction games goes back to the 1970s with Krueger's work in VideoPlace (Krueger, 2001), the design of full body interactive games is a new research and design area. Evaluation is complex, as the coordination of mental and physical skills is required for successful playing. Different methods, based mainly on the observation and written output have been used, while visualisations of human movement (ie. tracking) have been used in the analysis of sports and dance.

One of the first evaluation frameworks (Warren, 2003) was trying to answer how successfully the gamelets (i.e. sub elements of the games) incorporate the five important advantages of using computer vision over more traditional interfaces in video games which are Athleticism, Expressivity, Whole Body, Vocabulary of Action and Playability. Labanotation has been used in the interaction design context to evaluate Eyetoy Sony PlayStation (Sony Corporation, 2005), games (Loke, Larssen, Robertson, & Edwards, 2007), and it provided a valuable foundation for the design of movement-based interaction. Full-body interaction challenges for successful playing

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of Kick Ass Kung-fu (Höysniemi & Hämäläinen, 2005) requires (1) Locomotor skills, (2) Nonlocomotor skills, (3) Manipulative skills, (4) Movement awareness, (5) Body awareness, (6) Spatial awareness, (7) Focusing attention, (8) Observing visual feedback, and (9) Ability to remap movements. The above mentioned games have used different approaches, and their pioneering work is extremely valuable. It addresses issues of interaction and games design, such as the relation between the user movement and the games element on the screen. However, it does not analyse the user's physical experience.

Sports and health sciences and dance, on the other hand, have a great tradition of analysing human physical activity. Sports science analyses the performance of an individual player and a team. In professional sports this includes analysis of biomechanics, physiology, motor skills, game tactics, techniques and behaviour. Software such as Simi Motion (SIMI Reality Motion Systems GmbH, 2004) uses computer vision algorithms that perform motion analysis. Software Simi Scout (SIMI Reality Motion Systems GmbH, 2008) tracks the distance each player covers during a game. Speed and directions of movement, strokes and/or hits can also be measured. Lucent-Vision system (Pingali, Opalach, Jean, & Carlbom, 2001) tracks the motion trajectory of a tennis player. Data are visualized for further analysis with heat and coverage maps, speed charts, 3D images and animation, still and sequential imaging and more conventional graphs. Health experts are interested in what effect the full body and other physically interactive games have in respect of spiroergometry, heart rate and the whole body kinematics (Böhm, Hartmann, & Böhm, 2008).

In dance, Labanotation is a system of recording movement, and Laban Movement Analysis has been developed to analyse the movement. Originally devised by Rudolf Laban in the 1920's (Kroflič, 1992), it continues to be used in fields traditionally associated with the physical body, such as dance choreography, physical therapy and drama. Kroflič (Kroflič, 1992) based her own framework of Time, Body, Space and Relationship on Laban's work. The last category indicates that all categories are closely linked-up. In the EyesWeb (InfoMus Lab, 2008) project (Castellano, Bresin, Camurri, & Volpe, 2007), two expressive motion cues were considered: the Quantity of Motion (QoM), and the Contraction Index (CI). Both cues are global indicators of human movement; QoM is correlated with the user's energy, and CI with the space occupied by the user.

2 Materials and Methods

The Ambient Interactive Storybook (AIS) is an interactive storybook for an immersive environment, equipped with a web cam, a large visual display, and a PC using low level computer vision algorithms, such as detecting mass center and motion detection to measure the amount of motion. In AIS users spontaneously discover a story and characters, play games, solve problems, and express and reflect about their aesthetic experience with their body. The user experience is similar to Sony PlayStation's Eyetoy (Sony Corporation, 2005) games, but is targeting younger children. In ten full body interactive games (Koštomaj & Boh, 2009a), music sets the mood, but also influences the tempo of playing, as a higher music tempo usually requires from the user to move quicker and is therefore more physically demanding. Games are based on popular children's edutainment genres such as racing, matching, memory, catching and shooting, but are obviously adapted to the situation when the user sees him/her self on the screen.

Movement in AIS and in other full body interactive games differs from the movement in dance, physical therapy and drama, as it is based on open skills in an unpredictable environment. Even in a highly improvised dance one moves according to a plan (i.e. choreography), while in the AIS's full body interactive games it is the randomness of the game's elements that determines movement, which is therefore freer and less predictable. In this respect the movement is somehow similar to the movement in sports games. A good example is a basketball game, where there are many relationships between the players, space and the next action of a player, and the game is highly unpredictable.

Methods and participants - The experiment was conducted in Museum of Recent History, Celje, Slovenia in January 2008 with 8 participants aged between 5 and 13 years, and body height between 116 cm – 178 cm (Table 1:). Each participant played 10 games, 20 minutes each. The experiment was recorded with 2 video cameras.

3 Research Design

As no directly applicable research framework was found in previous works on sports and health sciences, Laban's and Kroflič's framework was used for the evaluation of the experiments. Before the start it was not clear what type of movement the observers could expect, therefore an open framework seemed to be the most appropriate.

Previous experiments using Laban's framework noted that it takes time to master Labanotation (Loke, Larssen, Robertson, & Edwards, 2007), but it "is a potentially useful tool to support the design of movement-based interaction". However, Labanotation was not used. Research was based on Laban's and Kroflic's framework with the research methods and strategies that are commonly used in games and interaction design (e.g. observations), as well as in sports science and dance (trajectory tracking, motion analysis, energy consumption, etc.).

In Laban Movement Analysis the **Body** category describes structural and physical characteristics of the human body while moving. This category is responsible for describing which body parts are moving, which parts are connected, which parts are influenced by others, and general statements about the body organisation. This area in sports science covers biomechanics with motion analysis and to some extent also the motor skills tests and physiology. According to the Laban Movement Analysis, the **Space** category identifies (1) kinesphere, which is the area that the body is moving within, and how the mover is paying attention to it; (2) Spatial Intention, the directions or points in space that the mover is identifying or using; (3) Geometrical observations of where the movement is being done, in terms of emphasis of directions, places in space, planar movement, etc. In the sports science research, one would conduct an analysis of the player position during the game, area covered, direction and speed of the movement, etc. The category **Time** covers Effort, or what Laban sometimes describes as dynamics, and what Labanotation calls "Length of time it takes to do the movement" (Kroflič, 1992). Sports and health science covers energy consumption through an endurance test using spiroergometry and monitoring the heart rate. The category **Relationship** indicates that all categories are closely linked-up and does not include any measurements. A good example is a measurement of energy consumption, which is strongly correlated with time and the area covered by a player.

3.1 Research Questions

The observations during the experiments focussed on the following research questions:

Body category: how many different postures a player uses during a game, what kind of a movement a player uses, how a player interacts with different parts of his/her body, how a player manipulates the body.

Space category: how much space a player needs during a game, in which directions a player moves, and what is the player's direction of gaze.

Time category: how a player responds to a certain dynamics and tempo of the game, and how much physical effort a player invests in the game.

3.2 Research Instruments

We found that using Laban's Kroflič's framework helps a designer to see a bigger picture of what needs to be analysed in the games. The research instruments, principles and methods were applied from both sports science, such as heat maps and coverage maps, and the dance, such as QoM and CI.

In the category **Body,** whole body kinematics or biomechanical measurements were not available for this experiment. A heat map was considered for the category body parts, but proved unreliable.

1. **The number of postures used in a game.** Each video was analysed, and the number of postures participants used in each game (i.e. standing, moving, lying, kneeling, running, crouching) was recorded.

2. **Quality of the movement.** Each video was analysed, and the observer gave a qualitative appraisal on the basis of how many different types of movement (i.e. standing, jumping, running, walking, bending, waving, crawling...) a participant used during the game.

3. **Body parts used in a game.** In the analysis of each video, the use of the participant's body parts was recorded in interaction with the game (i.e. trunk, legs, hips, arms and head).

In the category **Space,** a coverage map (Pingali, Opalach, Jean, & Carlbom, 2001) was chosen instead of the Contraction Index (Castellano, Bresin, Camurri, & Volpe, 2007), because it provided better and more accurate details. Direction of the movement answers to what Laban calls the spatial intentions and geometrical observations, and is a simplified version of the visualisation of routes (SIMI Reality Motion Systems GmbH, 2008). Gaze somehow complements the direction of movement, and was included in the analysis to find out whether a game required constant gaze toward the screen, or whether utilised sound and storytelling as a base for gameplay.

1. **Size of playing area.** Participant's left leg from the video (Image 1:) was tracked in each game to determine the size of the playing area.

2. **Direction of the movement.** Video and visualisations of tracking participant's left leg (Image 1:) were analysed to determine how many spatial lines (i.e. left and right, forward and backwards, circular, diagonal and standing) a participant used.

3. **Gaze.** Video was analysed to determine the ratio between the time a participant looked toward the screen, or when his/her gaze was turned away from it.

In the category **Time,** the tempo is defined as a speed of movement, and the dynamics as a rate of change in the speed of the movement. For example, the sprint is a high tempo game, and the long distance run a low tempo game. Although sprint has a high tempo, it also has a low level of dynamics, as the speed does not change greatly during the race. Basketball, on the other hand, is a game with a high level of dynamics, as the speed of playing tempo varies a lot. To measure a player's effort, equipment for spiroergometry (Böhm, Hartmann, & Böhm, 2008) was not available, therefore QoM (Camurri, Lagerlof, & Volpe, 2003) was used instead.

1. **Tempo.** Each video was analysed, and the observer gave a qualitative appraisal of the participant's tempo in each game.

2. **Dynamics.** Based on the video analysis, the observer gave a qualitative appraisal of the participant's dynamics in each game.

3. **QoM.** Each video was analysed using the Quantity of Motion (QoM) patch in the EyesWeb software (Camurri, Lagerlof, & Volpe, 2003). A mean for QoM for each participant's game was calculated.

4 Results with Discussion

4.1 General Observations from the Experiment

For successful playing, coordination of the child's physical and mental skills was required. All children were excited by the experience, and had put a lot of physical and mental effort into the 20-minute experience. They were deeply immersed into the story, into physical activities and the game environment, despite being watched and observed in a public space. Visual immersion was important, as it was exciting for the participants to see themselves on the screen while playing. Only the youngest participant (Participant H - Table 1) had a slow start and he needed more than one game to warm up, and fully understand and enjoy the experience. He had no previous experience of attending a sports or dance club, and only a limited experience of computers, unlike the majority of participants had. In developing a strategy for successful playing, participants used their previous knowledge and experiences of playing similar desktop computer games, and physical experience of exercising, sport, and/or dance. Children who were members of an athletics club would prefer to run; those who were in a basketball club would run forward and backward facing the screen all the time, while those from the dance club had used more expressive movement.

4.1.1 Body (Analysis of the Postures, Movement and Parts of the Body)

Analysis of the postures showed that participant's starting posture was standing. According to the tempo and the dynamics of the game, a participant used other postures, such as running, lying, kneeling, crouching, and others. Participants used more postures in games with a higher level of dynamics.

Analysis of the movement showed that in order to successfully interact with digital objects participants used movements such as: walking, running, jumping, bending, dancing, mimicking, drumming, rollerblading, hitting, crawling and standing still. More diverse movement was noted in games with a higher level of dynamics.

Using analysis by (Höysniemi & Hämäläinen, 2005) the following physical skills were identified: (1) locomotor skills (i.e. moving left and right to control avatars or objects, moving forward and backwards to reach the objects, moving forward to approach the camera or to readjust balance), (2) non-locomotor skills, such as speed (i.e. moving quickly to reach digital objects), balance (i.e. keeping balance after moving quickly), flexibility (i.e. bending to control an object), precision (i.e. patiently controlling objects), (3) manipulative skills (i.e. using limbs to control objects), (4) movement awareness (i.e. responding to the change of a digital object on the screen with a movement), (5) body awareness (i.e. knowledge of the position of the body and the digital objects), (6) focusing attention (i.e. distinguishing own image from digital objects), (7) observing visual and audio feedback (i.e. planing the next step).

Analysis of parts of the body used for interaction showed that most of the interaction was done with the body, less with arms, legs and head. Participants used more parts of the body in games with a higher level of dynamics. Specific interaction was noted when the story suggested a certain movement (e.g. to mimic a character or catch a star with the hand). A similar motion was noted by (D'Hooge & Goldsmith, 2001), who stated that 'When you see bubbles floating around you, your normal reaction is to pop the bubbles with your hands'.

In the category **Body,** not only the dynamics of the game influenced the movement, but also the rules of the game (e.g. to swim the river while avoiding all objects, or to catch certain objects), the interaction between the body and digital objects (e.g. to control the avatar left and right, slower or faster), the narrative component of the user interface (e.g. story and instructions that asked a participant to move in a certain way), the rhythm of the music, as a higher tempo required from participants to move faster, the visual feedback on the screen (i.e. a participant could see a projected image of himself/herself only within a limited distance on the left and right), and the physical space (i.e. size, lightning conditions and quality).

In this category the evaluation results helped the designer to understand how a particular full body interactive game, game genre or interaction offers an opportunity to induce a certain movement, such as smaller movements using genres that require patience, or expressive movements using storytelling.

4.1.2 Space (Analysis of the Playing Area, Directions of Movement and Gaze)

Analysis of the playing area was done by combining visualisations (Figure 1:) from different games by the same participant and from different participants of the same game. The results showed that games with a higher level of tempo and dynamics and a higher level of QoM required more space. Participants also used more space in games in which they did not look at the screen (i.e. gaze) for most of the playing time, as this allowed them to play out of the display boundaries.

Analysis of the direction of the movement showed that most of the movement was done in a left - right direction. Some intentional movement forward - backward was also noticed (i.e. in mimicking characters) and some unintentional movement forward - backward (i.e. when readjusting position after a participant lost balance in a game with a high level of dynamics). Some participants realized that if they moved closer to the camera, it was somehow easier to play. Participants used more directions in games with a higher tempo and in games where the rules did not require them to watch the screen most of time.

Analysis of the gaze pointed out that the participants observed the action on the screen most of the time. During the games with less strict rules and which did not require constant focusing on the screen, participants left the screen, used more space and moved in different directions, including in circles and diagonally.

Results of the **Space** category showed that the physical space is an important part of physical activity, as the size of playing area, objects (e.g. furniture), quality of floors (e.g. it is easier and safer to move on wooden floors) and lighting conditions in the space (e.g. light improves playing space) influenced the user’s experience.

These results also informed the designer about the required size of the playing area. In Figure 2: all visualisations from game 9 were combined. An average distance for each participant in the game was established, as presented in Table 1:.

Table 1. An average distance from the screen in game 9 and participant’s characteristics: sex (m for male, f for female), age, and body height

Participant	A f	B f	C f	D f	E m	F m	G m	H m
Age (years)	14	11	9	8	8	6	8	5
Body height (cm)	178	149	140	135	135	116	131	125
Distance (cm)	430	400	350	290	250	240	230	200

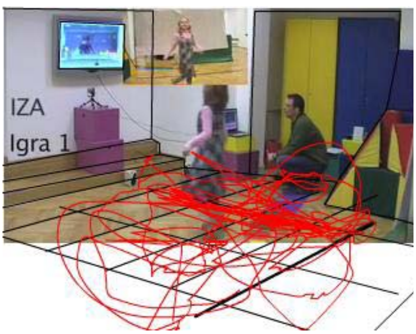

Fig. 1. Tracking participant’s left leg and determining the playing area

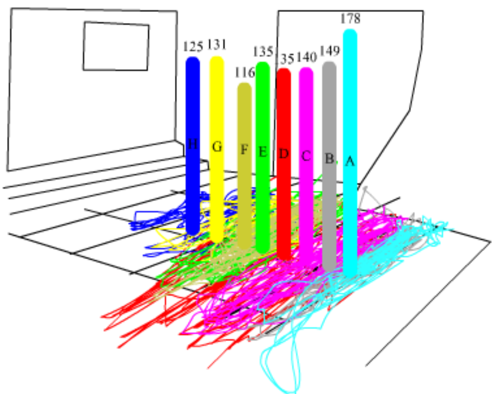

Fig. 2. Comparing participants’ movement and body height in game 9

Left - right was the dominant direction of the movement in the experiment. Such movement was also observed in most of the previous full body interactive games that used low level computer vision algorithms, such as Me2Cam (D'Hooge & Goldsmith, 2001), Sony Eyetoy (Loke, Larssen, Robertson, & Edwards, 2007) and QuiQui's Giant Bounce (Höysniemi, Hämäläinen, & Turkki, 2004). Left-right dominant movement was used by the authors in the design of educational full body interactive games, where players learned by making connections between the position of their body and the position of the digital objects in the direction left - right on the screen (Koštomaj & Boh, 2009b).

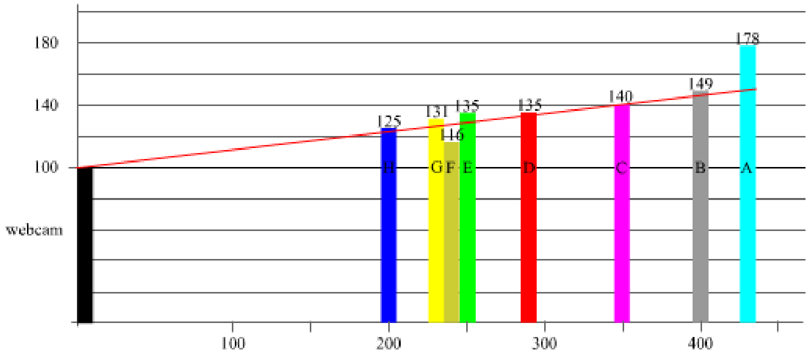

Fig. 3. Comparing participants' height and distance from the camera

As most of the computer games require constant focus on the screen, one of the interesting findings of this experiment was that games with less strict rules did not require the participants to watch the screen all the time. When they turned away, they could explore the playing area outside the screen, and therefore used more space, making the playing area bigger.

In the category Space, the main challenge for the designer is to create the environment, and to maximize the space as much as possible, to allow the physical activities that require more space (e.g. running, jumping).

4.1.3 Time (Tempo, Dynamics and QoM)

Analysis of the dynamics showed that a higher level of dynamics was noticed in the racing and catching genres, while lower levels of dynamics occurred in the matching and memory games and in games that required repetitive movements. In games with a higher level of dynamics, a participant used more postures, movement was more diverse, and more space was used. Sometimes a participant moved quickly, waited a couple of seconds, and then moved again.

Analysis of the tempo showed a higher tempo in games where a motion detection was used to define the speed of the game. A high level of tempo was also found in the catching game. In the high tempo games participants used more of the playing area.

Analysis of the QoM. A high value of QoM was found in games where the tempo of the game required a lot of movement with the whole body and where the participants used more space, moving in different directions. Low value of QoM was found in games where the participants did not observe the action on the screen all the time. In such games many had left the screen for some seconds and in that time the value of QoM was zero. Low value of QoM was also found in games that took a longer time to finish; in such cases participants put in less effort. A correlation between the energy consumption and QoM has been found (Camurri, Mazzarino, & Volpi, 2003). However, the results from the experiment indicated that QoM demonstrates a participant's physical effort, not his/her energy consumption. More work needs to be done in this area to establish a correlation between QoM and scientific measurements of energy consumption.

Many early commercial full body interactive games for Sony Eyetoy had a high tempo. Players had a high energy consumption, which resulted in exhaustion and a negative user experience. Most game genres trigger a competitive side in the player; if the player wants to achieve a better score, he/she needs to make a greater physical effort. An interesting approach was used in ‘Ere Be Dragons (Active Ingredient, 2007), where a heart beat monitor was introduced, which allowed playing the game only when the player’s rate was inside the healthy heart rates. In our experiment, slowing down was achieved by introducing a physical activity which required accuracy, smaller and finer motor skills; by manipulating motion detection algorithms to use their values for the speed of the elements in the game; by using music with lower tempo; by using genres such as memory or matching; and by making digital objects smaller or less visible.

The category **Time** informed the designer about how to use the length, tempo and dynamics of the game, with game elements such as music, gameplay, genres, to manipulate the participant’s effort.

5 Conclusions

This research has been designed for better understanding on how to design a user’s physical experience in full body interactive games. In the evaluation, elements important for the designer have been derived from Kroflič’s and Laban’s framework Body, Space, Time and Relationship, supported by sport science measurements. Findings from the experiment were not only useful in identifying the elements of the user’s physical experience in full body interactive games, but also helped the designer understand correlations between the measurements.

A summary of results shows that:

(1) The diversity of the movement is defined by the dynamics and rules of the game, interaction between the body and digital objects, narrative component, rhythm of the music, visual feedback on the screen, and the physical space.

(2) Physical space is an important part of physical activity, as the size of playing area, objects, quality of floors and lighting conditions in the space influence the user’s experience.

(3) The suggested width for the playing area is 4.50 m in depth (from the screen) and 5.50 m in width.

(4) The playing area can be bigger if games do not require a constant gaze directed to the screen. In such games audio and other haptic interfaces can play important role.

(5) The EyesWeb’s QoM patch can be used for measuring participant’s physical effort, but not energy consumption.

(6) Tempo and dynamics can manipulate user’s physical effort by introducing movement that requires smaller and finer motor skills; by manipulating motion detection algorithms, by using music with lower tempo; by using suitable genres and by making digital objects less visible.

Studying Laban’s work proved to be useful for informing interaction and games designers about issues important to the human body and human motion, and for making the transition towards the full body interactive games smoother. This knowledge has also opened the communication channels to experts in the fields of drama, dance and sports. The results will be used in further theoretical work to establish the components of user experience in full body interactive games and in further developments of educational and edutainment full body interactive games and stories.

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