Considerations for the design of exergames

Jeff Sinclair *, Philip Hingston †, Martin Masek ‡
School of Computer and Information Science, Edith Cowan University

Abstract

Exergaming is the use of video games in an exercise activity. In this paper we consider game design for successful exergames. To do this, we review the history of exergaming and the current state of research in this field. We find that there exists some research aimed at evaluating the physical and health characteristics of exergames, but research on how to design exercise games is still in the early stages. From an analysis of this information, and drawing on established principles from sports science for the prescription of exercise programs, we then attempt to identify success factors to guide designers of exergaming systems.

CR Categories: K.8.0 [Personal Computing]: General—Games

Keywords: exergaming, games

1 Introduction

The merger of video games with exercise equipment, known as exergaming, is a relatively old idea that since mid 2006 has seen an upswing in activity and interest. While there are most likely other factors at play, a major reason for the recent rise in interest in exergaming is concern over the current high levels of obesity in Western society (especially in children). The hope is that the fascination that video games have for children can be harnessed so as to engage children in greater physical activity. In the next section, we summarise evidence of the connection between video gaming and obesity.

Another factor in the increase in interest in exergaming is the potential for profit. Exercise equipment sales in the United States alone reached $5.2 billion last year [Weindruch 2007]. The area of exercise equipment is big business, however this value increased by only 3% in 2005 and as little as 1% in 2006. Major exercise equipment manufacturers are seriously looking at how to convert increasing concerns about lack of physical activity into increased sales of exercise equipment. Exergaming is seen by many as an area where this can be achieved.

The third factor that lifted the visibility of exergaming was the release in 2006 of the Nintendo Wii®. One of the key differentiators of the Wii is the provided motion sensitive controllers. The Wii has been often promoted in various media and advertising as a way to make children more physically active. This notion has generated a lot of interest in the area of exergaming.

The success of exergaming in the past has been patchy. Why have some exergaming systems been relatively successful and other not? To provide some answers and hopefully to avoid repeating mistakes of the past, we review the history of exergaming and survey the current state of research in this field in order to understand the success or otherwise of past attempts.

We find that Csikszentmihalyi's "flow" construct [Csikszentmihalyi 1975] is a helpful model that encompasses many success factors for video games. We then propose an extension of this construct from the psychological domain to the physical fitness domain, incorporating existing good practice in the prescription of fitness training regimes.

2 The Obesity Epidemic

Childhood obesity is an increasing problem in advanced countries [Booth et al. 2004] [Hersey at al. 2007] [Trost et al. 2001] [Vandewater at al. 2004], and rates of obesity in children have risen greatly over the last 30 years [Lanningham-Foster at al. 2006]. In Australia, one in three children and adolescents are either overweight or obese, with 12% being obese [Valenti et al. 2006]. From 1985 to 1997 the number of overweight 7-15 year olds almost doubled, and the number of obese children has more than tripled [Booth et al. 2003]. Childhood obesity is currently increasing at a rate of 1 per cent per year.

While the cause of obesity is multi-factorial, obesity in children and adolescents is generally caused by lack of physical activity, unhealthy eating patterns, or a combination of the two, with genetics and lifestyle both playing important roles [Stubbs and Lee 2004]. A decline in physical activity is of course one of the main factors predisposing a child to obesity [Marshall et al. 2004]. It is also known that exercise rather than limiting food intake is the best, safest, and most effective way to prevent obesity [Ross et al. 2004]. Children nowadays spend less time performing physical activities, and spend more time in front of the television, watching DVD's, and playing video games [Salmon et al. 2005]. Engagement in these activities steals time that was previously spent on physical activity in prior generations. Children aged 8 to 18 spend more time in front of computer, television, and game screens (44.5 hours per week) than any other activity in their lives except sleeping [Kaiser 2005].

Vandewater et al. [Vandewater at al. 2004] looked at the activities of a number of children up to the age of 12 over two 24 hour periods. The activities performed, and the percentage of time for the activity, were then examined in order to determine any relationship with obesity. No relationship between levels of television watching and obesity were found, however they did find a strong correlation between video game play and obesity. Hersey and Jordan [Hersey at al. 2007] also state that the link between childhood obesity and media use by children is firmly established. Given the increase in "screen time" and decrease in "physical activity" in children, there is now a renewed impetus behind the idea of including physical activity in computer games.

* e-mail:jsincla@student.ecu.edu.au
† e-mail:p.hingston@ecu.edu.au
‡ e-mail:m.masek@ecu.edu.au

GRAPHITE 2007, Perth, Western Australia, December 1–4, 2007.
© 2007 ACM 978-1-59593-912-8/07/0012 $5.00

3 Commercial Exergaming Systems

The idea of using exercise equipment to interface with a video game is nearly as old as video games themselves. In this section, we review the historical development of exergaming in terms of the various machines and input devices that have been utilized. We then analyze some of these in a later section on success factors in the light of research regarding the design of games.

3.1 Exercise bikes

The exercise bike has arguably been the most prolific candidate for teaming with computer games, the Atari Puffer project from 1982 being an often mentioned early example [Atari 2007]. In the project, Atari developed and prototyped an exercise bike in 1982 which connected to a game console. Although this project was not commercialized due to internal changes within Atari, similar products followed. In 1983, Antic magazine pictured a Suncom exercise bike game controller in the "new products" section of the September edition [Atari Magazine 1983]. A later example from the mid 80's was the HighCycle from Autodesk, which allowed users to pedal an exercise bike across a virtual landscape [Rizzo 2007].

Today there is quite a wide range of exercise bikes designed to be used as controllers, such as the Cateye GameBike™- marketed as a gym bike, the Tacx Fortius Trainer - produced as a training aid for cyclists, and the Fisher Price Smart Cycle - aimed at children and offering educational games as well as exercise. There are also a number of kits which are designed for modification of off the shelf exercise bikes for use with video games.

3.2 Foot operated pads

The use of foot operated pads as exercise-based input controllers has seen mixed success. Here we describe the attempts and leave analysis to a subsequent section of this paper.

In 1983 Amiga released a stand-on pad used for controlling video games on the Atari 2600, which was promoted as a means to get fit while playing video games [Knight 2002]. The Joyboard was similar in size to a set of bathroom scales and balanced on a central disk. A player would stand on the board, leaning in any of eight directions to make a contact. This was then used in much the same way as a conventional joystick would be used. While the Joyboard was claimed to be compatible with almost all Atari compatible video games, there were four games released specifically for it. These games were Mogul Maniac, a skiing game with nine downhill courses; Surf's Up, a surfing game; S.A.C. Alert, a fighter pilot flying game; and Off Your Rocker, where players needed to follow a pattern of moves shown on the screen [Ahl 1983].

In 1987 Nintendo released what was called the Power Pad (also sold as Family Trainer or Family Fun Fitness). This consisted of a mat with eight buttons activated by the player using his or her feet.

At least six games were released for the Power Pad, most of which were centered around a sports theme. None of these was a significant commercial success [Games Graveyard 2007] and the Nintendo Power Pad was commercially very short lived.

Over a decade later, in 1988, an extremely similar product, called Dance Dance Revolution®(DDR) was released in the video game arcades by Konami of Japan, and then later into the home console market. DDR also consists of a set of buttons pressed by the player stepping on them. The screen displays a set of dance steps matched to music, which the user is required to copy. DDR was a huge success and by the end of 2003 Konami had reported 6.5 million sales of the game [Game Spot 2007]. DDR now comes in many variants and is supported for most major gaming platforms. This comparison of the Amiga Joyboard, Nintendo Power Pad and DDR is an indication of how an exercise based interface needs to be matched with the correct game in order to be successful.

3.3 Motion sensors

The Sony EyeToy®was first released in 2002. This consists of a special camera connected to the Playstation 2. There are a number of games available which use the camera to track actions performed by the game player. The EyeToy has had a solid commercial performance but has yet to have a blockbuster game release.

Nintendo released the Power Glove in 1989. The Power Glove consisted of a glove worn by video game players, which contained a motion sensor and additionally broadly registered the positioning of the fingers. The Power Glove was initially successful, eventually selling 1.5 million units. This success was short lived and the Power Glove was commercially available for little over a year. Two video games were specifically released for the Power Glove. Bad Street Brawler, which is a standard side scrolling fighting game, and Super Glove Ball which is a Breakout style clone, where the player throws balls to knock down walls in order to advance.

In 2006 Nintendo released the Nintendo Wii. This consists of a game console in which the controllers contain built in motion sensors. The Wii comes pre-packaged with a software title called Wii Sports. This is a collection of five sporting titles designed to showcase the motion sensor abilities of the controller. The games included are tennis, baseball, bowling, golf and boxing. Boxing uses the additional add-on known as the Wii Nunchuk. The Nunchuk contains a motion sensor and connects to the normal controller to extend it into a two handed device.

The Wii has been heavily promoted as activity-inducing. This release has caused a surge in interest in the area of exergaming.

3.4 Other physically interactive games

In 2004 Power Grid Fitness released the Kilowatt game controller. The controller consists of a metal bar that extends off the ground like an exaggerated joystick. The bar contains stain gauge sensors to measures the pressure exerted against it. In 2005 Power Grid fitness revamped the Kilowatt and released what is called the Exerstation, essentially a cheaper reduced version of the Kilowatt system. There appears to be few if any commercially available games which were specifically designed for the Kilowatt or Exerstation controllers.

4 Using Games to Promote Exercise

A number of studies have been done in the area of exergaming. The bulk of these studies investigate whether making children more active while playing video games actually works to burn calories. It is perhaps not surprising that the studies show this to be the case.

One way to encourage physical activity is to make it a requirement for more popular activities. Making physical activity a requirement, either directly or indirectly, for such activities, has been shown to have the potential to promote physical activity.

Saelens at al. [Saelens and Epstein 1998] connected a television, a VCR and a video game console to an exercise bike. The bike required cycling in order to activate the other equipment. The study found that when given a choice of activities, the children studied were prepared to undertake the physical activity, cycling the bike, in order to access the desired activities of television watching, videos or video games. This was despite the option of undertaking other activities, such as reading or drawing, without having to use the exercise bike.

Goldfield et al. [Goldfield et al. 2000] performed a similar study. In this case there was no direct feedback from the physical activity performed. Subjects accumulated points on a pedometer by performing physical activities. These points could then be redeemed at a later point for desirable activities, such as television or video games. This study also demonstrated that children would be willing to undertake physical activity, in order to obtain access to television watching and video games.

Luke's 2005 masters thesis [Luke 2005], "Oxygen cost and heart rate response during interactive whole body video gaming", contained a detailed examination of the oxygen uptake of participants playing the EyeToy®Groove game for PlayStation2®. Participants were fitted with a mouthpiece connected to a metabolic analyser in addition to a heart rate monitor. These devices were used to make measurements through several sessions of play.

The video game used in the study involved the player performing body movements and touching specific parts of the screen in time to a selected song, in order to gain points. Luke concluded that the energy expenditure was enough to meet the requirements for moderate exertion and could therefore be used as a legitimate form of exercise. While this did constitute exercise, Luke concluded that the actual game play of the EyeToy Groove game did not make the ideal as a form of exercise. There were short periods of exertion, being roughly two and a half minutes, with sizable gaps between. What this highlights is the need to ensure that in order to be a practical form of exercise, it is important that the games be carefully designed with this purpose in mind.

Lanningham-Foster at al. [Lanningham-Foster at al. 2006] followed up on this study by examining the energy expenditure of activity promoting video games, compared to standard video games and watching television. They also used the Sony EyeToy in their study as well as a Dance Dance Revolution (DDR) pad. Their study concluded that there was a significant increase in energy expenditure for activity promoting video games, when compared to television or traditional video games. They also draw the conclusion that this could be used as a potential method to help combat obesity.

Hoysniemi's 2006 dissertation [Hoysniemi 2006] was on the design and evaluation of physically interactive games. In this study she asks important questions on how physically interactive games should be designed. She looks at the areas of entertainment, usability and suitability. The results were mainly qualitative and used three case studies for the research. Two of the case studies used camera and audio based interfaces. The first was a game aimed at children, where the body movement is used to control a game character. The second was a martial arts game where the user fights on screen characters by using full body motion. Additionally in both of these games, shouting is used to control some aspects of the game play. The third case study involved the Dance Dance Revolution game.

Hoysniemi looked at the use of peer tutors as an evaluation method for testing the usability of the game. She also examined the use of the Wizard of OZ methodology to prototype vision based games, and a methodology for describing the children's movements recorded during the prototyping.

Finally she looked at feedback from martial artists who played the martial arts based game. The results showed that it was possible to use low-level computer vision to generate an immersive embodied game play that could be intensive physical training. It is important to note that Hoysniemi also states that the martial artists who played the game, found the biggest drawback with the interaction model of the game, was the lack of physical feedback.

Smith [Smith 2005] performed a pilot study on a number of different exergames, with the use of 3 different exertion interfaces. He tested the Cateye GameBike, the Sony EyeToy and Konami's DDR pad, with a varied set of games. He identified four areas which he felt were important in order to maximize engagement and physical fitness: warm-up and cool-down activities; management of game load times; the integration of physiological measures; and dynamic game play adjustment.

A group of researchers from the University of Washington has examined the use of technology to promote physical activity [Consolvo et al. 2006]. They performed a pilot study where participants competed against other members of a group to see who was more active during a predefined period. This involved the participants wearing a pedometer connected to a PDA. The steps taken during the day were compared amongst member of the group, who all competed against each other. The study proposed four key design requirements for technologies that promote physical activity. These were: give users proper credit for activities; provide personal awareness of activity level; support social influence; and consider the practical constraints of users' lifestyles. It was shown that these design requirements should be considered in the design of exergames.

Researchers with the University of Texas, the Marshfield Clinic Research Foundation and the Mayo Clinic, have also commenced on similar research [Fujiki at al. 2007]. The study is using accelerometers combined with PDA's to measure activity performed during the day. The PDA displays the results in real-time on a computer generated race track. The race track shows the competing members of a group as animated figures on the race track, where activity dictates the distance covered around the track.

Lund et al. [Lund et al. 2005] have developed a rubber tile based system for building physically interactive games, known as the PlayWare platform. In order to facilitate physical interaction, each tile contains a set of four different coloured light emitting diodes (LEDs), which can combine to generate 8 different output colours, and the ability to produce simple sounds. A force sensing resistor is mounted in each tile to provide an input method, generally activated by being stepped on. Each tile also contains its own internal microprocessor and connection ports along the edges to allow the connection of the tiles, and to facilitate communication between the tiles.

The authors document two different games that were constructed for the system. One called Color Race, involved the participants moving around the tiles to press the sensor for the tile which is lit with a particular colour. As a tile of a particular colour is pressed, a new tile would light up with that colour. The participants raced against each other to be the first to press ten tiles of their particular colour. In the second game called Ping Pong, a coloured light moves back and fourth across the tiles in a pseudo random manner. The participants needed to step on the appropriate edge tile in order to get the coloured light to move back towards the other edge of the tile arrangement.

Yannakakis et al. [Yannakakis at al. 2006] developed a game for the PlayWare tile platform called Bug Smasher. In this game the player needed to step on the lit tiles, which represented bugs, in order to squash the bugs. As bugs are squashed, more bugs appeared in a controlled manner. The authors experimented with the modification of the bug generation parameters, to determine which combination constituted the most enjoyable game. The games were evaluated by having players play two versions of the game with different settings, and then rate the two games against each other, indicating which game was more fun. Their study mapped the changes in the bug generation algorithm, to three factors, challenge, curiosity and fantasy. It demonstrated that increases in the fantasy factor of the game made it more fun for all of the players, while the most enjoyable balances of challenge and curiosity were dependent of the particular individual player.

Tucker [Tucker 2006] has developed a physically interactive version of Tetris. The system consists of a set of weights which are lifted by pulling down on either of two handles. The corresponding handle is pulled down with the left or right arm in order to move the Tetris piece left or right, while pulling both handles together results in the piece moving downwards. One important concept that Tucker expresses in his design of the system is the removal of any timing constraints. The normal automatic advancement of the Tetris pieces is removed from the system. Tucker explains how the slower paced games may be much more suitable for exercise based games, however, he is unable to provide any concrete evidence that this is the case.

Tucker performed user testing of the system with 15 users and found that the user response to the system was overwhelmingly positive. A number of minor design issues were discovered with the system, but in general the players were successfully engaged by the system. It is interesting to note that he recorded the fact that many users expressed a desire for more multimedia feedback.

5 Success Factors

The most important outcome for exergaming systems is (arguably) to achieve health benefits. Assuming aerobic exercise will be undertaken as part of the game, generic guidelines for an effective aerobic session recommend:

1. Warmup: A 5 to 10 minute period of low intensity exercise.
2. Stimulus: Minimum 20 minutes at 77% to 90% of maximal heart rate.
3. Cooldown: 5 Minutes of low intensity exercise to return heart rate to resting levels.
4. Three days per week.

In general, an exercise program must consider the mode or type of exercise, as well as the combination of duration, intensity and frequency. Exact duration, intensity, and frequency depend on the individual - the figures cited above are one configuration recommended by the American College of Sports Medicine [ACSM 2005]. In particular, the intensity of exercise required to attain the recommended heart rate depends on the fitness of the individual. A common measure used in the prescription of exercise programs is the “rating of perceived exertion”, in which individuals subjectively rate how hard they feel they are working on some scale. For example, on a 15-point scale ranging from 6 (no exertion) to 20 (maximal exertion), the recommended intensity for improving aerobic capacity is an RPE of 12-13 (somewhat hard) to 15-16 (hard). Measurements on this scale correlate very well with maximum heart rate [Wilmore and Costill 1994, pp. 522-523].

Considering the above parameters, the physical difficulty level of the exercise needs to be adjusted to maintain the required heart rate parameters (intensity). Equally importantly in the context of exergaming, the exergame must be playable for the required time period (duration). In addition, the activity must be captivating enough to have the player return to it on a regular basis (frequency). These last two factors mandate that we must ensure that whatever is built is actually *fun*. A study of young adults who play DDR, ages 18 to 27, found that the top reason for playing was to have fun [Lieberman 2006]. If few people use a particular system, or the system is only used for a limited period, because the game is not fun, then ongoing health benefits will not be realised. Thus there are two interrelated dimensions to achieving success in an exergaming system: its *effectiveness* in terms of meeting exercise requirements, and its *attractiveness* as a fun and captivating activity that will compel the player to exercise for the recommended duration and with the recommended frequency.

5.1 Attractiveness

In the early 1980’s, Malone carried out a number of psychological studies focussed on what makes computer games fun [Malone 1980] [Malone 1982]. He identified three qualitative factors affecting the entertainment level of computer games; challenge, curiosity and fantasy. These factors were used by Yannakakis et al. [Yannakakis at al. 2006] as mentioned earlier, to examine different variations of their games on the PlayWare platform. It demonstrated that increases in the fantasy factor of the game made it more fun for all of the players. However, the optimal balance between challenge and curiosity were dependent on the individual player. This idea that the attractiveness of a game is dependent on how it matches the player is also supported by the “flow” construct developed by Csikszentmihalyi in 1975 ([Csikszentmihalyi 1975]).

Flow is the state of total engagement in an activity. It is the equivalent to what is called in the sporting world “being in the zone”.

There are nine components of the experience of “flow”:

1. Balance between perceived skills and perceived challenge (the activity is neither too easy nor too difficult).
2. The merging of action and awareness.
3. Clear goals (expectations and rules are discernible and goals are attainable and align appropriately with one’s skill set and abilities).
4. Unambiguous feedback (successes and failures in the course of the activity are apparent, so that behaviour can be adjusted as needed).
5. Concentrating and focusing, a high degree of concentration on a limited field of attention (a person engaged in the activity will have the opportunity to focus and to delve deeply into it).
6. A sense of personal control over the situation or activity.
7. A loss of the feeling of self-consciousness (no feelings of self-doubt or self-concern).
8. Transformation of time (one’s subjective experience of time is altered).
9. Autotelic experience (the activity is intrinsically rewarding - it is undertaken for its own sake).

When in the flow state, people become absorbed in their activity, and focus of awareness is narrowed down to the activity itself, action and awareness merging.([Csikszentmihalyi 1975, p. 72]).

The key component of flow is that skills need to be matched with challenges in order to maintain the interest of a participant - termed “The golden rule of flow” [Jackson and Csikszentmihalyi 1999, p. 9]. This corresponds to challenge in Malone’s model. Arguably, we could equate Malone’s curiosity with personal control, and fantasy with concentration, focus, and a distorted sense of time. So there is at least a degree of agreement here.

The flow concept has been applied in many different domains, including several that relate to exergaming: sports, education and video games. In particular, Sweetser et al. [Sweetser and Wyeth

2005] present a modified version of flow, specialised to the video game domain, called "gameflow". The components of this model are:

1. Concentration - games should require concentration, and the player should be able to concentrate on the game.
2. Challenge - games should be sufficiently challenging and match the player's level of skill.
3. Player skills - games must support player skill development and mastery.
4. Control - players should feel a sense of control over their actions in the game.
5. Clear goals - games should provide the player with clear goals at appropriate times.
6. Feedback - players must receive appropriate feedback at appropriate times.
7. Immersion - players should experience deep but effortless involvement in the game.
8. Social interaction - games should support and create opportunities for social interaction.

The listed characteristics of flow (and gameflow) can be divided into elements that can be controlled directly by the game designer to affect player state, and elements that are simply artefacts of the flow state. For example: clear goals, direct and immediate feedback and balance between ability and challenge are elements that can be built into the game explicitly and tuned. Concentration, loss of self-conciousness, and a distorted sense of time are characteristics of the player that are present when the tuneable parameters have been set at the right levels. Nevertheless, the design of exercise-based games needs to take both categories of elements into account.

5.1.1 Role of the input device in game attractiveness

Whatever exercise promoting device is chosen as input, it must afford the artefacts of flow. One of the most important is concentration. For a player to enter the flow state, they must be able to focus on a narrow field of attention. This can be either the game played, or the input device being used. If the game is to be the centre of attention, the exercise equipment should not demand attention be placed upon it. This can be used to explain the proliferation of input devices based on exercise bikes. Whilst seated on an exercise bike the player is relatively stable compared to other aerobic exercise equipment. On a treadmill for example, the player needs to concentrate on keeping up with the machine, and not running into the edges, which competes for attention with the game.

The concept can also be applied in reverse. Dance Dance Revolution is a game where the narrow field of attention is focused on the device, rather than the game. In this game the visual output in terms of information on screen is relatively simple, a set of instructions on which foot pad to activate next. This allows the player to concentrate on their physical motion across the dance pad. Perhaps the more elaborate games made for the Nintendo Power Pad, a device similar in concept to the dance pad, were its downfall. This same component of the flow theory might be used to explain why the Amiga Joyboard was not successful - requiring players to balance on a disc while also having to focus on action within a game might have prevented them from entering the flow state.

In exergames, the role of feedback in maintaining balance between player ability and challenge is important in helping the player exercise for the required time period in order to obtain health benefits. We now examine the other dimension, the effectiveness of the exergame in providing a valid exercise.

5.2 Effectiveness

In order to maximise the exercise benefits of the exergame, the intensity and type of exercise needs to be considered. Target heart rate plays a role, but it is important to realize that as players' fitness levels improve, the physical intensity level required to reach their target heart rate will increase.

This concept has overtones of the skill versus challenge balance in flow theory. Physical fitness corresponds to the body's 'skill' in being able to cope with the exercise, and exercise intensity level corresponds to 'challenge' of the exercise on the body. Unlike flow though, which can only be measured through several subjective criteria, the fitness/intensity balance has an absolute measure in the form of heart rate.

From the previous review of literature, we have seen several studies that considered existing games in order to evaluate them as legitimate forms of exercise. Although most of those games involved aerobic activities, the explicit tuning of gameplay to heart rate was not utilized by the gameplay.

6 Dual Flow

We propose that to optimize the effectiveness of exergaming systems, a dual flow model would be useful (see Fig. 1).

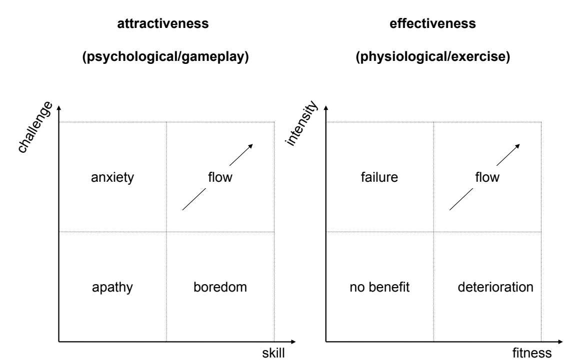

Figure 1: *A dual flow model for exergaming*

The dual flow model encompasses the two dimensions of attractivness and efectiveness of the exercise. The atractiveness of an exergame can be modelled by the standard flow model from [Csikszentmihalyi 1975]. This is a psychological model balancing the player's perceived skill with perceived challenge. The second dimension, efectiveness, is the physiological counterpart of flow - the physical balance between fitness (the body's 'skill' in tolerating exercise), and intensity (the challenge of the exercise on the body).

6.1 Balance in attractiveness

The left part of Fig. 1 illustrates the standard skills versus challenge balance of the flow model which is often represented by such a diagram, featuring four quadrants. Boredom is reached when skills surpass the challenge, and if the challenge is too high compared to skill level, anxiety sets in. A state of apathy results when there is both the lack of skill and any meaningful challenge.

6.2 Balance in effectiveness

The balance between intensity and fitness is represented in a similar four quadrant balance model in the right part of Fig. 1. If intensity and fitness are matched, the quadrant of physiological flow is reached and the fitness of the subject improves with continued exercise. Where the intensity of exercise far surpasses the fitness of the participant, a state of failure occurs - the exercise participant is unable to continue the exercise. If the participant has a low fitness level and there is no perceivable intensity in the exercise (e.g. playing an ordinary computer game with keyboard and mouse) there is no benefit to the participant. If fitness exceeds the exercise intensity there is also potential for the participant to enter a state of deterioration where fitness level will drop.

6.3 Role of feedback in the dual flow model

The key requirements in the dual flow model for exergaming are the balance between skill and challenge, and between fitness and intensity. Games that are not designed for exercise need only consider the skill/challenge balance. Commercially, such computer games try to achieve this balance through extensive playtesting. Through playtesting, levels of challenge are determined to suit the target audience. In exergaming this fixed matching of difficulty level to player capacity is less effective. Factors influencing success in an exergame involve not just the player reflexes and game experience (attractiveness), but also the player's physical condition (effectiveness).

Tuning each successive level of an exergame to achieve a balance of player skill, level of general fitness, and current physical tiredness becomes problematic. The general assumption with traditional computer games is that the player's skills increase with playing time and so difficulty level is increased accordingly. In exergames, while skills might also increase with duration of play, lengthy sessions at increasingly harder intensity will lead to exhaustion and failure. This difficulty of setting the right balance could be another reason why seemingly similar systems enjoy quite different levels of commercial success. One way to avoid this problem is to construct games with relatively simple mechanics that focus on the input device rather than the game. These simple games, such as Dance Dance Revolution, make it less costly to develop a wider variety of difficulty levels (eg. choosing a different set of dance steps for a song) where one is bound to suit whoever is playing. Another option is to make the game *adaptive* to the player.

If it is desired for the game to be the centre of attention, rather than making the game appeal to the widest user base possible it becomes practical to somehow monitor the player's skill level, and modify the difficulty of the game adaptively. Thus we see that feedback plays a central role. Rather than just the simple feedback of clearly indicating success or failure to the player, feedback from the player relating to fatigue, exercise level, and boredom should be used to infer the player's current physical state and adjust the level of challenge accordingly. Experiments with the Bug Smasher game on the PlayWare platform [Yannakakis at al. 2006], where player preference was deduced by the style of play is an example of one such feedback-driver adaptive system, in this case on the psychological dimension.

7 Future Work

In the light of the flow model, and the dual needs of attractiveness and efectiveness we are in the development stages of games targetted for use with exercise-based input devices such as exercise bikes and foot operated pads. With these experimental games we aim to test aspects of classical flow theory and our new dual flow model.

8 Conclusions

The idea of exergaming, while not new, is still in its infancy when it comes to systematic research, particularly in terms of game design. One of the important factors in the generation of an exergaming system is the need to make the game attractive to players, and at the same time effective as an exercise. There is currently some useful research in the area of fun and video games and there is a need to examine how these concepts of fun can be applied to the exergaming arena. Furthermore, similar concepts can be applied to exercise effectiveness. Monitoring the events, actions and responses of an exergame player during game play is one potential area for investigation. This data can then be used in real-time to determine the appropriate levels of a set of parameters in order to make the game fun and effective for the particular individual.

References

AHL, D. H. 1983. Controller Update. *Creative Computing*, 9(12), 142.

AMERICAN COLLEGE OF SPORTS MEDICINE. 2005. *ACSM's guidelines for exercise testing and prescription*, Lippincott Williams and Wilkins: Baltimore.

ATARI GAMING HEADQUARTERS WEBSITE:ATARI PROJECT PUFFER PAGE [ELECTRONIC VERSION]. 2007. Retrieved 7th May 2007 from `http://www.atarihq.com/othersec/puffer/`.

ATARI MAGAZINES WEBSITE. 1983. New Products [Electronic Version]. *Antic*, 2, 80. Retrieved May 7 2007 from `http://www.atarimagazines.com/v2n6/newproducts.html`.

BOOTH, M.L., CHEY, T., WAKE, M., NORTON, K., KYLIE, H., DOLLMAN, J., AND ROBERTSON, I. 2003. Changes in the prevalence of overweight and obesity among young Australians, 1969-1997. *American Journal of Clinical Nutrition, 77*, 29-36.

BOOTH, M., OKELY, A. D., DENNEY-WILSON, E., HARDY, L., YANG, B., AND DOBBINS, T. 2004. *NSW Schools Physical Activity and Nutrition Survey (SPANS) 2004: Summary Report.* Sydney: NSW Department of health.

CSIKSZENTMIHALYI, MIHALY. 1975. *Beyond Boredom and Anxiety*. Jossey-Bass: San Francisco, CA.

CONSOLVO, S., EVERITT, K., SMITH, I., AND LANDAY, J. A. 2006. Design requirements for technologies that encourage physical activity. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*, 457-466.

CRAWFORD, C. 1982. The Art of Computer Game Design. from `http://www.vancouver.wsu.edu/fac/peabody/game-book/Coverpage.html`.

FUJIKI, Y., KAZAKOS, K., PURI, C., STARREN, J., PAVLIDIS, I., AND LEVINE, J. 2007. NEAT-o-Games: Ubiquitous Computing Meets Exertion Interfaces. In *Computer Human Interaction (CHI) 2007*, San Jose, USA.

GAME SPOT AUSTRALIA WEBSITE. DANCE DANCE REVOLUTION HITS 6.5 MILLION IN SALES [ELECTRONIC VERSION]. 2007. Retrieved 15th July 2007 from http://au.gamespot.com/xbox/puzzle/ddrxbox/news.html?sid=6084894&mode=recent.

GAMES GRAVEYARD WEBSITE. 2007. Power Pad/Family Fun and Fitness/Family Trainer [Electronic Version]. Retrieved 15th July 2007 from http://www.gamersgraveyard.com/repository/nes/peripherals/powerpad.html.

GOLDFIELD, G. S., KALAKANIS, L. E., ERNST, M. M., AND EPSTEIN, L. H. 2000. Open-loop feedback to increase physical activity in obese children. *International Journal of Obesity, 24(7)*, 888-892.

HERSEY, J. C., AND JORDAN, A. 2007. Reducing Children's TV Time to Reduce the Risk of Childhood Overweight, *The Children's Media Use Study*, Centers for Disease Control and Prevention.

HODGSON, M. 2005. Get in the game. *Fitness*, Summer 2005, 16-19.

HOYSNIEMI, J. 2006. *Design and Evaluation of Physically Interactive Games.* Doctoral Dissertation, University of Tampere, Tampere

JACKSON, S., AND CSIKSZENTMIHALYI, M. 1999. *Flow in sports.* Human Kinetics, Champaign, IL.

KAISER FAMILY FOUNDATION. 2005. Generation M: Media in the lives of eight to eighteen year olds. [Electronic Version]. Retrieved 1 July 2007 from http://www.kff.org/entmedia/entmedia030905pkg.cfm.

KNIGHT, G. 2002. Amiga History Guide:Amiga Joyboard [Electronic Version]. Retrieved 23 April 2007 from http://www.amigahistory.co.uk/joyboard.html.

LANNINGHAM-FOSTER, L., JANSEN, T. B., FOSTER, R. C., REDMOND, A. B., WALKER, B. A., HEINZE, D., AND LEVINE, J. 2006. Energy Expenditure of Sedentary Screen Time Compared With Active Screen Time for Children. *Pediatrics, 2006(118)*, e1831-e1835.

LIEBERMAN, D. A. 2006. Dance Games and Other Exergames: What the Research Says [Electronic Version]. Retrieved 28th July 2007 from http://www.comm.ucsb.edu/faculty/lieberman/exergames.htm.

LUKE, R. C. 2005. *Oxygen cost and heart rate response during interactive whole body video gaming.* Masters Thesis, California State University, Fresno

LUND, H. H., KLITBO, T., AND JESSEN, C. 2005. Playware technology for physically activating play. *Artificial life and robotics, 9(4)*, 165-174.

MALONE, T. W. 1980. What makes things fun to learn? heuristics for designing instructional computer games. In *Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems*, Palo Alto, California, United States.

MALONE, T. W. 1982. Heuristics for designing enjoyable user interfaces: Lessons from computer games. In *Proceedings of the 1982 conference on human factors in computing systems*, Gaithersburg, Maryland, United States.

MARSHALL, S.J., BIDDLE, S.J.H., GORELY, T., CAMERON, N., AND MURDEY, I. 2004. Relationships between media use, body fatness and physical activity in children and youth: a meta analysis. *International Journal of Obesity, 28*, 1238-1246.

RIZZO, S. 2007. CyberSightings. *CyberPsychology & Behavior, 10(2)*, 316-320.

ROSS, R., JANSSEN, I., DAWSON, J., KUNGL, A.M., KUK, J.L., WONG, S.L., NGUYEN-DUY, T.B., LEE, S., KILPATRICK, K., AND HUDSON, R. 2004. Exercise-induced reduction in obesity and insulin resistance in women; a randomized controlled trial. *Obesity Research, 12*, 789-798.

SAELENS, B., AND EPSTEIN, L. 1998. Behavioral engineering of activity choice in obese children. *International Journal of Obesity, 1998(22)*, 275-277.

SALMON, J., BALL, K., CRAWFORD, D., BOOTH, M., TELFORD, A., HUME, C., JOLLEY, D., AND WORSLEY, A. 2005. Reducing sedentary behaviour and increasing physical activity among 10-year-old children: overview and process evaluation of the 'Switch-Pay' intervention. *Health Promotion International, 20*, 7-17.

SMITH, B. K. 2005. Physical fitness in virtual worlds. IEEE Computer, 38(10), 101-103.

STUBBS, C.O., AND LEE, A.J. 2004. The obesity epidemic: both energy intake and physical activity contribute. *The Medical Journal of Australia, 181*, 489-491.

SWEETSER, P. AND WYETH, P. 2005. GameFlow: A Model for Evaluating Player Enjoyment in Games, *ACM Computers in Entertainment, Vol. 3*, No. 3, July 2005.

TROST, S. G., KERR, L. M., WARD, D. S., AND PATE, R. R. 2001. Physical activity and determinants of physical activity in obese and non-obese children. *International Journal of obesity, 2001(25)*, 822-829.

TUCKER, T. 2006. *Tetris Weightlifting: An Exploration in Entertainment Fitness.* Masters Project, Indiana University, Indiana.Retrieved 23rd July from http://www.tetrisweightlifting.com/artifacts/tetris_weightlifting_paper.doc.

VALENTI, L., CHARLES, J., AND BRITT, H. 2006. BMI of Australian general practice patients. *Australian Family Physician, 35*, 570-571

VANDEWATER, E. A., SHIM, M.-S., AND CAPLOVITZ, A. G. 2004. Linking obesity and activity level with children's television and video game use. *Adolescence, 27(1)*, 71-85.

WEINDRUCH, L. 2007. Sporting Goods Sales Reach $52.1 Billion in 2006; NSGA Expects 3% Growth in 2007 [Electronic Version]. GearTrends Network Specialty NEWS website. Retrieved 1 July 2007 from http://www.snewsnet.com/cgi-bin/snews/09093.html.

WILMORE, J.H. AND COSTILL, D.L. 1994. *Physiology of Sport and Exercise*, Human Kinetics.

YANNAKAKIS, G. N., HALLAM, J., AND LUND, H. H. 2006. Comparative Fun Analysis in the Innovative Playware Game Platform. In *Proceedings of the 1st World Conference for Fun 'n Games*, Preston, England.