Exercise and Play: Earn in the Physical, Spend in the Virtual

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Contemporary lifestyle is becoming increasingly inactive: a little physical (sport, exercising) and much sedentary (TV, computers) activity. The nature of sedentary activity is often self-reinforcing, such that increasing physical and decreasing sedentary activity is difficult. We present a novel approach aimed at combating this problem in computer gaming. Rather than explicitly changing the amount of physical and sedentary activity a person sets out to do, we propose a new game design that leverages engagement with games in order to motivate players to perform physical activity as part of a traditional sedentary game playing. This work presents the design and evaluates its application to an open source game, *Neverball*. We altered *Neverball* by reducing the time allocated for the game tasks and motivated players to perform physical activity by offering time based rewards. A study involving *180* young players showed that the players performed more physical activity, decreased their sedentary playing time, and did not report a decrease in perceived enjoyment of playing the active version of *Neverball*. A survey conducted amongst *103* parents revealed their positive attitude towards the activity motivating game design. The obtained results position the activity motivating game design as an approach that can potentially change the way players interact with computer games and lead to a healthier lifestyle.

KEYWORDS: Serious Games, Game Design, Physical Activity, Motivation, Behavioural Change, User Study

INTRODUCTION

According to the World Health Organisation, over *1.6* billion individuals are overweight or obese (WHO, 2006). A contributing factor for this phenomenon is the occurrence of a positive energy balance, i.e., where one's energy intake exceeds one's energy expenditure. This is often explained by an increasingly sedentary lifestyle: low amounts of physical activity (such as walking, sport, and exercising) and high amounts of sedentary activity (such as TV, computer games, and reading).

The nature of the sedentary activity is often addictive and self-reinforcing (Koezuka et al., 2006). Hence, adjusting one's energy balance by explicitly increasing the amount of physical and decreasing the amount of sedentary activity performed is not easy. In our research we present a novel approach to combat this problem. Rather than setting out to explicitly decrease the amount of sedentary activity in one's normal lifestyle, we propose to change a typical sedentary activity to incorporate certain forms of physical activity. This paper demonstrates a practical application of this paradigm in computer gaming. We present a novel computer game design, which leverages players' enjoyment and engagement to motivate them to perform physical activity as part of sedentary playing.

Our design can be applied to a wide variety of games in which a player's game character is represented by quantifiable features, e.g., time, energy, or speed. To encourage players to perform physical activity while playing, we propose to modify the design of computer games such that players can gain virtual game related rewards in return for the real life physical activity they perform (Berkovsky et al., 2009). Physical activity can be captured by wearable sensors attached to the player. According to our design, at any point in time players can perform physical activity, which will instantaneously provide them with the reward and reinforce the game character, e.g., gain time, boost energy or increase speed. This reinforcement increases the likelihood of accomplishing the game tasks and players' enjoyment, while gradually increasing the difficulty of the game tasks to further motivate players to perform physical activity. This game design is referred to as *PLAY, MATE!* (PhysicaL ActivitY MotivATing gamEs).

This paper presents and evaluates an application of the *PLAY, MATE!* design to a publicly available computer game, *Neverball* (http://www.neverball.org). In *Neverball*, players navigate a ball through a maze-shaped surface avoiding obstacles and collecting coins, while accomplishing these two tasks in a limited amount of time. We altered *Neverball* according to the *PLAY,* *MATE!* design by (1) reducing the time allocated to accomplish the game tasks, and (2) motivating players to perform physical activity by offering time based rewards. Each player was equipped with a tri-axial accelerometer configured to recognise jump events, such that for every captured jump the player gained one extra second to accomplish the game tasks.

We conducted an experimental evaluation involving *180* participants aged *9* to *12*. The evaluation ascertained that applying the *PLAY, MATE!* design increases the amount of physical activity performed while playing and changes the distribution between the sedentary and active playing time. Although participants performed physical activity, they did not report a decrease in perceived enjoyment of playing. A survey conducted amongst *103* parents of the participants revealed their positive attitude towards the *PLAY, MATE!* design.

Hence, the contributions of this work are three-fold. Firstly, we proposed a novel *PLAY, MATE!* design for physical activity motivating games and exemplified its practical application to *Neverball*. Secondly, we experimentally evaluated the acceptance of the design by real players and its influence on their playing behaviour. Thirdly, we showed that the *PLAY, MATE!* design and active gaming paradigm were highly regarded both by young players and their parents. These results demonstrate the positive impact of the *PLAY, MATE!* design and clearly position it in the field of "games for good". Also, the results demonstrate the great potential of physical activity motivating games in changing the normally sedentary interaction style of young and adolescent players with computer games.

The rest of this paper is structured as follows. Section *2* surveys the related work on motivating technologies and games. Section *3* models the interaction between a player and a game and presents the principles of the *PLAY, MATE!* design. Section *4* illustrates ways of applying the *PLAY, MATE!* design to *Neverball*. Section *5* presents the experimental evaluation we conducted and analyses its results. Section *6* summarises the work and outlines our future research.

RELATED WORK

Information technology solutions to the obesity problem have been studied from various perspectives. Several works focused on the design issues of such applications. Consolvo et al. (2006) discussed general design principles of physical activity motivating technologies and applications. Campbell et al. (2008) focused on specific game design principles that can be applied to fitness applications. Following the design principles developed in these works, several practical applications have been developed.

Lin et al. (2006) developed a social application recording users' physical activity and linking it to the growth and activity of a virtual fish. Toscos et al. (2006) developed a mobile application recording a users' physical activity and sending persuasive messages encouraging exercise. In both cases, the physical activity of the users was quantified by the number of steps captured by a pedometer and then manually fed into the system. Hence, the users were requested to carry the pedometer everywhere and to periodically feed the counter reading into the system. From the technical perspective, physical activity self-reporting is often discovered to be unreliable and inaccurate (Klesges et al., 1990). From the behavioural perspective, these applications were aimed at changing the lifestyle of users by encouraging them to perform physical activity. The change was mostly accepted by previously motivated users, while other users resisted it.

Several applications take a persuasive approach (Fogg, 2003) to combating the obesity problem. Nawyn et al. (2006) developed a home entertainment system remote control promoting a reduction in TV viewing time and an increase in non-sedentary activities. Maheshwari et al. (2008) presented a user study evaluating the effectiveness of persuasive motivational messages for overweight individuals. Out of a plethora of Web based activity motivating applications surveyed by Zhu (2007), only a small number led to a short-term increase in physical activity. Similar to the above examples of information technologies, persuasive applications were mostly accepted by previously motivated users and resisted by others. In contrast, the *PLAY, MATE!* game design does not rely on extrinsic motivational factors, but rather leverages existing engagement with computer games to motivate users to perform physical activity.

Another area aiming to increase efficacy and sustainability of exercising and physical activity is of immersive virtual environment technologies. Ijsselsteijn et al (2006) presented a study investigating the effect of immersion and coaching on motivation of exercise bicycle riders. The results showed a positive effect of both factors on intrinsic motivation. Fox and Baileson (2009) presented a study evaluating the impact of virtual representation of self on the amount of voluntary physical exercising. It was found that rewarding or punishing the virtual representation of self depending on the amount of performed exercising (by visualising apparent weight loss or weight gain of the virtual representation) causes participants to engage and perform more exercise. However, these works deal with exercising, which is naturally a physical activity, and do not show whether a similar effect could be obtained for activities, which are naturally sedentary, and whether this effect would be beneficial in this case.

Game technologies involving players' physical activity have been developed and successfully disseminated in commercial products, like *Dance-Dance Revolution* (http://www.konami.com/ddr/) and the Nintendo Wii (http://www.nintendo.com/wii). The former is a dance pad, on which players step to control the game, and the latter is a gaming console, which uses an accelerometer-equipped device, allowing players to control the game by their body movements. Sales figures of these products demonstrate their tremendous commercial success: Wii alone sold over 45 million consoles in the first 2 years of sales. However, both technologies should be treated primarily as commercial products that provide natural bodily interfaces to interact with computer games rather than direct motivators of physical activity.

To the best of our knowledge, the only study of practical integration of physical activity into computer games was undertaken by Fujiki et al. (2008). A player's activity, captured by an accelerometer, were instantaneously transmitted to a PDA and visualised by a simple race-like game interface. The activity affected the visualisation of the game: speed of the game character, its standing in comparison to other players, and facial expression of the player's avatar. However, the race-like interface was designed exclusively to visualise the player's physical activity, lacking the attractiveness and immersion of contemporary games. Rather than designing new games and interfaces, our work aims to develop a new game design that, if integrated with a variety of existing and future games, will motivate players to perform physical activity as part of playing (Berkovsky et al., 2009).

PHYSICAL ACTIVITY MOTIVATING GAME DESIGN

We start the presentation of our physical activity motivating game design by modeling the standard playing process. Playing mainly consists of player interaction with a game environment, which is typically indirect and mediated by a game character. Hence, a game character can be considered as a player's virtual embodiment in the game environment. Hence, player *P* controls the game character *C*, which is actually involved in the game *G*. The interaction between a player *P* and character *C* is unidirectional: *P* manipulates and controls *C*. Conversely, the interaction between the character *C* and the game *G* is bidirectional: *C* executes the manipulations of *P* and influences *G*, which reacts according to the game logic and influences *C*. For example, consider a well-known *Pac-Man* computer game. There, the player manipulates the *Pac-Man* character to navigate through the maze, avoid ghosts, and collect coloured dots and bonus items. The arrows in Figure 1(a) schematically depict the interactions between *P*, *C*, and *G*.

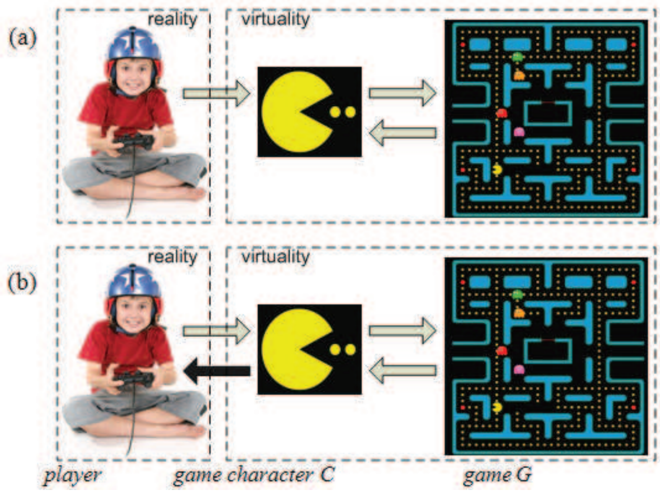

***Figure 1.* (a) Standard Player Interaction with the Game, (b) Player Interaction Including the Motivational Feedback.**

Since no direct interactions normally occur between *P* and *G*, we consider *C* as the model of *P* in *G*. In most games, *C* is represented by quantifiable features and their respective values. For example, consider the following *Pac-Man* character representation *{remaining-time:40, maximal-velocity:14, dots-collected:16}*. The value of a certain feature can be modified in three ways: (1) directly by *G*, e.g., reduction of the remaining time, (2) by *P* manipulating *C*, e.g., changing the direction of motion, and (3) by *P* controlling the interaction between *C* and *G*, e.g., collection of dots in *Pac-Man*. It should be noted that these modifications mostly occur simultaneously and *P* controls *C* accordingly.

To sustain a prolonged engagement of *P* with *G*, the flow of *G* is divided into several tasks, i.e., levels, that need to be accomplished by *P*. Formally, accomplishing a task means reaching the required value of a certain critical feature (or combination of values across multiple features), while satisfying other constraints of *G*. For example, consider the following *Pac-Man* game task: to collect *50* dots within *3* minutes of playing time, while avoiding the ghosts. According to (Sweetser and Wyeth, 2005) and (Febretti and Garzotto, 2009), the ability to accomplish the tasks is one of the main factors for the enjoyment and engagement of playing.

DESIGN PRINCIPLES OF *PLAY, MATE!*

Although contemporary games are often related to negative social stereotypes, they can be leveraged to promote more active behaviour and potentially lead to a healthier lifestyle. The goal of the *PLAY, MATE!* design is to change the sedentary nature of the game playing activity to include certain forms of physical activity. According to the design, physical activity is introduced as an integral part of playing. In this way, the engagement of *P* with *G* is leveraged to motivate *P* to perform physical activity. In essence, the motivational factor establishes a positive reinforcement based persuasive feedback between *G* and *P* (Arroyo et al., 2005), illustrated by the dark arrow in Figure 1(b). The primary target of this feedback is to influence *P* and eventually achieve the desired behavioural change, i.e., physically active playing.

The motivation to perform physical activity is achieved by modifying the following components of *G* and aspects of interaction between *P* and *G*:

- Game related motivator. *P* is made aware of the possibility of gaining virtual rewards in *G* in return for performing real physical activity. In addition, *G* is modified to motivate *P* to perform physical activity, such that certain functions of *G* or features of *C*, which are disabled or diminished at first, can be enabled or reinforced by the activity rewards.
- Activity interface. *P* is provided with an external interface capturing the physical activity performed, processing it, and converting real activity of *P* into virtual rewards in *G*.
- Game control. Since performing physical activity and controlling *C* simultaneously could be over-complicated, *P* is given supplementary control over the flow of *G*.

Using the above modifications, *P* is motivated to perform physical activity in the following way. Firstly, *G* is modified such that certain functions of *G* are disabled or certain features of *C* are diminished. Secondly, *P* is made aware of the fact that performing physical activity will enable the functions of *G* or reinforce the features of *C*. A composition of these two factors, combined with the existing engagement with and the enjoyment of playing, motivates *P* to perform physical activity, enable the functions of *G* or reinforce the features of *C*. As a result, *P* uses the supplementary game control to interrupt the sedentary playing and perform physical activity. When performed, the activity is captured by the physical activity interface and converted into the virtual game rewards, which enable the functions of *G* or reinforces the features of *C*.

Consider the following example of the *PLAY, MATE!* design applied to the *Pac-Man* game. The game is modified such that the velocity of the *Pac-Man* character is decreased. However, the player is made aware of the possibility to reinforce the *Pac-Man* character, i.e., increase its velocity, by performing physical activity. The player is equipped with a wireless pedometer, which acts as the activity interface. The pedometer counts the player's steps and transmits the number to the game. The number of steps is processed and the velocity of the *Pac-Man* increases accordingly. It may be difficult for the player to control the *Pac-Man* character simultaneously with stepping. To perform physical activity and continue playing the game, the player can slow down or eventually pause the *Pac-Man* game at any point in time.

Premack's principle is a behavioural theory can be used to underpin the validity of the *PLAY, MATE!* design (Premack, 1959). According to this principle, if two activities have different a-priori probabilities of occurring, the high probability activity can be used to motivate or reinforce the low probability activity. That is, the high probability activity motivates the low probability activity by making the former contingent on the latter. A common example of Premack's principle is motivating children to eat vegetables by making ice cream (high probability activity) contingent on eating the vegetables (low probability activity). In computer gaming, we will assume that the sedentary playing is the high probability activity and physical activity is the low probability activity. The main motivating factor of the *PLAY, MATE!* design is allowing the player to gain virtual game rewards in return for performing real physical activity. That is, physical activity is motivated by making the game playing (precisely, game rewards that ease the playing) contingent on the physical activity.

We would like to highlight the non-coercive nature of the *PLAY, MATE!* design. Firstly, the game related motivators are introduced gradually, to keep the game tasks challenging while accomplishable (Sweetser and Wyeth, 2005). As a result, *P* can accomplish the tasks either in a difficult sedentary playing or in an easier way, by performing physical activity and gaining the rewards. Secondly, feedback about the functions of *G* that are enabled or features of *C* that are reinforced is instantaneously visualised, such that *P* can independently determine the desired amount of physical activity. Hence, *P* remains in control of the decisions regarding when and how much physical activity to perform.

Note that the effort required to apply the *PLAY, MATE!* design to an existing game (game related motivator implantation and physical activity interface calibration) is negligible in comparison with the effort required to design and develop a new game. This is due to the fact that when the design is applied to an existing game, many available components, such as game logic, input/output, visualisation, and others, can be reused rather than developed from scratch.

APPLYING PLAY, MATE! TO *NEVERBALL*

To experimentally evaluate the *PLAY, MATE!* design, we applied it to an open source *Neverball* game (http://www.neverball.org). In *Neverball*, players navigate a ball to a target point through a maze shaped surface and collect a required number of coins in a limited time. Ball control is achieved by virtually inclining the game surface, which causes the ball to roll. Figure 2 shows a screenshot of *Neverball*. *Neverball* consists of multiple levels (i.e., instantiations of the tasks) with gradually increasing degrees of difficulty: the structure of the maze, the location of obstacles and pitfalls, the number of coins to collect, and the amount of time allocated vary considerably across the levels. Out of the available levels, we selected and used *16* levels that would suit inexperienced *Neverball* players.

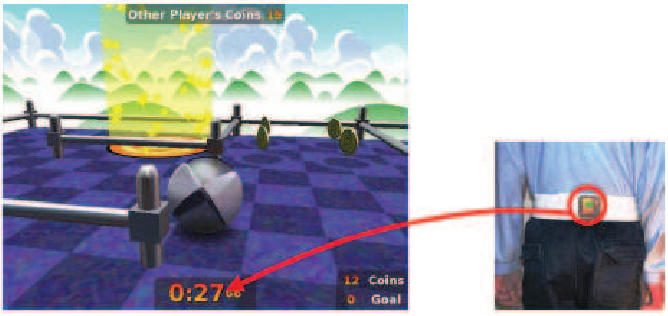

Figure 2. Neverball **Interface and Accelerometer.**

We applied a time based game related motivator, which referred to the time allocated to accomplish each level. We shortened the level times[1] and made players aware of the possibility of gaining extra time in return for performing physical activity. We conjectured that players' engagement with the game and aspiration to accomplish the levels will motivate them to gain extra time by performing physical activity. Table 1 summarises the original and shortened level times (in seconds).

We used a compact (*42x42x10* mm) and lightweight (*15* gr) tri-axial accelerometer referred to as the *activity monitor* to capture player's physical activity (Helmer et al., 2008). The accelerometer was attached to the player's waist, so as not to interfere with player's motion, using an elastic band (see Figure 2) and wirelessly transmitted the three measured acceleration signals 500 times per second. This allowed us to reconstruct the magnitude of the acceleration, filter out noises and abnormal spikes, perform time based normalization, and discretise the acceleration signal into activity bursts, which are referred to as *jumps*. For every jump captured, players gained one extra second to accomplish *Neverball* levels. The increased remaining time was instantaneously visualised, such that players were in control of the amount of physical activity performed. Since manipulating the ball simultaneously while performing physical activity would be difficult for players, we provided them with a control function that allowed players to pause and restart *Neverball* at any point in time.

Table 1. **Original and Shortened Level Times.**

level	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
t_{orig}	*240*	*90*	*120*	*180*	*180*	*90*	*240*	*120*
t_{short}	*60*	*38*	*40*	*75*	*75*	*38*	*100*	*40*

level	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
t_{orig}	*180*	*120*	*180*	*300*	*120*	*180*	*240*	*240*
t_{short}	*45*	*40*	*60*	*75*	*40*	*60*	*100*	*100*

In summary, the *PLAY, MATE!* design is applied to *Neverball* as follows. Players are motivated to perform physical activity by applying a *shortened level times* motivator and making them aware of the possibility of gaining extra time by performing physical activity. When the remaining time is perceived to be insufficient, players can pause the game and perform physical activity, e.g., jump, or step on the spot. The physical activity is instantaneously captured by the activity monitor, transmitted to *Neverball*, processed and visualised. When the remaining time is perceived to be sufficient, players can resume the sedentary playing.

EXPERIMENTAL EVALUATION

We conducted an experimental evaluation aimed at ascertaining the acceptance of the *PLAY, MATE!* design. The acceptance is indicated by the amount of physical activity performed and perceived enjoyment of playing (Hsu and Lu, 2004). *180* participants from three primary schools in Hobart (Australia) participated in the evaluation. We presumed that *Neverball* is appropriate for relatively young players aged *9* to *12* and recruited accordingly: *25* participants were *9* years old, *49* were *10*, *74* were *11*, and *32* were *12* years old. *88* participants were boys and *92* were girls. Participants having previous experience with *Neverball* or having limitations

[1] The shortened level times were based on playing times exhibited by an expert player in a pilot playing session.

preventing them from performing physical activity were excluded.

The recruited participants were randomly assigned to two equal size groups of *90* participants. The first group played the normal *sedentary* version of *Neverball*, i.e., no game related motivator was applied. This group is the baseline group, since it represents the current sedentary gaming requiring no physical activity. The second group played the *active* version of *Neverball*, i.e., the *PLAY, MATE!* design with the shortened level times motivator was applied.

The participants were involved in the following activities. Initially, the participants played three levels of *Neverball*, to familiarise them with the game. Then, the participants were equipped with the activity monitors and informed of the possibility of gaining extra time in return for performing physical activity. Then, they had a *20* minute playing session, in which they played the version of *Neverball* according to their group (*sedentary* or *active*). Finally, they answered a post-study questionnaire and reflected on their perception of the playing. In addition, we asked the parents of the participants to answer a survey to reflect on their attitude towards the *PLAY, MATE!* design.

It should be highlighted that all the participants regardless of their group were equipped with the activity monitor and aware of the possibility of gaining extra time in return for performing physical activity. Hence, even in the *sedentary* group the participants could perform physical activity and gain additional time, although they had no real motivation to do this. This minimised the effect of novelty of using the activity monitor.

Acceptance of PLAY, MATE!

To ascertain the acceptance of the *PLAY, MATE!* design, we focus on two indicators: the amount of physical activity performed and the players' perception of the enjoyment of playing. The first shows whether the *PLAY, MATE!* design can motivate players to perform physical activity, while the second shows whether they find the active games enjoyable.

The amount of physical activity performed was quantified by the number of jumps captured by the activity monitor. Figure 3 depicts the average number of jumps performed. The average number of jumps performed by users in the *sedentary* group, who had no real motivation to perform physical activity, was *41.87*. It was considerably lower than the average number of jumps performed by users in the *active* group, which was *257.54*. The difference between the groups was statistically significant, $p<0.01$[2].

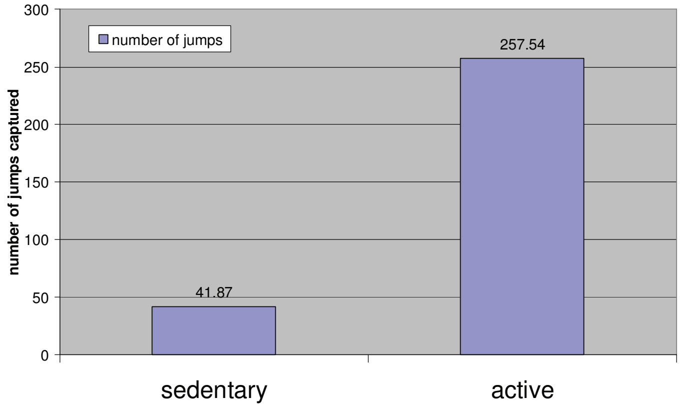

***Figure 3*. Average Number of Jumps Captured.**

To valdate this observation, we compared the sedentary playing time, T_{sed}, to the physical activity time, T_{act}, observed during the *20* minute playing session. These times were informed by the amount of time *Neverball* was played and paused, respectively, assuming that participants did not spend time on unrelated activities and neglecting the transition times. Figure 4 depicts the average relative time distribution between T_{sed} and T_{act}.

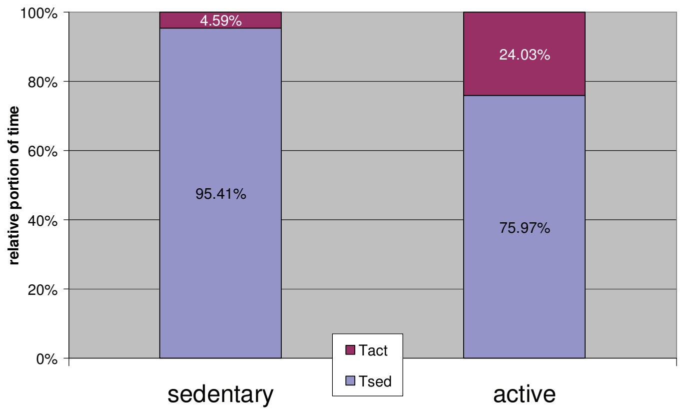

***Figure 4*. Distribution Between Sedentary and Active Time.**

Two patterns of behaviour can be clearly distinguished. For the *sedentary* group, *95.41%* of the *20* minute session time was spent on sedentary playing and *4.59%* on performing physical activity[3]. For the *active* group the time distribution was notably different. Only *75.97%* of time was sedentary, while *24.03%* of time was active.

[2] All statistical significance results hereafter refer to a two-tailed t-test assuming equal variances.

[3] The observed time distribution supports our assumption regarding the high and low probability activities in context of Premack's principle applied to computer games.

The difference between the groups was statistically significant, $p<0.01$.

In addition to the amount of physical activity, we analysed the participants' reported enjoyment and perception of physical activity performed while playing. In the post-study questionnaire, the participants reflected on their perception of the playing session on a [*-1*,*+1*] continuum, where *+1* is perceived as sedentary playing and *-1* is perceived as physical activity. Figure 5 depicts the average perception.

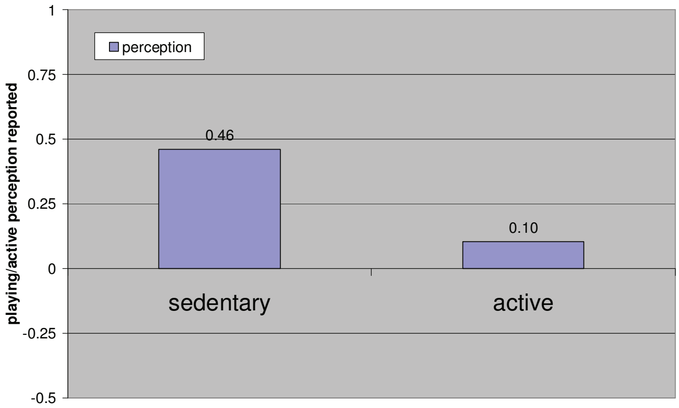

***Figure 5*. Average Perception of Playing.**

The average perception of playing in the *sedentary* group is *+0.46*, i.e., the participants perceive the playing session as mostly sedentary activity. However, in the *active* group the perception is *+0.1*, i.e., the participants perceive the playing session as almost equally sedentary and physical activity. The difference between the groups was statistically significant, $p<0.01$. This ascertains that the perception of the participants is realistic and corresponds to the amount of physical activity performed shown in Figures 3 and 4.

Although the participants realistically perceived the amount of physical activity performed while playing, they did not report a decrease in perceived enjoyment of playing. Figure 6 depicts the average enjoyment of playing reported on a 6-Likert scale ranging from "*absolutely hated*" to "*was cool, really loved*". The average enjoyment of playing in both groups is very high and comparable: *5.52* for the *sedentary* group and *5.48* for the *active* group. The difference between the groups was not statistically significant.
We conjecture that applying the *PLAY, MATE!* design to *Neverball* had mixed influences on the enjoyment of playing. Firstly, introducing physical activity as part of the game interrupted the flow of playing, as sedentary playing became interlaced with physical activity. This could have decreased the enjoyment of playing. Secondly, players were provided with a new game interaction means through the activity interface. It is a new interface not available in the state of the art games, which allows more control over the game and could have increased the enjoyment. The results in Figure 6 show that these factors balanced each other, such that the reported enjoyment of playing did not change significantly.

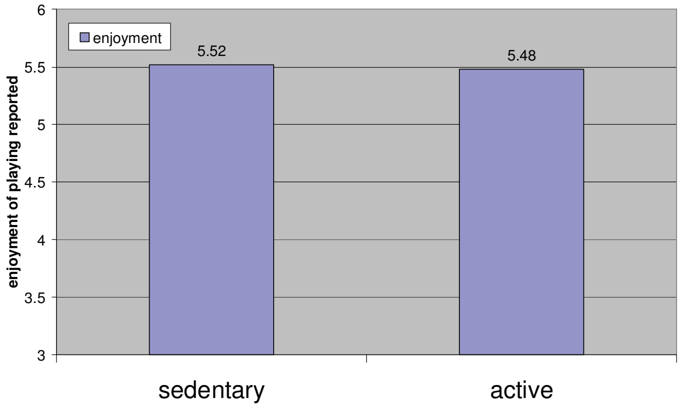

***Figure 6*. Average Enjoyment of Playing.**

We will summarise our main findings and statistical significance test outcomes in Table 2. The data refers to the number of jumps, relative active time, perception of playing, and reported enjoyment of playing for the *sedentary* and *active* groups. Statistical test outcomes include the *t* score, probability *p*, and Cohen's *d*.

***Table 2*. Results and Statistical Tests Summary.**

	sedentary	*active*	*t*	*p*	*d*
average number of jumps	*41.87*	*257.54*	*t(178)= -15.04*	*p*<.001	*2.25*
average relative active time	*4.59%*	*24.03%*	*t(178)= -15.19*	*p*<.001	*2.28*
average perception of playing	*0.46*	*0.10*	*t(178)= 6.37*	*p*<.001	*0.96*
average enjoyment of playing	*5.52*	*5.48*	*t(178)= 0.38*	*0.35*	*0.06*

Parents' Survey
We distributed a parents' survey, aimed at gauging their attitude towards the *PLAY, MATE!* design. Parents were asked to estimate the average daily amount of time they allowed their children to play sedentary games and their average monthly expenditure on sedentary games and accessories. Possible answers for the allowed times ranged from "less than 30 mins" to "more than 2 hours" and from "less than $20[4]" to "more than $100" for the expenditure. Then, we introduced the main ideas of the

[4] In Australian dollars ($AUD *1* = $USD *0.9*).

PLAY, MATE! design and the ways it can be applied to create future active games. Finally, we asked the parents to estimate the average daily amount of time they would allow their children to play, and the average monthly expenditure they would be happy to spend on games and accessories, if all the games were substituted by their active analogues.

The survey was answered by *103* parents. Figure 7 summarises the results. For the playing time of sedentary games, *52.43%* of parents selected "less than 30 mins", *35.92%* of parents – "30 mins to 1 hr", *10.68%* – "1 hr to 2 hrs", and only *0.97%* selected "more than 2 hrs". For the expenditure on sedentary games, *90.29%* of parents selected "less than $20", *9.71%* of parents – "$20 to $50", whereas none selected "$50 to $100" or "more than $100". The parents' answers considerably increased for the active analogues of the games created by applying the *PLAY, MATE!* design. For the playing time of active games, *16.50%* of parents selected "less than 30 mins", *47.57%* of parents – "30 mins to 1 hr", *28.16%* – "1 hr to 2 hrs", and *7.77%* selected "more than 2 hrs". For the expenditure on sedentary games, *55.34%* of parents selected "less than $20", *39.81%* of parents – "*$20 to $50*", *3.88%* – "$50 to $100", and *0.97%* selected "more than $100".

Overall, *54.37%* of parents indicated that they would allow their children to play for longer and *38.83%* indicated that they would agree to increase the expenditure on games and accessories, if current sedentary games were substituted in the future by their active analogues. Furthermore, *33.01%* of respondents indicated that they would both allow their children to play longer and agree to increase the expenditure.

These results show a positive attitude of parents towards the active games played by their children. They are willing to increase both playing (screen) time if the games included aspects of physical activity and their monetary expenditure. Hence, the *PLAY, MATE!* design does not only provide a new gaming paradigm enjoyable by players, but is also highly regarded by their parents.

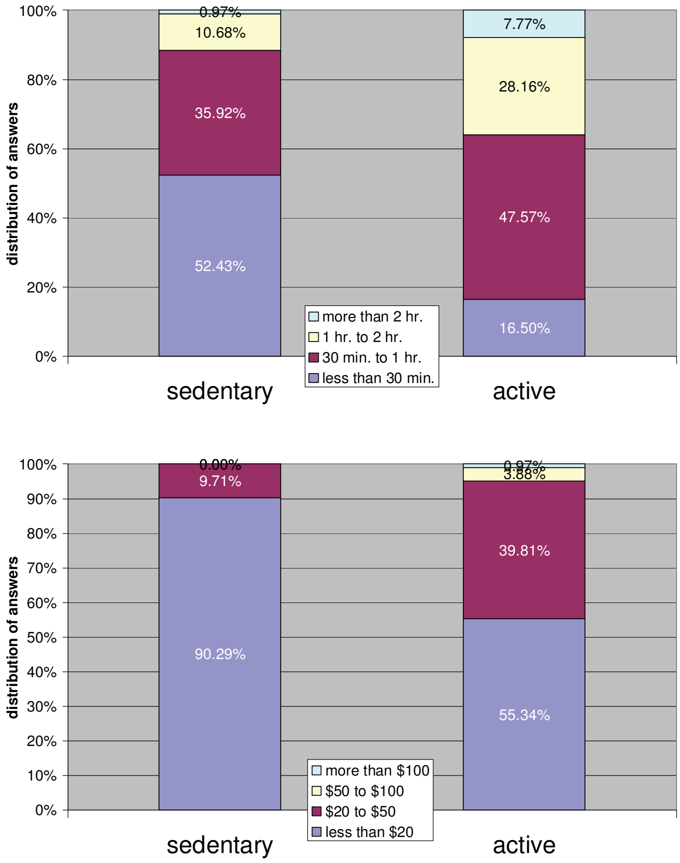

***Figure 7*. Parents' Attitude towards the *PLAY, MATE!* Design. Distribution of Answers for Average Daily Playing Time (Top) and Average Monthly Expenditure (Bottom).**

CONCLUSION

In this work we presented the *PLAY, MATE!* design for physical activity motivating games. The key concept underpinning the design is that players' engagement with computer games can be leveraged to motivate them to perform physical activity as part of playing. According to the design, physical activity is introduced as an integral part of playing, such that performing physical activity enables the players to gain game related rewards. We presented the components of the design and exemplified its application to the publicly available *Neverball* game.

We presented the results of a user study involving *180* participants aged *9* to *12* and *103* parents. The study allowed us to draw several conclusions. Firstly, it ascertained that young players can be motivated to perform physical activity while playing. Secondly, it showed that despite performing physical activity and realistically perceiving this, players did not report a decrease in perceived enjoyment of playing. Thirdly, the parents' survey showed their positive attitude towards physical activity motivating games. Hence, these results clearly demonstrate that the *PLAY, MATE!* design can potentially change the normally sedentary interaction of players with games and essentially lead to a healthier lifestyle.

Although these results are encouraging and demonstrate the potential of physical activity motivating games, they raise several issues, which we will investigate in the future.

- Game related activity. In the presented application of the *PLAY, MATE!* design, the physical activity was decoupled from the game, i.e., jumping did not match any particular player action in *Neverball*. However, this decoupling could potentially decrease the enjoyment of playing and discouraging players from playing activity motivating games. We will investigate ways to connect the type of physical activity performed by players and their actions in the game.
- Player dependency. The acceptance of the *PLAY, MATE!* design may be player dependent. For example, one would expect experienced gamers to be easily motivated by the game rewards, whereas users that do not play computer games often, may resist it and require other motivators. We will experimentally evaluate the impact of these dependencies and develop dynamic strategies for a player dependent application of the design.
- Preserving game flow. Interrupting the game to perform physical activity can potentially reduce the enjoyment of playing, as players will not be concentrating solely on the game, but also on the physical activity. We will investigate the use of activity interfaces that will allow the user to continue controlling the game character while performing the physical activity.
- Ubiquitous activity motivator. The *PLAY, MATE!* design instantaneously rewards players for the physical activity they perform. However, it can be modified to accumulate physical activity over time and eventually convert this activity into game rewards. We will enhance the design to support this functionality, which will transform it into a ubiquitous physical activity motivator.
- Longitudinal user study. We plan to conduct a thorough user study, in which we will observe players interacting with activity motivating games in a more natural environment, e.g., at home. This will help us to understand whether the *PLAY, MATE!* design eventually leads to the desired behavioural change and a healthier lifestyle, providing an alternative way to combat the obesity problem.

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