Designing Games to Motivate Physical Activity

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ABSTRACT
Engagement with computer games causes children and adolescent users to spend a substantial amount of time at sedentary game playing activity. We hypothesise that this engagement can be leveraged to motivate users to increase their amount of physical activity. In this paper, we present a novel approach for designing computer games, according to which the users' physical activity reinforces their game character. This way the users are seamlessly motivated to perform physical activity while maintaining their enjoyment of playing the game.

General Terms
Design, Human Factors.

Keywords
Game design, physical activity, engagement, motivation.

1. INTRODUCTION
Awareness of the overweight problem has increased in the recent years. According to US National Health and Nutrition survey, over 60% of adults and over 20% of children are overweight, while international statistics published by World Health estimate over 1.6 billion overweight individuals. One of the reasons for this phenomenon is the *positive energy balance*, i.e., condition where one's energy intake exceeds energy expenditure. Low energy expenditure is explained by an increasingly sedentary lifestyle: low amount of physical activity (e.g., walking, sport, exercising) and increasing amount of sedentary activity (e.g., TV, computer games, reading).

The nature of the sedentary activity is often addictive and self-reinforcing. Hence, adjusting the energy balance by increasing the physical and decreasing sedentary activity cannot be achieved easily. In this paper we present a novel alternative approach to this problem. Rather than explicitly decreasing the amount of sedentary activity in one's lifestyle, we propose to change the inherently sedentary nature of this activity by incorporating into it certain aspects of physical activity. In particular, we aim to design computer games that will leverage users' engagement with and enjoyment of a game to motivate them to perform some physical activity and help them to maintain the energy balance.

Persuasive'09, April 26-29, Claremont, California, USA.

We consider a common class of games, those in which the user's game character is represented by a set of quantifiable features, like the remaining time, energy, and speed. Traditional games are built around principles of micro goals and marginal challenge [1], such that users have to accomplish game tasks requiring gradually increasing capabilities. To encourage players to perform some physical activity while playing, we propose to modify the design of the games by gradually introducing challenges and increasing the game difficulty. When the game becomes over-challenging, the users can perform some physical activity and instantaneously reinforce the features of their game character, e.g., gain time, boost energy, or increase speed. Hence, players convert their real physical activity into virtual game commodities. This reinforcement increases both the likelihood of accomplishing the game tasks and the users' enjoyment, whereas gradually increasing the difficulty of the tasks seamlessly motivates the user to perform further physical activity. We call this conceptual game design *PLAY, MATE!* (PhysicaL ActivitY MotivATing gamEs).

This paper presents the initial steps towards the development and dissemination of *PLAY, MATE!* game design. Section 2 surveys the related work on motivating technologies and games. Section 3 presents the design principles of *PLAY, MATE!*. Section 4 illustrates how these principles could be applied to the Neverball game. Finally, section 5 outlines our future work.

2. RELATED WORK
Information technology solutions to the overweight problem have been studied from several perspectives. Consolvo *et al.* discussed general design principles of physical activity motivating technologies [3], while Campbell *et al.* focused on the concrete game design principles in everyday fitness applications [1]. Following the design principles presented in both papers, several practical systems have been implemented.

Lin *et al.* developed a social application recording the users' physical activity and linking it to the growth and activity of a virtual fish [5]. Toscos *et al.* developed a mobile application recording the users' physical activity and sending persuasive messages encouraging further exercising [8]. In both cases, the physical activity of the users was captured by a pedometer, quantified by the number of measured steps, and manually fed into the system. Hence, the users were required to carry the pedometer everywhere and to periodically feed the counter reading into the system. These systems were aimed at changing the everyday lifestyle of users by indirectly encouraging them to perform physical activity. The change was accepted by already motivated users, while other users resisted to it.

Game technologies involving users' physical activity have been implemented and disseminated in commercial products, like Konami Dance-Dance Revolution (www.konami.com/games/ddr), Nintendo Wii (www.nintendo.com/wii), and PCGamerBike (http://www.pcgamerbike.com). The first is a dancing pad with arrows, on which users step to control the game. The second uses an accelerometer-equipped input device, allowing users to control the game by their body movements. The third is a programmable controller using bicycle pedalling motion to control the game. Despite being similar to our proposed approach (motivate users to perform physical activity while playing), all the above can be considered as commercial products providing bodily interfaces (or controllers) to interact with computer games rather than motivators of physical activity.

As far as we are aware, the only study of practical integration of physical activity into computer games was undertaken by Fujiki *et al.* [4]. A user's activity data recorded by an accelerometer were instantaneously transmitted to a PDA and visualised by a simple race-like game interface. The data affected the visualisation of the game character: facial expression, race speed, and race standing in comparison to other users. However, the race-like interface was designed exclusively to visualise the user's physical activity, lacking the attractiveness and immersion of commercial games with 3D and virtual reality graphical interfaces. Rather than designing new games and developing new user interfaces, we aim at developing and disseminating a new game design that, if integrated with a variety of existing and upcoming games, will seamlessly motivate users to perform physical activity.

Several applications that take a persuasive approach to tackle the overweight problem and influence users were recently presented. Chi *et al.* developed a ubiquitous system calculating the calorie value of cooked meals and promoting healthy cooking [2]. Maheshwari *et al.* presented a user study evaluating the effectiveness of persuasive motivational messages for overweight individuals [6]. Similarly to the case of novel information technologies, persuasive approaches were accepted by already motivated users and mostly resisted by others. In contrast, our approach does not rely on the existing motivation, but rather leverages engagement with games to motivate users to perform some physical activity.

3. DESIGN PRINCIPLES OF *PLAY, MATE!*

The core part of the gaming process consists of the user's interactions with the virtual game environment. These interactions are typically indirect and occur by means of the game character: the user *U* controls the game character *C*, which actually interacts with the game environment *G*. For example, consider a well-known Pac-Man game (http://www.pacmangame.net/). There, *U* controls the Pac-Man character *C* to follow the rules and achieve the goal of *G*: navigate through the maze, avoid ghosts, and collect coloured dots and bonus items (see figure 1).

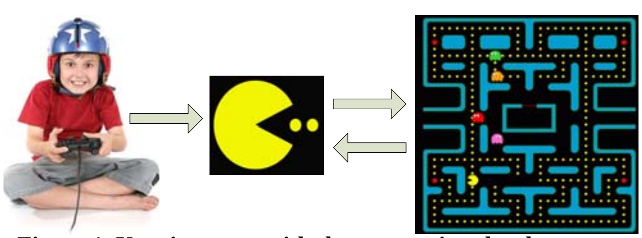

Figure 1. User interacts with the game using the character.

Since no direct interaction occurs between *U* and *G*, *C* virtually represents *U* in the context of *G*. More formally, *C* is modelled by a set of quantifiable features reflecting the state of the character within the game and their respective values. We denote this by $C=\{f_i:v_i\}$. For example, consider the Pac-Man character model *{dots-collected:6, remaining-time:40, maximal-speed:14}*. In most games, v_i can be modified in three ways: (1) directly by *G*, e.g., reduction of the remaining time, (2) by *U* directly controlling *C*, e.g., speed and direction of the motion, and (3) by *U* controlling the interactions of *C* with *G*, e.g., collection of the dots. These modifications typically occur concurrently, such that *U* has to process multiple input data originated by G and by the interactions of *C* and *G*, and control *C* accordingly.

To maintain a sustained engagement of *U*, *G* is divided into several tasks of gradually increasing difficulty, which *U* has to accomplish. Formally, accomplishing a task means reaching the required values V_i' of certain features f_i while satisfying the constraints of other features, e.g., to have the Pac-Man character collect *50* dots within *3* minutes. According to [7], the ability to accomplish the tasks is one of the main criteria for the enjoyment of playing, and engagement of *U* with *G*.

PLAY, MATE! proposes to leverage the existing engagement of *U* with *G* to seamlessly motivate *U* to perform physical activity by introducing physical activity as part of the game. This motivation is achieved by modifying the following components of *G* and aspects of interaction between *U* and *G*:

1. Game difficulty. *G* becomes more difficult, such that the tasks of *U* are harder, i.e., V_i' needed to accomplish the tasks are harder to reach.
2. Physical activity effect. In addition to directly controlling *C* and the interactions of *C* with *G*, *U* can directly affect the v_i of certain f_i of *C*.
3. Physical activity interface. To affect the v_i of certain f_i, *U* is provided with an external interface capturing the physical activity of *U* and transferring these data to *C*.
4. Game control. Since performing physical activity and controlling *C* concurrently could be over-complicated, *U* is given more control over the flow of *G*.

These modifications are intended to motivate the user to perform some physical activity as follows. The game becomes more difficult and does not allow the user to accomplish the tasks easily. The difficulty is introduced gradually to keep the tasks challenging while accomplishable [7]. The user is made aware of the fact that the features of the game character can be controlled and reinforced if the user performs a certain amount of physical activity. The combination of the difficulty of the tasks, engagement with the game, and enjoyment of accomplishing the tasks necessitates the user to reinforce the game character. As a result, the user is seamlessly motivated to interrupt the sedentary playing and perform physical activity. When performed, this activity is captured by the physical activity interface and transferred to the game. The received data regarding the amount, duration, and intensity of the physical activity are processed and reinforce the game character. Since the user is provided with immediate feedback and the character reinforcement is instantaneously visualised by the game interface, the user remains in control of the amount of the physical activity. Hence, at any point of time, the user can resume the sedentary playing having had the game character reinforced.

Let us consider *PLAY, MATE!* design principles applied to the Pac-Man game. The game becomes more difficult by decreasing the maximal speed of the Pac-Man character. To be able to accomplish the tasks, the user can reinforce the Pac-Man, i.e., increase its maximal speed by performing some physical activity. The user is equipped with a pedometer that counts the user's steps and transfers their number to the game. This number is received by the game and the maximal speed of the Pac-Man increases accordingly, i.e., the speed depends on the number counted by the pedometer. It may be difficult to control the Pac-man while jumping, stepping, or walking around. To combine the two, the user can slow down or eventually interrupt the flow of the game at any point of time.

Note that the effort required for applying *PLAY, MATE!* design to an existing game, i.e., appropriate adjustment of the game difficulty and calibration of the physical activity interface, is minor in comparison with the effort of designing and developing a new game. This is due to the fact that *PLAY, MATE!* reuses many components already available in the game, such as the game logic, visualisation component, standard input, and others.

4. APPLYING *PLAY, MATE!* TO NEVERBALL

To evaluate the proposed *PLAY, MATE!* design empirically, we have to identify an appropriate computer game, modify it to be able to adjust the game difficulty, find an appropriate device for the physical activity interface, and calibrate it to interface the existing game mechanisms.

We will use Neverball (http://icculus.org/neverball/) as an underlying game for this study. Neverball is an open source GNU General Public License game developed in C programming language. The availability of the game source code allows us to adjust the game difficulty. In Neverball, the user navigates a ball through a maze-shaped surface to avoid static and dynamic obstacles impeding the ball and collects coins on the way. Control over the ball is achieved by inclining the game surface, which causes the ball to roll (see Figure 2-right). Neverball requires the user to navigate the ball to the target point of the maze and collect the required number of coins, while accomplishing these two tasks in a limited amount of time. Moreover, the game consists of multiple levels with gradually increasing degree of difficulty in terms of the maze structure, the obstacles, the number of coins to collect and the time allocated.

We will use an accelerometer technology based pedometer[1] to capture the user's physical activity. Unlike pendulum-based pedometers, accelerometer-based pedometers filter out shaking and vibration and only count real physical activity. They also measure the intensity level of the activity (low, moderate, or high) and the amount of time spent at each intensity level. Based on the weight and height of the user, the pedometer converts the captured activity intensity and time into the estimated calorie expenditure. These data are uploaded to the machine hosting the pedometer's software component and running Neverball. The pedometer is compact and waistband mountable, such that it does not obstruct the user's motion (see Figure 2-left).

Figure 2. Pedometer (left) and Neverball interface (right).

PLAY, MATE! design is applied to Neverball as follows. The game becomes more difficult by shortening the amount of time allocated to accomplish each level. This is done by modifying the initial time to accomplish the level of Neverball logic component. Once the user starts navigating the ball, the time to accomplish the level decreases. Since the remaining time indicator is permanently shown and updated, the user is in control of when to interrupt the game and perform physical activity. When the remaining time is perceived to be insufficient, the user interrupts the game by invoking the pause function of Neverball logic component and performs physical activity, such as jumping, stepping, or other indoor exercising. The estimated calorie expenditure is instantaneously captured by the pedometer and transferred to the pedometer's software, which, in turn, invokes the time update function of Neverball logic component. If the captured physical activity exceeds the minimal threshold, time update event is processed, and the indicator of the remaining time increases accordingly. Hence, the user's physical activity is converted into time that allows to accomplish the level. When the remaining time is perceived to be sufficient, the user resumes the sedentary playing and continues to navigate the ball.

5. FUTURE WORK

In this paper we presented the initial steps towards the development and dissemination of *PLAY, MATE!*, a novel game design that seamlessly motivates users to perform physical activity. The motivation is achieved by increasing the game difficulty and introducing physical activity as part of the game. We assume that in these conditions, the engagement with the game will actually motivate the users to perform physical activity, increase their amount of physical activity, and help users maintain their energy balance.

We are currently establishing the experimental setting to evaluate the proposed design with primary school children. In the rest of this section we briefly discuss the research questions we plan to investigate in the upcoming experiment and in future studies.

Evaluation of *PLAY, MATE!* design. The proposed *PLAY, MATE!* design is based on the assumption that the users' engagement with the game can motivate them to perform some physical activity. We will empirically validate this assumption and evaluate the acceptance of *PLAY, MATE!* design. Two acceptance indicators will be measured: the amount of physical activity performed while playing and the enjoyment of the game. These will be measured while playing the original and *PLAY, MATE!* versions of Neverball.

***PLAY, MATE!* enjoyment factors.** The main factor for playing games is the enjoyment of the game. *PLAY, MATE!* design

[1] Several commercial and academic pedometers supporting data upload to the pedometer software component are available. The decision regarding the specific device to be used is still pending.

introduces different playing conditions, as the difficulty of the tasks is increased and the user is indirectly required to perform some physical activity as part of the game. We will experimentally evaluate whether *PLAY, MATE!* games are enjoyable, which factors make them enjoyable, and compare these factors with the enjoyment factors of the standard sedentary games.

Users' perception. Since the proposed *PLAY, MATE!* design involves physical activity performed as part of playing, this may change the users' perception of the games. We will experimentally evaluate to which extent the users consider *PLAY, MATE!* version of the games to be a sedentary playing or a physical activity, as this may have implications on their enjoyment. It will be interesting to investigate how this perception changes depending on the amount of physical activity performed.

Adjusting the amount of physical activity. *PLAY, MATE!* design is mainly aimed at motivating users to perform physical activity. Hence, we intend to modify and gradually increase the amount of physical activity the users are indirectly required to perform, while maintaining the essential enjoyment of playing. This will allow wider dissemination of *PLAY, MATE!* games, as we will explore the possibility of their integration with lifestyle and wellbeing programs.

Game related activity motivators. The engagement with the game underpins *PLAY, MATE!* design, as it constitutes the main motivator to perform physical activity. We will investigate whether other factors (especially, the factors that belong to the playing realm, e.g., competitiveness) can reinforce this engagement, and further motivate the users. We will experimentally evaluate the combined effect of these factors on the acceptance of *PLAY, MATE!* design.

Impact of human characteristics. The acceptance of *PLAY, MATE!* design may depend on the user's characteristics. For example, gamers, i.e., young and game literate users, may accept it and be easily motivated by the game engagement, whereas users that do not play computer games very often, may resist it and require other motivators. We will experimentally evaluate the impact of such human characteristics and model dynamic strategies for applying different motivators for different types of users.

Keeping the game flow. Interrupting the game to perform physical activity can potentially reduce the enjoyment, since in *PLAY, MATE!* version of the games the user is no longer concentrated solely on the game, but also on the physical activity. We will investigate the use of various activity interfaces that will allow the user to continue controlling the game character while performing the physical activity (i.e., without concentrating on the physical activity).

Daily activity accumulator. *PLAY, MATE!* design implies immediately rewarding the users for the physical activity they perform. However, it can be extended to accumulate users' daily physical activity and convert it into game commodities. We will investigate how to expand *PLAY, MATE!* to support this functionality and eventually convert it into a ubiquitous physical activity motivator.

Longitudinal user study. Finally, we plan to conduct a longitudinal field study where we will observe users playing *PLAY, MATE!* games at their natural environments for extensive periods of time. This will help us to understand whether *PLAY, MATE!* is usable, whether it leads to an increase in the users' physical activity, and whether it can eventually lead to a wider behavioural change and healthier lifestyle, providing an alternative way to tackle the overweight problem.

6. ACKNOWLEDGMENTS

This research is jointly funded by the Australian Government through the Intelligent Island Program and CSIRO. The Intelligent Island Program is administered by the Tasmanian Department of Economic Development and Tourism. The authors thank Nilufar Baghaei, Stephen Giugni, Andrew 'Boo' Davie, and Peter Clifton for their comments on earlier versions of this paper.

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