DynoFighter: Exploring a Physical Activity Incentive Mechanism to Support Exergaming

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ABSTRACT

We present a study and game design that explores how motion controlled physical activity levels can be used to support exergaming and an improved user experience in a traditional game genre. We developed DynoFighter, a two player full body competitive fighting game where a player's activity levels influence their strength in the game, making it advantageous for players to exert themselves in order to win. We conducted a between subjects experiment to compare DynoFighter with and without its physical activity incentive mechanism and examined players' heart rate and activity levels, as well as their overall user experience with the game. Our results show that although there were no significant differences in physical exertion levels, players showed significantly more immersion and enjoyment as well as an increase in perceived exertion levels with DynoFighter's physical activity incentive mechanism.

Index Terms: H.5.m [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous—Miscellaneous

1 INTRODUCTION

Exposure to motion controlled games through such game consoles as the Nintendo Wii, Microsoft XBox 360 and XBox One, and the Sony PS3 and PS4 has increased in recent years. These consoles provide an opportunity to move away from a primarily sedentary gameplay style to a more physically intensive and healthy one [11]. A variety of motion controlled games already exist and they fall into two categories [5] - non-exertion with basic gesture controls and exertion that requires a higher degree of motion and often mimics real world sports and exercising. The former, while making players move to some extent, may not produce positive health outcomes, while the latter category of games has been shown to support moderate exercise levels during game play [10, 14], but may lack the attractiveness of a game and feel more like an exercise session. While these exertion based games may attract casual gamers and those people already interested in health and fitness, they might not be necessarily attractive to gamers who are interested in more traditional game genres such as first person shooters and fighting games.

To support gamers, we hypothesize that exergames need to mimic already existing game styles and provide mechanisms to incentivize players to partake in physical activity at sustained levels so that the resultant activity improves game performance and experience. To explore this idea, we developed DynoFighter, a competitive two-player fighting game that has two important features to support sustained physical activity. First, we developed a player activity incentive mechanism that uses a player's rate of motion to influence their strength within the game, making it advantageous for players to exert themselves more in order to win by making their attack and defense moves stronger. Second, by placing players in a competitive environment we further affect players' exertion levels as they try to keep up with one another [9]. To evaluate DynoFighter, we performed a between subjects experiment that compared the game with and without the player activity incentive mechanism. The main contribution of our work is our activity incentive mechanism that can be added to future exergames to improve game immersion and perceived level of exertion as well as an analysis of how the results of our user study can lead to new avenues for future research.

Figure 1: Two players interacting with our DynoFighter game prototype.

2 RELATED WORK

There has been a significant amount of work done on the exploration of exergaming and how these types of games can be used to support sustained physical activity [10, 14]. Work by Nenonen et al. [8] promotes increased activity with an idea of using the heart as a controller for a biathlon game. At various stages in the game players had to either have a high heart rate to gain an increase in the speed or to have a low heart rate and gain greater accuracy when shooting. Using heart rate directly like this may be difficult without knowing a person's fitness level and health information. Chen et al. [1] discuss effects of priming players with expectation of exercise or play time from a game in order to see variations in activity levels. They found that priming the use of the game for exercise actually increased the duration of use and that health feedback, such as calories burnt during game play, elicited a trend towards increased positive feedback. Based on this result, we decided to include the heart rate display into our game, adding a certain fitness aspect to the game and a form of incentive and competition between players as they compare scores. In contrast to this work, we make use of the cause of the heart rate changes (i.e., movement), allowing for greater flexibility in interpreting data by assigning various weights to different parts of the body when calculating in-game benefits.

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A common issue with player motivation and exergaming occurs in sports related games. Often these exergames oversimplify motion and lack immersion, where complex moves of the real world are stripped to basic gestures that offer little to no chance of depth based on player skill. However, a number of approaches exist to add depth to a game. Sheinin et al. [12] discuss this issue on how game controllers can encourage skill development and promote activity. For example, to move faster, a player may press and hold a button, providing little chance for two players to move differently from each other. However, if the player's speed is controlled by repeated key presses, the one able to do so quicker would get an edge in the game, allowing for the development of skills within a game, making it more attractive to players. This concept was not tested on exergames that require full body motion, but the same principles can be applied to add depth to the game for skill development. In DynoFighter we added this skill depth via a direct link between how much a player moves and their strength in the game, allowing players to develop strategies based not only on executing basic gestures, but on incorporation of other types of movement into the game to keep an activity meter full.

A competitive or cooperative game setting could also be a source of increased physical activity. In the StepStream system, Miller et al. [4] found an increase in activity, the number of steps taken per day, is achieved through an on-line record of steps for a number of students in a middle school. While participants were not able to see each other's raw numbers, an achievement point system was visible. Points were awarded on individual achievements such as a new record of steps taken per day. This kept the environment competitive which encouraged participants to be more active, but at the same time balanced based on individual fitness. In DynoFighter we use this competitive aspect to affect the player's movement levels by making it a two-player game.

3 DYNOFIGHTER GAME DESIGN

DynoFighter's core design makes use of Mueller et al.'s Movement-Based Game Guidelines [6]. First and foremost, we chose to embrace motion ambiguity in gesture recognition. We wanted to make sure that the game remained fast paced and players did not feel overloaded with a large number of gestures. Thus, we created a fairly basic gesture set that still lends itself to strategy within the game and provides a familiar feeling for most of the moves. However, if the recognition engine has poor accuracy, the game attractiveness will suffer and players will be driven away. To overcome this problem, we set recognition requirements fairly loosely to accept a wide range of ways to trigger attacks such as kicks and punches, ensuring that players are not required to keep perfect form for each of the gestures and can develop their own personal style of fighting while being comfortable with the body movements they have to perform. Second, with our physical activity incentive mechanism, we add intended fatigue to the game that players are enticed to undertake in order to become stronger and win. To push activity levels even further we made DynoFighter a two player game. This competitive atmosphere has the potential to promote higher rates of exertion as players are trying to keep up with each other's rates of attack and the general movements setting a pace to each round [9] as well as using upbeat dance music to set the initial pace.

3.1 Physical Activity Incentive Mechanism

The main contribution of our work is DynoFighter's player activity incentive mechanism. We developed a player activity level metric based on player skeleton data and heart rate. We made the incentive mechanism modular so it would be possible to turn it on and off for experimentation. For players' heart rate information we chose to use a wireless chest strap heart rate monitor that would not interfere with player movements.

To calculate player activity level AL we first use equation 1 to find the distance traveled JD by each of the N player joints for the past T frames based on a joint history buffer J. Time frame T can be adjusted depending on the desired level of game dynamics. In our implementation, we used a window of 600 frames, which is approximately 30 seconds. Using an empirically derived set of joint weights JW the activity level is calculated with equation 2. The choice of weights is dependent on the application and for our game setting we chose to give higher weights to leg movements, since players have to exert themselves more to move legs than arms. It is important to note that player skeleton sizes have to be normalized so as to not give an advantage to taller players. The final AL value is scaled to a 0-100 range based on an experimentally derived AL_{max} value, that represented top exertion levels we wanted players to achieve.

$$JD_n = \sum_{t=0}^{T} Dist(J_{(n,t)}, J_{(n,t+1)}) \tag{1}$$

$$AL = \frac{\sum_{n=0}^{N} JD_n * JW_n}{AL_{max}} \tag{2}$$

The activity level metric is used in the game as a multiplier that affects the amount of damage attacks do and how fast energy and health regenerate. Thus, the more active the player, the stronger they become in the game. Although, since AL is calculated based on the last T frames, players have to remain highly active at all times to maintain a high AL. This feature is important to keep the player motivated throughout the game to keep a high exertion level, otherwise players could simply "bank" their high performance at some stage during gameplay and then benefit throughout. However, in games where playing takes place over multiple sessions spanning days or even weeks the cumulative exertion metric could be useful. For example, in games such as MMORPG, where players often have to kill enemies to gain experience to advance, another source of such experience could be the activity level during the gameplay or even off-line during physical exercise.

3.2 Gestures

With the skeleton tracking data provided by a Microsoft Kinect depth camera, we designed a simple yet robust heuristics-based gesture recognition system. It is able to recognize multiple gestures performed at once, such as a kick and a punch thrown together to provide a fluid system for the user. A total of five gesture types are accepted by the game including right or left punches (either arm forward), right and left kicks (either leg forward), fireball (both arms forward), stun (both arms out to the sides), and heal (both arms up). Players are allowed to execute as many punches and kicks as they can, but the special attacks (fireball, stun, and heal) require an in-game resource called energy to execute, which slowly regenerates over time (regeneration is faster at higher levels of physical activity).

3.3 Graphical User Interface

Figure 2 shows a screenshot of DynoFighter. A player's important statistics bars are visible in the top corners (Health, Energy, and Activity levels). Heart rates are animated using a heart glyph that beats based on activity level. The activity bar, heart rate, and the heart glyph are all a part of the physical activity incentive mechanism and are removed in the base game version. Finally, above each avatar are special attack availability indicators to help manage in-game resources. In the lower corners of the screen players are given feedback on their moves executed/recognized and damage dealt. We supported an extra form of feedback that let players see their skeletons as they are being tracked by the Kinect as well as a live video feed mirrored to match player positions.

Figure 2: Screenshot of the DynoFighter game interface.

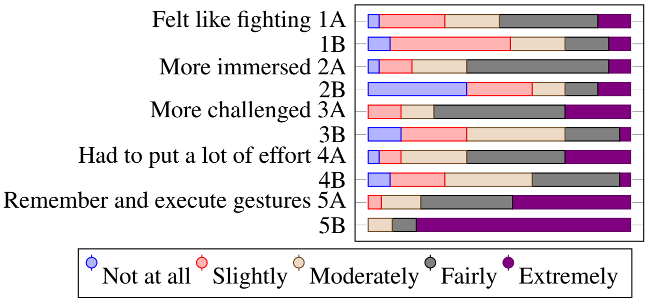

Figure 3: Significant responses. A - Activity, B - Base

4 USER EVALUATION

We conducted an experiment to evaluate the difference between the base game and the player activity incentive version. In our pilot tests we saw high exertion from players in both versions, however it seemed that the participants were more active with the incentive mechanism. Based on this our hypothesis was:

H1: The activity incentive game mode will lead to higher exertion levels compared to the base game mode.

4.1 Subjects and Apparatus

We recruited 48 participants (41 males and 7 females ranging in age from 18 to 26) from the local university population that signed up in pairs of two and were asked to come together. The experiment duration ranged from 45 to 60 minutes and all participants were paid $10 for their time.

The experiment setup consisted of a 55” HDTV, a Microsoft Kinect RGB-D camera, and two chest strap heart rate monitors. We used the Unity3D game engine and ANT+ library (heart rate monitor connection protocol) for the implementation of the game. Participants were located about 8 feet away from the Kinect with about 3 feet between the players.

4.2 Experiment Design

We used a between subjects design with game type (Activity Incentive, Base) as the independent variable. Our dependent variables were the average heart rate and the rate of motion as well as the results from a post-questionnaire based on the Game Experience Questionnaire [3] with questions utilizing a 5-point Likert scale. Each group of participants (24 groups, 12 per game type) conducted 12 trials. Rate of motion for each game was derived from the sum of the distances traveled by each of the joints scaled to game length and player size. The final rate of motion is the mean of the rates of motion from all of the games. Pairs of participants were assigned to a game type in an alternating fashion.

4.3 Procedure

The experiment began by giving the participants a consent form that explained the experiment procedure. A short pre-questionnaire collected general demographic information about the player’s age, gender, and video game experience. Next, participants were instructed to put on heart rate monitors. Then they were given a demonstration of all of the gestures and an explanation of their effects. The base game group was shown the basic GUI. The activity incentive group was instructed that their powers in the game would scale based on their overall movement levels, which are not limited to gesture execution. Additionally, the activity incentive group was shown the extra GUI features - heart rate numbers and the activity bar. Participants in both groups played a few practice rounds to get familiar with the gestures and the GUI. Next, participants played a total of twelve games. Between each game a short break was given to rest and lower the heart rates. Longer breaks were allowed if necessary. Finally, a post-questionnaire collected data about player’s workout habits, DynoFighter gameplay experience, and any additional comments.

5 RESULTS

5.1 Quantitative Objective Results

We did pairwise sample t-tests to analyze the quantitative data. The mean heart rate ($t_{46} = -0.305, p = 0.762$), maximum heart rate ($t_{46} = 0.605, p = 0.548$), and the average rate of motion ($t_{46} = 1.219, p = 0.229$) were not significantly different between the two groups. The mean heart rate for the activity incentive group was 130 ($\sigma = 18.762$) and 132 ($\sigma = 13.806$) for the base group. The max heart rate for the activity incentive group was 165 ($\sigma = 18.134$) and 161 ($\sigma = 20.867$) for the base group. The mean rate of motion for the activity incentive group was 14.5 ($\sigma = 3.324$) compared to the base group at 13.4 ($\sigma = 2.428$).

We also examined the pair-wise relationship of the rates of motion between each pair of participants and found that the less active player in each pair was on average at an 89.2% ($\sigma = 6.228$) activity level of the opponent for the activity incentive game group and at 90.9% ($\sigma = 6.524$) for the base game group. Actual rates of motion values between pairs varied between 7.8 and 19.9 for both groups combined.

5.2 Quantitative Subjective Results

We analyzed the questionnaire data using Wilcoxon signed rank tests. We found significant differences in game immersion and perceived exertion levels between the activity incentive and the base game groups (see Figure 3). Specifically, we found that activity incentive group participants felt more like they were actually fighting ($Z = -2.149, p < 0.05$), were more immersed in the game ($Z = -2.836, p < 0.05$), were more challenged by the game ($Z = -3.367, p < 0.005$), and had to put a lot of effort into winning ($Z = -2.144, p < 0.05$). Additionally, we found significant differences in a participant’s ability to remember and successfully execute gestures, with base group being more successful ($Z = -2.356, p < 0.05$).

6 DISCUSSION AND FUTURE WORK

Our experiments showed no significant difference in heart rate or rate of motion between the base game and the version with the physical activity incentive mechanism, rejecting H1. Based on the questionnaire data, we saw a significant increase in game immersion and perceived level of exertion, which indicates that the activity incentive mode made the game more appealing to the players. The increase in the perceived level of exertion can be viewed in different ways. Players expecting a certain level of exercise may feel better due to a feeling of greater accomplishment. However, players could also be disappointed that their perceived level of exertion did not accompany the actual exertion levels they obtained. This dichotomy lends itself to a future study to better understand this result. It is also unclear how much this increased perception should be attributed to the enhanced GUI. A future study on the effect of the game interface versus the game mechanics is warranted.

Questionnaire data also showed the decreased ability to recall or execute gestures in the activity incentive version of the game. This was expected due to an increased level of difficulty in the game with more dynamic mechanics and extra visual feedback. We feel that this is an important measure to base the refining of the initial game design and it becomes increasingly more important in games with a higher number of actions/gestures. In our case, since the overall response from the activity incentive group remained positive, we feel that the amount of difficulty added was not to the game's detriment and is possibly linked with changes in game immersion and perceived level of exertion. A study to explore these relationships further and finding the perfect zone of ”gesture confusion” to be used as a game development guideline is needed.

We feel that the lack of significant quantitative objective results was caused by the game's high base activity level, which left little room for players to exert themselves any further. According to the data in [14, 15] our game is at the high end of the exergame exertion spectrum. A future study using a game of a lower base activity level is needed to fully determine the viability of the activity incentive mechanism in increasing the exertion levels. Our current game design could be modified to fit such a study. For example, basic actions could have a reuse timer, lowering the base activity level, and filling up the activity bar could give access to a powerful attack, further increasing the benefits of being more active.

Based on the pair-wise relationship of participants' activity levels we see that, while individual pairs differ greatly from each other, the difference within the pairs was always small. This result suggests a correlation between players' rates of motion in a competitive environment where either a weaker opponent is trying to keep up or a stronger one is not as motivated to exert themselves further. A study on combining players of vastly different rates of motion would be needed to further explore this correlation.

Since opponents in the game can have vastly different fitness levels, a need for game balancing exists that would level the playing field and allow for more meaningful competition [2]. One approach could be to use heart rates to adjust game difficulty [7, 13]. In our case, a weighted sum of the activity level and the heart rate could be used instead of the activity level alone to add a measure of balance to the game. The need for game balancing would be based on the participating players' expectations. A skilled player may want to always win against a weaker player simply because they have put in a lot of time to develop their skills. On the other hand, the same player may like a challenge in an absence of a similarly skilled opponent and properly implemented game balancing would be able to provide this.

The development of DynoFighter and the results of our study have lead to other ideas for including physical incentive in existing game genres. These ideas can be applied to an array of games with relative ease. Rate of motion, range of motion, and complex combinations to supplement basic motions can all be applied to a game to increase exertion while preserving overall gaming atmosphere. How often some action or combination of actions is performed can affect the strength of the result within the game. If breaking a block in a game such as Minecraft requires ten swings of a pickaxe using gestures, simply performing them faster would break the block faster. Similarly, range of motion can be applied to breaking a block by swinging from a higher initial arm position requiring only five big swings versus ten small ones. Finally, complex combinations to supplement basic motion can be applied to the same scenario by allowing the player to take a running start before each swing reducing the number of required actions to even fewer.

7 CONCLUSION

We presented a new exergame, DynoFighter, in which we have explored the possibility of increasing player exertion and enjoyment through a physical activity incentive mechanism that encourages players to maintain high activity levels to support winning. Our experiment showed that players were able to achieve high heart rates in both game conditions, but players in the activity incentive game group showed high level of game immersion and enjoyment, as well as increased perceived level of exertion. This result shows that our technique has potential applicability to incentivize players to engage and enjoy motion-based gaming. We also believe our results have created a springboard for exploring other research questions on physical activity incentives in exergames.

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