Chase or Be Chased. Motivating Physical Output Using Chase Based Game Mechanics.

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***Abstract*— A lack of adaptive resistance control within exergame design means that exercise intensity and output depend on human motivation rather than automated intervention. Chase Or Be Chased explores different game mechanics that enable the computer to dictate the level of task intensity expected from the user during an exercycle game. A study involving 30 participants investigated whether user output can be increased through two mechanics: the first (Be Chased) increased resistance as a disincentive if the user was overtaken by a chasing avatar; the second (Chase) decreased resistance as a reward if the user overtook another avatar. The findings revealed that there was no significant difference between incentivised or unincentivised game mechanics. However, both mechanics increased output relative to a control.**

Keywords*— *(extended reality, dynamic resistance, exergaming, immersion, grand theft auto, physical output, exertion)

I. Introduction

In 2023, more than 1.9bn adults worldwide were estimated to be overweight with studies predicting that one fifth of adults worldwide will be obese by 2025 [17]. Diet and sedentary lifestyle choices are some of the contributory factors; for example, fewer than half of American adults adhere to the recommended 2.5 hours of moderate, aerobic physical activity per week [25]. The application of gamified immersive physical exercise is one way to counteract obesity and its associated health conditions. Research has demonstrated that exergames can motivate enhanced physical output [21] and that “encouraging young adults to switch from inactive to active videogames may provide a substantial population-level public health benefit for obesity prevention” [12].

Embodied interaction coupled with the dissociative attributes of immersion can increase physical output during exergame activity [16]. However, motivating users to complete repetitive and monotonous physical tasks still remains a challenge in exergame design as virtual interactions can feel artificial and less physical than those experienced in real world exercise. Stach & Graham, suggest that haptic feedback is crucial to activate the tactile sensations associated with physical exercise for exergames to emulate the physicality of real-world sports. This has not always been possible due to a lack of affordable hardware. According to Benko et al., advances in haptic feedback have failed to keep pace with audio, visual and interactive technologies, causing “a lack of meaningful haptics from conveying a sense of force during immersive interactivity” [2].

A relatively new and affordable hardware interface that is capable of generating robust kinaesthetic feedback is the home smart trainer. Peloton [20] and Zwift [26] are two training platforms which integrate electromagnetic trainers such as these in their virtual workouts. However, the ways that these commercial exercycle games apply resistance is typically limited to replicating virtual slopes and terrain and therefore much of the exercise intensity of the training session is reliant on human motivation.

This study investigated whether user output can be increased when the requirements of the game dictate task intensity through game mechanics that rely on variable resistance. Two simple game mechanics were developed to explore whether incentivised and disincentivised resistance feedback can be used to encourage enhanced physical output.

A virtual car within a modified version of the video game Grand Theft Auto Five (GTAV) [22] was controlled by cycling a stationary bicycle connected to a Wahoo Kickr Smart Trainer (Figure 01). The speed of the virtual car within the game environment was synchronised with the speed of the smart bike trainer. The game altered the trainer resistance relative to the user’s real-time performance as well as the virtual terrain.

In each condition the user was tasked with moving a virtual car over a distance of 1.5km. In the first condition, ‘Chase’, users raced against an AI car. Resistance was automatically reduced for five seconds every time the user overtook the AI car. In the second condition, ‘Be Chased’, users were chased by an AI car. If the speed of the user’s car dropped below a predefined speed the chasing car rammed the player's car causing resistance to automatically increase for five seconds.

II. Related Works

A. Resistance

Farrow, et al.’s exercycle study [6] measured user output but also integrated resistance to see if intensity could be increased without impacting the user’s level of enjoyment. Their study demonstrated that resistance can be increased by 10% without impacting on the user experience. In their study, intensity was raised by adjusting the ergometers resistance, however, the rate of resistance was not dynamic and had no correlation with the virtual terrain viewed by the user.

Fig. 01. Bike connected to Wahoo Kickr Smart Trainer

Michael & Lutteroth's study 'Race Yourself' [15] combined competition with dynamic resistance and enabled participants to race and compete against 3D representations of their estimated fitness potential. Resistance did feature as a game mechanic, however, player performance had no bearing on the degree to which it was implemented. Dynamic resistance is also featured in Haller et al.'s study 'HIIT the Road' [8]. The exergame involved cycling through a virtual environment in which particular props trigger contrasting results when hit. Colliding with an 'obstacle' caused extra resistance on the physical interface whereas collecting a 'reward' lowered its resistance. There are definite similarities in the way Chase or Be Chased and HIIT the Road feature resistance as rewards and penalties; however Haller et al.'s study examined the impact of virtual spectator applause on user performance and did not measure the impact of resistance on user output.

B. *Immersion & Dissociation*

Exergames seek to increase physical output by distracting participants from real world exertion using goal oriented immersive gameplay. According to Jennet et al. [9], 'immersion involves a lack of awareness of time, a loss of awareness of the real world, involvement and a sense of being in the task environment. Most importantly, immersion is the result of a good gaming experience'. Dissociation from the physical aspects of these games has increased in recent years brought about by improvements to both visual fidelity and human activity recognition. According to Mäyrä & Ermi [14], sensory experiences such as these support the engagement process by leading players to forget about the sensory input from the real world and focus on the sensory input from the virtual world. In addition to visual improvement, the evolution of exergame control hardware has also helped to dissociate users from the physical aspect of the exercise. Physical control that once consisted of basic hand gestures now involves whole body interaction [1] & [11] which according to Nijhar et al. [18] enhances the sense of immersion.

The dissociative benefits of immersion have also been used to reduce sensations of physical pain and fatigue during virtual exercise. Chuang et al. [4] compared the physiological responses between immersive exercycling and regular exercycle activity. Their results demonstrated that VR provides mental support and motivated participants to resist fatigue and maintain endurance.

C. *Incentivized & Disincentivized Exertion*

Conventional video games often employ the metaphor of loss and gain through use of virtual energy levels. Chase or be Chased physicalises this metaphor through the use of incentivised and disincentivised exertion. The two closest studies which used a similar concept and involved physical activity are by Finkelstein et al. [7] and Patel et al. [19]. Finkelstein et al. sought to test if financial incentives for walking could increase physical activity among sedentary older adults. In Patel et al.'s study, overweight adults who achieved daily exercise goals were given a payment of $1.40, while participants who failed to reach the daily target of 7000 steps were fined $1.40. In contrast to the findings of Finkelstein et al., Patel et al. demonstrated that financial incentives framed as a loss were most effective for achieving physical activity goals. Patel et. al.'s study is based on Kahnemans' loss aversion theory which states that people will work harder to avoid losing a small deposit than they will to win an equal amount [10].

D. *Biofeedback Loops*

A common theme in all exergames involves the use of biofeedback loops, whereby a user's physiological output is directly affected by their awareness of their own real-time corporal data. The Chase or Be Chased system design is based on the concept of the biofeedback loop but one that features adaptive game mechanics relative to user performance. Two prior studies have adjusted aspects of real-time game play relative to the user's physiological data. Masuko & Hoshino [13] designed a heart rate controlled 'boxercise' video game where the in-game contents were actively adjusted based on real-time physiological feedback. The motivation behind the game design was to motivate participants to exercise at a predefined optimal level. Stach et al. [24] also adjusted virtual game attributes in a multiplayer exergame with a view to minimising disparity between the competitor's physical strength. The authors of this study ranked avatar attributes in real-time relative to the user's fitness level rather than the user's power. The fact that both games adjusted aspects of game difficulty relative to the user's physiological readings were of interest, however, the system designs of both studies lacked any form of dynamic resistance.

III. Method

A. *Game Design*

A modified version of the videogame GTAV was used whereby the cadence of a stationary bicycle connected to a smart trainer would control the virtual speed of a virtual car (Figure 02). A 1.5km virtual route was mapped out within the game which equated to 1.5km real world units and the same route was used in all of the user study conditions. The virtual terrain was highway asphalt so it would not provide any excess friction for the rider, however increases and decreases to the slope gradient over the route led to changes in the trainer's resistance. A heads-up display on the right of the screen provided the user with real-time feedback relating to wattage output, bike cadence, distance covered, accumulated time and slope gradient.

Fig. 02. The car avatar

1) Being Chased Condition

For this condition, the avatar car was placed at the starting line of the 1.5km route and users were tasked with getting the car to the virtual finish line by means of pedaling the smart trainer. The course features a pink jeep which appears at the starting line and was programmed to 'shadow' the avatar vehicle by following parallel to it on the left hand side (Figure 03).

Fig 03. The AI Pink Jeep

Prior to playing any of the conditions, participants selected a speed threshold from a choice of five speeds during a pretest session. If the avatar's speed dropped below this predefined threshold the chasing car performed a U-turn to alert the participant that it was going to attempt to ram them). During the following five seconds, if the participant increased their output and accelerated to above the chosen speed threshold the chasing car would drive parallel to the player and continue to shadow them. However, if the participant failed to increase output following the U-turn the chasing car would aggressively ram into the back of the player's car (Figure 04). Ramming generated extra resistance on the smart trainer for a period of five seconds. If rammed, a five second grace period was factored in before the chasing car could execute any subsequent ramming maneuverer. This was to prevent a vicious circle occurring.

2) Chasing Condition

Once this game was initiated an AI car was generated and automatically driven at the speed of the user's pre-test threshold along the predefined path between the start and finish line. The player's car was placed parallel to the AI car on the starting line and the user was tasked with pedaling the smart trainer so as to move the avatar vehicle to the finish line at their own pace and were also given the option to race against or overtake the AI car if they wanted to. Each time the user's car overtook the AI vehicle a bonus was given in the form of a five second reduction in wheel resistance.

Fig. 04. Repercussions for pedaling too slow

3) Control Condition

This condition featured the 1.5km route and had no additional A.I. vehicles.

B. Experimental Design

The experiment was conducted with 30 volunteers (six female), average age: 41± 7.7 years, weight: 75±12.5 kg, height: 1.75± 0.09 m and BMI: 24.2±2.5 kg/m2). A confirmation procedure ensured that participants had no underlying health conditions and that they engaged in regular exercise at least once a week. The criteria for defining regular weekly exercise was either running 5km, cycling 15km or swimming 800m once per week.

A within-subjects repeated measures design was used, so each participant participated in all three riding conditions. The sequence of conditions was counterbalanced to mitigate learning effects or fatigue.

After each condition participants had a five-minute rest period during which they could sit down, rehydrate and complete a Borg Scale questionnaire [3] as well as an adjusted Physical Activity Enjoyment (Paces Scale) questionnaire. The Borg scale measured Rate of Perceived Exertion (RPE) and the Paces scale measured data relating to levels of enjoyment, interest, like, absorption, stimulation and fun. Completion times, energy expenditure, perceived exertion and enjoyment were recorded in order to understand the impact the differing game mechanics had on performance.

C. Procedure

In order to calculate the optimum predefined speed for each participant it was important to find a balance between user exertion and user enjoyment. Prior research has demonstrated that enjoyment levels start to decrease once user intensity is around the lactate threshold [5]. A study by Scherr et. al [23] involving 2560 athletes has indicated that RPE can be used to gauge lactate-threshold training effort, equating it to 13 on the Borg scale.

Keeping the exertion level below 13 ensured that the user remained within their lactate threshold and in doing so prevented their enjoyment levels from decreasing.

Participants were asked to cycle for one minute keeping the trainer at a constant speed of 15kph followed by a five-minute rest. These steps were repeated four more times at 20kph, 25kph, 30kph and 35kph. Of the five RPE values provided by each participant, the speed corresponding to the highest value that was greater than 6 but less than 13 was selected as their speed threshold.

On completion of the pretest participants were given a five-minute break to rest and rehydrate before undertaking the three conditions in counterbalanced order with a five-minute rest between each condition.

On completion of the third condition participants had the option of either receiving a bottle of Lucozade sport or else partaking in a choice between the Chase Condition or Being Chased condition. This was a behavioural measure to see if participants found the game more enjoyable than a small reward: its purpose was to measure something more objective than self-reported measures.

D. *Analysis*

Repeated-measures ANOVAs were used to compare the corresponding means, with Average Speed, Average Watts, Maximum Speed, Completion Time and RPE as factors. Significant measures were subjected to post-hoc analyses by means of paired sample, two tailed t-tests using Bonferroni corrected alpha values ($\alpha = .05$). For the optional game, a chi-square test was used. Data relating to levels of enjoyment, interest, liking, absorption, stimulation and fun was gathered by means of an adjusted Paces scale. Likert results were compared with a non-parametric Friedman test and significant results were followed up with a post-hoc analyses using a Wilcoxon signed-rank test with Bonferroni-adjusted alpha level of .017 (0.05/3).

IV. Results

The aim of this study was to test the motivational effects of game mechanics that provided two kinds of resistance-based feedback within an exercycle video game. The authors had hypothesised that avoiding potential disincentivised game mechanics in 'Being Chased' would generate greater physical output than the incentivised based aspect in the 'Chase' condition. However, this hypothesis was false: no significant differences were recorded relating to average watts, duration of ride, RPE or maximum speed between the Being Chased and Chase conditions ($p>0.05$). However, there were significant effects on physical output, RPE and ride duration for both 'Chase' and 'Being Chased' relative to the control condition.

A. *Average Watts*

There was a significant effect of the riding condition on the Average Watts value $F(2, 58) = 8.88$, $p < 0.01$. Post hoc tests using Bonferroni correction revealed significantly higher wattage output ($p<0.05$) while playing Being Chased (M = 200.56, SE = 13.54) and Chase (M = 206.4, SE = 13.82) relative to the wattage output while playing the Control condition (M = 171.77, SE = 14.6). There was no significant difference between the Being Chased and Chase conditions ($p>.05$).

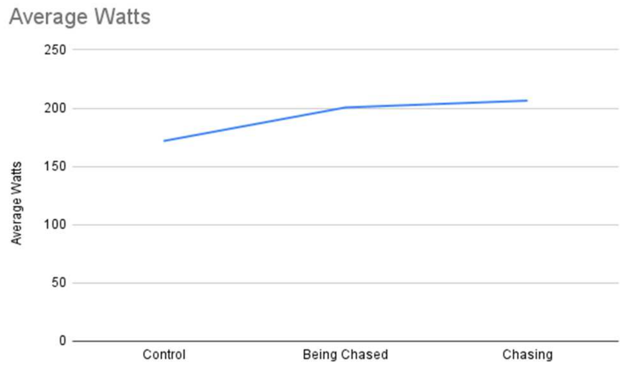

Fig 05. Average Watts

B. *Duration of Ride*

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 0.9499$ $p = 0.4867$, therefore Greenhouse-Geisser corrected tests are reported ($\varepsilon = 0.95$). The results show that there was a significant effect of the riding condition on the trial Duration, $F(2, 58) = 3.76$, $p < 0.05$. Post hoc tests using Bonferroni correction revealed significantly lower completion times ($p<0.05$) while playing Being Chased (M = 153.47, SE = 5.86) and Chase (M = 152.9 SE = 5.3) relative to the Control condition (M = 164.7, SE = 5.74). No significant difference was found between the Being Chased and Chase conditions ($p>.05$).

C. *Rate of Perceived Exertion*

The results show that there was a significant effect of the riding condition on RPE, $F(2, 58) = 10.5$, $p < 0.05$. Post hoc tests using Bonferroni correction revealed significant differences between RPE while playing Being Chased (M = 14.06 SE =0.3) and Chase (M = 14.13 SE = 0.3) relative to the Control condition (M = 12.6, SE = 0.4), but no significant difference was found between the Being Chased and Chase conditions ($p>.05$).

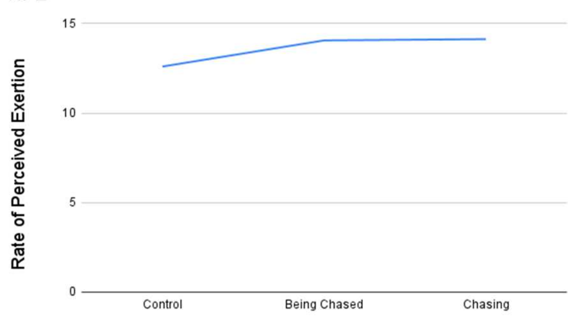

Fig. 06. Rate of Perceived Exertion

Relative to the control condition, participation in the 'Chase' and 'Being Chased' conditions had a significant effect on enjoyment, fun, stimulation and how absorbed users felt. This data had been gathered using the Paces scale.

D. Enjoy/Hate

Post-hoc tests using a Wilcoxon signed-rank test with Bonferroni-adjusted alpha level of .017 (0.05/3) showed that participants enjoyed playing Being Chased (Mdn = 1) more than they did playing Control (Mdn = 3), T= 246.5, Z = -3.3 p<.01 and that participants enjoyed playing Chase (Mdn = 1) more than they did playing Control (Mdn = 3), T= 356, Z = -4.01 p<.00001. However, comparable data between Being Chased and Chase was not significant (p > .017).

E. Fun

Post-hoc tests using a Wilcoxon signed-rank test with Bonferroni-adjusted alpha level of .017 (0.05/3) showed that participants found playing Being Chased more fun (Mdn = 7) than playing the Control condition (Mdn = 5), T= 10, Z = -4.3949 p< .00001 and that participants found playing Chase (Mdn = 6) to be more fun than playing the Control condition (Mdn = 5), T= 27, Z = -4.0078. p<.00001. However, no differences were found in the levels of fun reported between the Being Chased and Chase conditions (p > .017).

F. Stimulating

Post-hoc tests using a Wilcoxon signed-rank test with Bonferroni-adjusted alpha level of .017 (0.05/3) showed that participants found playing Being Chased more stimulating (Mdn = 6) than playing the Control condition (Mdn = 4.5), T= 0, Z = -4.703 p < .00001, Chase more stimulating (Mdn = 5) than playing the Control condition (Mdn = 4.5), T= 8, Z = -3.9539 p < .01, and Being Chased (Mdn = 6) more stimulating than Chase (Mdn = 5), T= 296.5, Z = -3.6055 p<.01.

G. Absorbing

Post-hoc tests using a Wilcoxon signed-rank test with Bonferroni-adjusted alpha level of .017 (0.05/3) showed that participants found playing Being Chased more absorbing (Mdn = 2) than playing the Control condition (Mdn = 3), T= 244, Z = -3.8147 p< .01 and that participants found Chase more absorbing (Mdn = 2) than playing the Control condition (Mdn = 3), T= 120, Z = -3.4078 p<.01. However, no differences were found in how absorbed participants reported between the Being Chased and Chase conditions (p > .017).

H. Optional Game

A Chi-Square test was carried out to test whether participants were more likely to play an extra game featuring one of the Chase conditions (N=21) or if they would choose to receive a sports drink (N = 9) after completing the study. The results were significant, (p < 0.05). Participants were more likely to play an additional game than to receive the small reward of the sports drink. Of those who chose playing an optional game, the majority chose to play the Chase condition however there was insignificant data to verify its popularity over Being Chased. No significant difference was found, $^2(2)=1.19$, $p > 0.05$.

V. Future Work

The authors hypothesised that avoiding potential punishment in 'Being Chased' would generate greater physical output and enjoyment than the reward based aspect of overtaking in the 'Chase' condition. his theory had been based on Kahneman's theory which states that people will work harder to avoid a financial loss than they will to gain an equivalent financial reward. Wattage and completion times compared between the chase based conditions were not significantly different and therefore this hypothesis could not be verified as data differences were too low. Continuing with a subsequent study involving higher numbers of participants would more than likely yield an effect size offering limited practical value. However, the advantages of applying Kahneman's theory as a game mechanic to enhance exertion remain unanswered and could yield interesting results using an alternative game design.

A future study could yield interesting results by combining both Chase conditions and investigating how altering between both Chase states can impact on maintaining engagement during long term exergame activity. The physical activity would not necessarily be limited to cycling and could, in theory, be transferred to interfaces such as rowing machines and cross trainers. Collaborating with virtual fitness communities would enable a longitudinal study to be conducted remotely. This would provide a chance to experiment with more sophisticated game mechanics with a view to encouraging long term engagement.

VI. Conclusion

The purpose of Chase or Be Chased, was to determine whether incentivised or disincentivised game mechanics generated greater physical exertion. There was no relevant data to differentiate between the benefits of variable resistance framed as a penalty or as a reward as a game mechanic. However, the study demonstrated that chase based game mechanics can be used to motivate enhanced physical output through the medium of an exergame without diminishing the enjoyment aspects of gamified physical activity.

The ability to fully automate predefined levels of physical exercise could open up many possibilities for physical training, skill acquisition and rehabilitation. Understanding to what extent human motivation can be replaced by automated exertion would require a longitudinal study with a more complex system design and is worth considering for future work. Automating intervention in this manner has the potential to improve the quality and efficiency of home based training, assist cycling enthusiasts reach stamina targets and reduce costs associated with third party instructors such as spinning classes and personal trainers. In addition to its application in the commercial health and wellness sector, results from this study will provide the HCI community with unique research findings relating to the areas of exertion, dissociation, motivation, enjoyment, immersion and loss aversion.

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