Pushing Without Breaking: Nudging Exergame Players While Maintaining Immersion

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Abstract**—**In exergames, players sometimes over-exert themselves, risking adverse health effects. Informing such players to slow down is necessary, but might distract from gameplay and damage the drive to continue exercising. We used the concept of nudges to create a set of design principles that can be incorporated into a game, to influence player behaviour without breaking their immersion. We created a game that uses these principles, testing them against no feedback at all, and against a precise text-based interface. We found that nudging techniques worked as well as textual feedback to keep players from over-exerting. We saw no significant difference in immersion between nudge and textual feedback, but players considered the nudge feedback to be more natural.

Keywords**—***exergame, exertion interface, game design, HCI, nudges, persuasive interfaces, serious games, video game therapy*

I. Introduction

This paper presents a design framework for influencing, or "nudging," player behaviour in exercise-based video games (exergames), particularly in controlling level of exertion. The essential premise behind exergames is that fun activities such as playing games are more attractive than important but "chore-like" activities such as physical exercise. Ideally, the desire to continue experiencing a game can motivate a player to participate in the associated exercise regimen.

Both the game and the exercise aspects of the exergame must support each other effectively, or the combination will not function as intended, and players will become either bored or discouraged. An important element in exergames is to inspire and support effort by the player. Players who are not working hard enough may be unable to achieve the desired fitness goal. Another problem, addressed in this paper, is that an exergame may motivate the player to over-exert, failing to meet its goal of providing a well-balanced exercise session. Such over-exertion might occur if the player is particularly stimulated by a difficult or fast-paced segment of gameplay, or working too hard in the warm-up or cool-down phase.

The problem of over-exertion is easy to solve in theory, simply by providing a message in the game interface telling the player to reduce effort. The risk is that reminding the player so explicitly that they are playing to exercise may reduce the value of embedding exercise in play. For the purposes of this paper, this feeling of being engaged in the gameplay will be called "immersion." The challenge is how to prevent players from exceeding target levels of exertion without disrupting this sense of immersion. We theorize that this can be accomplished with "nudges," interface cues that gently push players in the direction of the desired choice, without their being explicitly instructed [1]. If players feel that reducing exertion is their own idea, based on cues embedded in the gameplay, immersion should be maintained.

In this paper, we present a design framework for nudging video game players. We propose that incorporating these design principles into a system of player feedback in an exergame (or other video game) will allow players to correct their behaviour with little to no detrimental effect on immersion or enjoyment.

We tested these design principles by developing an exergame called *PlaneGame*, which employs this framework to nudge players toward lower levels of exertion. The design principles underlying *PlaneGame* are explained in Section III. We evaluated the effectiveness of nudges in *PlaneGame* through a study. Participants played the game under three conditions: with nudge feedback, without feedback, and with a textual display of their exact performance (i.e., cycling speed). We found less over-exertion in both the nudge and textual conditions, with minor differences between the nudge and textual feedback conditions.

II. Background and Related Work

A. Risks of Over-Exertion

The need to moderate exertion during exercise is well established. In its *Complete Guide to Fitness & Health*, the American College of Sports Medicine (ACSM) emphasizes the importance of conducting a warm-up before exercising [2]. Even after warming up, overly vigorous exercise puts the exerciser at risk of coronary events [3].

B. Effectiveness of Exergames

While the health benefits of exergames vary from game to game, it is evident that some exergames are capable of promoting metabolically-relevant exercise. Rhodes *et al*. [4] found that adherence and affective attitude in cycling were greater when playing video games than when listening to music. Leininger *et al.* [5] compared playing *Dance Dance Revolution* (DDR) to exercising on a treadmill, and found that DDR resulted in as much oxygen consumption as walking on a treadmill, but added a greater level of enjoyment.

However, while exergames can trigger increased exertion, players often do not reach desired exercise levels. The ACSM recommends a minimum of 30 minutes of moderate intensity exercise 5 times per week, or 20 minutes of vigorous exercise 3 times per week [6,7]. Peng *et al.* [8] and Biddiss and Irwin [9] performed meta-analyses of 16 and 18 studies respectively on energy expenditure in exergames, and found that the games sometimes failed to meet these recommendations. It is clear that exergames need to better control player exertion levels in general, though in this paper, we emphasize controlling over-exertion rather than stimulating sufficient exertion.

C. Immersion in Games

Numerous theories of game design have identified immersion, the feeling of being engaged in gameplay, as a critical component in the enjoyment of a game. In the *GameFlow* model [10], an adaptation of the concept of flow specifically for games, immersion is listed as one of the eight essential elements of GameFlow. In "Time flies when you're having fun", Agarwal and Karahanna [11] list Focused Immersion as one of the five dimensions of cognitive absorption. In the development of their *Presence Questionnaire* and *Immersive Tendencies Questionnaire*, Witmer and Singer [12] conclude that immersion is a necessary component of presence, which is linked to the success of virtual environments, including video games.

Engagement is critical to the concept of an exergame, as it relies on player interest in the gameplay to maintain adherence to an exercise program. The above researchers show that immersion is an important part of producing engagement.

D. Nudges

The term "nudge" as used in this paper, meaning an indirect suggestion toward a desired outcome, was coined by Thaler and Sunstein [1]. As an example of the concept, the authors cite a tactic used by an airport in Amsterdam to improve the cleanliness of their bathrooms. In order to improve men's aim when urinating, an image of a fly was added to the interior of the airport urinals, giving something to aim at. This nudge successfully reduced urine spills by 80%. Other examples of successful nudges include encouraging grocery shoppers to purchase organic and local foods by adding a barcode scanner and light-up LEDs to shopping carts [13], and encouraging a reduction in electricity consumption by delivering pamphlets to households comparing their energy consumption to that of their neighbours [14].

The use of nudging techniques has also been applied in HCI contexts, whether explicitly named or not. Coventry *et al.* [15] describe a system for employing nudges in a cyber-security context to encourage computer users to practice safer behaviours, such as choosing more secure passwords. The authors note that several nudging tools are used in HCI for ease of use design. In "Emerging Patterns in Active-Play Video Games" [16], the authors relate nudges to the field of persuasive interface design.

E. Immersive Nudges in Active Contexts

The role of immersive nudging in controlling exertion has been explored in existing exergame research. In *'Ere be Dragons* [17], players are told how their heart rate compares to their optimal rate through five bands of feedback, from low to high. When a player over-exerts, the environment becomes a dense forest accompanied by high-speed audio, while low exertion leads to a desert with quiet, slow sounds. In *Balloon Burst* [18], players are tasked with shooting down balloons; they can increase the rate at which these appear by pedaling. If players exceed the maximum cadence, however, they are cued by haptic feedback in the game's controller.

Beyond exergames, Waterhouse *et al*. [19] find that speeding up or slowing down the tempo of music has a corresponding effect on power expenditure and cadence in listening cyclists. Mandryk *et al.* [20] use a system of overlays to turn commercial games into biofeedback games. The overlays are triggered by negative changes in EEG readings, and partially but progressively block vision of the game to encourage players to calm down. The graphical effects of the overlays are chosen to match or complement the game (for example, mud splatters on the screen in a dirt-biking game).

Given the importance of immersion, the indirect nature of nudges may make them a suitable tool for affecting player behaviour without reducing engagement. There has been some limited investigation of the applications of nudges to HCI, but to the authors' knowledge no-one has yet investigated the possibility of using nudge principles to reduce over-exertion in exergames while maintaining immersion.

III. DESIGN PRINCIPLES

In order for a user interface in a game to operate by nudging, participants must feel motivated by the nudges to correct their behaviour. A nudging interface should guide players to a behaviour that is required of them, and persuade them to perform it, while fitting into the game world as smoothly and believably as possible.

We propose four design principles for building feedback into digital games in order to nudge players to a desired behaviour. We theorize that employing these four principles will push players to avoid behaviours considered undesirable in the game design, with low impact on immersion in the game world. We illustrate these design principles through their use in our game *PlaneGame*, described below.

A. Principle of Immersion

<u>Nudges should fit the game world</u>: To avoid disrupting immersion, nudges should feel as though they are a natural part of the game environment. A game element that corresponds to an actual objective or concept within the game world will be more immersive than something with no connection to the game's reality that has been added only to push the player.

For example, if players are not meant to go in a certain direction, an invisible wall with no explanation clearly exists –

and will be experienced by the player – only as an element of software design. A bricked-over archway with a "Keep Out" sign, however, will be more believable as part of the game world, and will not break the player's sense of being in a real environment. The latter approach can be considered a nudge because, while in either case the player cannot get through, in the brick scenario the player is unlikely even to try, because the visuals indicate that it is not an option.

B. *Principle of Comprehension*

Nudges should be clear and conspicuous: Players must comprehend the stimulus that is intended to nudge them. This necessitates two things. First, the player must clearly understand what the feedback is telling them. This might be because the feedback is obviously linked to its effect: if a player crashes into a wall, and a piece of their vehicle falls off, they know that hitting walls is bad for the vehicle. Player comprehension may also be aided through feedback familiar from other games. For example, if players are being attacked from a certain direction, that side of the screen flashes red in many games. Players familiar with these other games may find this feedback to be immediately clear to them, despite not being a literal depiction of the character's experience.

The feedback must also be conspicuous enough that players notice and can react to it once it appears. For example, suppose we want players to avoid driving through mud in a driving game. We may try to discourage going through mud by making the mud slow down the player's car. But if the car slows too gradually, players might not realize that the mud is the cause. So instead we might have the car lose speed very noticeably the moment it enters the mud, making the effect more conspicuous.

C. *Principle of Progression*

Nudges should progress from low to high severity: To increase pressure on players who (intentionally or not) ignore nudges, greater deviation from the desired behaviour should be met with increased severity of feedback. How exactly "greater deviation" is measured will depend on the needs of the game. For example, if a player's avatar walks out into a snowstorm, we may want them to go back inside, and so we make the feedback become more punitive the further they go from the door. Alternatively, if avatars need to walk through the storm, but are meant to do so as quickly as possible, the feedback should become increasingly severe the longer they spend in the snow.

How feedback becomes more severe will also vary from game to game; possibilities include intensifying an existing form of feedback or switching to a gameplay channel with more effect on the player. To return to the snowstorm example, players who stray too far or spend too long in the storm could experience progressive obstruction of vision. If this cue does not incite them to seek shelter (based on distance) or realize they are taking too long (based on time), the player's avatar might begin accumulating damage from frostbite and hypothermia.

D. *Principle of Multiples*

Nudges should employ multiple feedback channels: Principles should support each other using multiple forms of feedback. Possible feedback channels include visual, auditory, haptic, or direct gameplay effects. There are several reasons multiple channels might be helpful.

First, different types of nudges can provide redundancy to reinforce the need to change behaviour. A player who missed a visual cue because they were watching another part of the screen might still be alerted by audio, while a player listening to music may miss an audio cue, but still react to a visual or haptic one.

Second, forms of feedback that are particularly good at specific tasks will work together to produce a stronger whole. Gameplay effects like losing control of the game character are strong motivators, but without context, it might be difficult to understand why the loss of control is happening, and other feedback can fill this gap. For example, perhaps a player's robot comes too close to a strong electric field, and a humming sound and bolts of electricity can explain why character control is being lost.

Third, additional modes of feedback can, through an additive effect, help satisfy other principles. Having three things happen at once is more conspicuous than only one event.

IV. Game Design

To illustrate these principles, we developed *PlaneGame* (Fig. 1), a single-player racing game. The racing game genre was selected with the idea that competing against other racers would drive players to greater levels of exertion in an attempt to outpace the rival AI racers. The increased exertion would trigger more feedback, providing more data on how players responded to the feedback.

In *PlaneGame*, the player plays as an airplane and races against computer-controlled birds to collect floating rainbows.

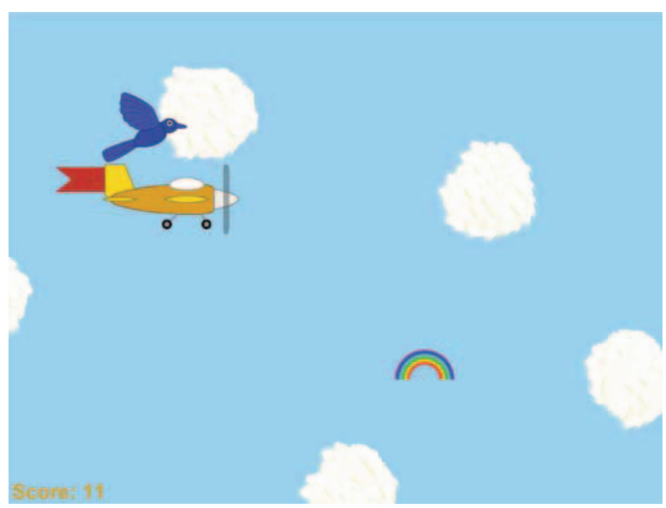
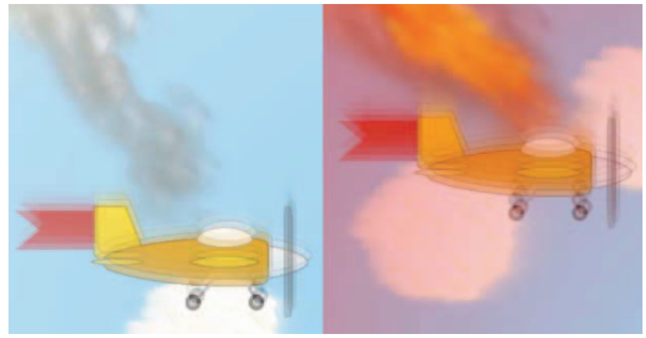


Fig. 1 Screenshot of *PlaneGame*. The player's plane avatar and an AI bird are both racing to capture the rainbow for points.

Fig. 2 Study setup. The player sits at the exercise bike, and holds the game controller. The game appears on the television screen.



(a) **(b)**

Fig. 3 a) early feedback, smoke and slight screen greying
b) advanced feedback, fire and screen reddening

The player uses a recumbent bicycle to power their avatar. Each time a rainbow appears on screen, a bird drops down from the top of the screen and races alongside the player. When either the player or the bird collects the rainbow, a new rainbow is spawned ahead. These mini-races provide a sequence of short competitions, ensuring the player cannot fall so far behind as to be unable to catch up, or advance so far ahead as to have no incentive to pedal hard. In this way, each mini-race both allows for and requires a new effort.

There are two sources of input for the player. Altitude is controlled using a standard video game controller, with a single button causing the plane to rise while pressed and drop when released. In order for the game to function as an exergame, the speed of the plane corresponds to the player's cycling pace on a recumbent exercise bike (Fig. 2). The rate at which the player pedals (called cycling cadence or just cadence) is read using a Garmin Speed and Cadence Sensor, a magnet-based sensor attached to the bicycle's crankshaft. This sensor reports each time it passes one of three evenly-spaced magnets on the body of the bike, allowing the software to compute the cadence in revolutions per minute (RPM).

The player's cadence influences gameplay by how close it is to a target cadence. If the player's current cadence is at least as high as the target cadence, then the plane will move at its top speed; lower cadences will slow the player's plane.

Since maintaining an exact speed is difficult, we establish a range of ±6RPM around the target cadence, called the target range. If players are below the target cadence, but still within the target range, the plane will still be faster than the birds. Likewise, players are not considered to be cycling too quickly unless they are exceeding the top of the target range.

A. *Design Principle Implementation*

To test the immersive design principles with *PlaneGame*, it was necessary to add a layer of feedback to the base game, to inform players when their cadence goes above the target range.

First, under the Principle of Immersion, the feedback needed to fit with the game world. The base concept has the plane's engine overheat if the player pedals too rapidly. Natural consequences of an overheated engine include smoking from the engine compartment (Fig. 3a).

Under the Principle of Multiples, this concept was expanded. In addition to visual smoke and fire, the feedback layer includes additional visual modification: the plane shudders back and forth and there is whole-screen motion blur. Audio feedback is also incorporated in the form of the engine becoming louder, rougher, and more grating.

Under the Principle of Comprehension, the screen also turns grey around the edges: this suggests being out of breath, and is also commonly used in games to indicate acute health threats. This ties the feedback to physical over-exertion in order to increase clarity. Conspicuity was judged to have already been satisfied by the multiple feedback channels as, combined, they are difficult to ignore.

Under the Principle of Progression, all the forms of feedback increase as the player's deviation increases (more smoke, more shaking and blurring, louder engine, and greyer screen). Also, after a certain point, the engine produces fire as well as smoke, and the edges of the screen begin turning red rather than grey (Fig. 3b).

To link increased deviation from the target range to increased response severity, a metric of deviation from the target is needed. For *PlaneGame*, this value (henceforth referred to as "Disparity") is a combination of distance above the target range (in RPM) and how long the player has been above the target range (in seconds): disparity = distance/10 + time/5, a formula whose constants were derived through iterative refinement in pilot testing.

Finally, with all the feedback in place, the game was again checked against the Principle of Immersion. Pilot testers reported that this feedback gave a strong impression of the plane malfunctioning, suggesting that it was well integrated into the game environment.

V. Study Design

The study was designed to test the implementation of the immersive game design principles along two axes: effectiveness in preventing players from exceeding a target level of exertion (using cycling cadence as a proxy), and immersiveness. To test these factors, the version of the game that employs the design principles ("nudge") was tested against two other conditions: a control condition with no feedback to prevent over-exertion ("control"), and a condition that

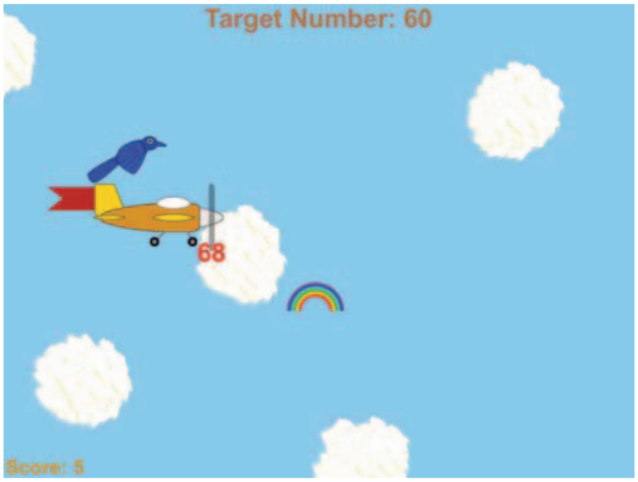


Fig. 4 Screenshot of the textual condition. The target cadence is at the top of the screen, with current cadence beneath the plane.

provided numeric feedback specifying the player's distance from target cadence ("textual").

In addition to the three conditions, participants played at two different target speeds. One was faster, to stand for the standard pace used in an exercise session. The other was slower, to simulate an exercise warm-up.

The textual condition was expected to be more effective at controlling exertion than the nudge condition, but less immersive for the player, and the control condition was expected to be ineffective at cadence control, but the most immersive due to freedom from any distraction.

A. *Conditions*

- Control: In the control condition, the only indicator of current distance from the target cadence is the speed of the plane relative to that of the birds. Once the plane reaches full speed at the target cadence, there is no direct feedback indicating whether the current cadence is correct or too high. A sufficiently motivated player might find the correct cadence by pedaling only as quickly as is necessary to reach top speed, but the game offers no aid.
- Nudge: In the nudge condition, the design principles are employed to inform players when they are above the target, as previously described. As in the control condition, there is no indication of being below target, other than the slow pace of the plane, or how close the current cadence is to exceeding the top of the target range.
- Textual (Fig. 4): In the Textual condition, players are shown the target cadence at the top of the screen for reference, while their current cadence is displayed immediately underneath the plane. Whenever the player's cadence is above the target range, the current cadence text turns red. Like the nudge condition, the textual condition lets the player know they are above their target range. In fact, it provides more information, as the textual condition allows players to know exactly where they are relative to the target cadence.

To test player response during both warm-up and main-game speeds, two different cadence targets were chosen: 40RPM (warm-up) and 60RPM (main-game). Pilot testing showed 40RPM to be slow enough that it was slightly difficult to maintain, while 60RPM was a more comfortable speed that was easy to reach. Both cadence targets were low enough that pilot-test players had little difficulty exceeding them.

B. *Method*

Each participant played the game under six conditions, three game conditions for each of the two cadence targets. These conditions were order-balanced according to Latin square to compensate for the effects of increasing skill at the game as participants progressed.

Before beginning the game, players were given an explanation of how to play. Participants familiarized themselves with the gameplay by playing a version of the game with no target cadence in which the plane always moved at top speed, and no cadence feedback was provided.

After this test round, participants were informed that they needed to reach the target cadence for the plane to reach full speed. They were cautioned against exceeding the target cadence, and the three conditions were introduced verbally and through printed screenshots. Players were also informed of the two speeds used in the game. Players were not forewarned which version of the game they would be playing, but had a three-second adaptation period before the game began, allowing them to note both the condition and target speed and to adapt accordingly.

C. *Data Collection*

Three forms of data were collected. First, the game logged target cadence, current score, time and distance away from the target range, and current Disparity value (see Section IV).

Second, after each segment of gameplay, participants filled out a 13-question questionnaire. The first two questions asked if it was easy to return to the target cadence when speed was too high, and how motivated players were to do so. The remaining questions were the Involvement/Control subscale of Witmer and Singer's Presence Questionnaire [12], which was used to measure participants' sense of immersion by proxy through the related concept of presence.

Finally, participants engaged in a semi-structured interview exploring their subjective impressions and rankings of the three versions of the game.

D. *Participants*

A total of 24 university students were recruited as participants. Participants were screened to include only those who had at least 50 hours of lifetime experience with video games, and who did not use a stationary exercise bike or go long distance biking regularly (defined as more than once per week).

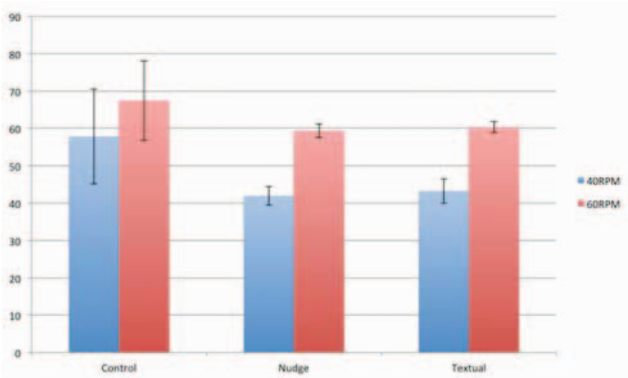


Fig. 5 Average cadence (RPM). Control values are significantly higher than Nudge and Textual values. Error bars range maximum to minimum individual participant values.

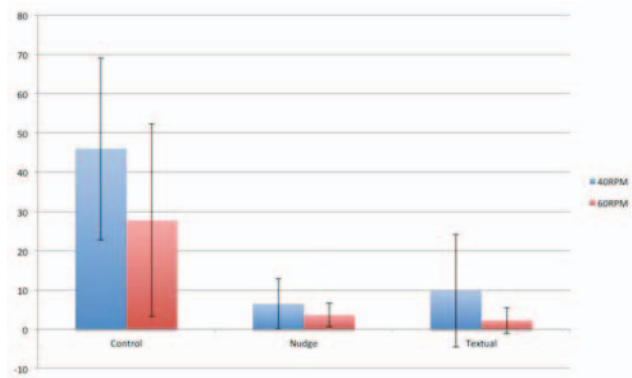


Fig. 6 Total time above target range (s). Control values are significantly higher than Nudge and Textual values. Error bars range maximum to minimum individual participant values.

VI. Results

A. Game Logs

Three measures from the game logs were compared across the three game conditions (control, nudge, and textual). These measures were: the player's average cycling cadence during gameplay, total seconds that cadence was above the top of the target range, and final game score. Each of the two speeds (40RPM and 60RPM) was compared separately.

A one-way repeated measures ANOVA was conducted to compare the effects of the game conditions on players' average cycling cadence (Fig. 5). At a target cadence of 40RPM, a significant effect was found; Wilks' Lambda=.310, $F(2,22)=24.16$, $p<.001$. Post hoc comparisions via paired samples t-tests with Bonferroni correction showed the control condition (M=57.84, SD=12.67) produced a significantly higher average cadence than the nudge condition (M=41.94, SD=2.55); t(23)=6.53, p<.001. The control condition also had a greater average cadence than the textual condition (M=43.24, SD=3.22); t(23)=5.64, p<.001. No significant difference was found between the nudge condition and the textual condition at the $\alpha=.05/3$ level; t(23)=2.11, p=.046.

At a target cadence of 60RPM, game condition again showed significance for average cadence; Wilks' Lambda=.522, F(2,22)=10.06, p=.001. Post hoc t-tests showed higher average cadence in control (M=67.47, SD=10.65) than nudge (M=59.37, SD=1.84); t(23)=3.99, p=.001. Average cadence was also higher in the control condition than the textual condition (M=60.33, SD=1.45); t(23)=3.40, p=.002. Again, no significant difference was found between nudge and textual at the Bonferroni-corrected $\alpha=.05/3$ level; t(23)=2.09, p=.048.

At 40RPM, an RM-ANOVA on time over target range (Fig. 6) showed significance; Wilks' Lambda=.214, F(2,22)=40.48, p<.001. Post hoc t-tests showed significantly more time over target in the control condition (M=45.95, SD=23.13) than in the nudge condition (M=6.50, SD=6.37); t(23)=8.36, p<.001. Participants also spent more time above the target range in control than in textual (M=9.86, SD=14.40); t(23)=6.41, p<.001. No difference was found between the nudge and textual conditions; t(23)=1.60, p=.123.

Time over target range also showed significance for 60RPM; Wilks' Lambda=.214, F(2,22)=40.48, p<.001. Time over target was significantly higher in the control condition (M=27.79, SD=24.52) than in the nudge condition (M=3.65, SD=3.00); t(23)=5.06, p<.001. Control was also higher than textual (M=2.29, SD=3.30); t(23)=5.30, p<.001. There was no significant difference between nudge and textual; t(23)=1.49, p=.150.

Game score showed significant differences across conditions at a target cadence of 40RPM; Wilks' Lambda=.684, F(2,22)=5.08, p=.015. Scores in the control condition (M=24.13, SD=1.15) and textual condition (M=24.13, SD=1.42) were indistinguishable; t(23)=0.00, p=1.000. However, t-tests showed significantly lower scores in the nudge condition (M=22.79, SD=2.13) than the control condition; t(23)=3.00, p=.006. Scores were also lower in nudge than in textual; t(23)=2.82, p=.010. The RM-ANOVA for a target cadence of 60RPM found no significance at the $\alpha=.05$ level; Wilks' Lambda=0.797, F (2,22)=2.80, p=.082.

B. Questionnaires

The questionnaire provided to players after each round of the game has two single questions, plus the Involvement/Control subscale of Witmer and Singer's Presence Questionnaire [12]. Each of the questions was on a 7-point Likert scale, and therefore the answers are ordinal data and must be analyzed by non-parametric measures. As before, the three game conditions were compared, and the two target cadences were analyzed separately.

A Friedman test of the first question ("Is it easy to return to your target speed when you're pedaling too quickly?") was not statistically significant for a target cadence of 40RPM; $\chi^2=2.96$, p=.232. The question also lacked significance at 60RPM; $\chi^2=0.36$, p=.860.

The second question ("Do you feel motivated to slow down when you're pedaling too quickly?") showed significance on a Friedman test at 40RPM; $\chi^2=19.46$, p<.001. Post hoc tests with the Wilcoxon signed-rank test showed that players felt less motivated to slow down in the control condition (Mdn=5.5, r=1-7) than in the nudge condition (Mdn=7, r=2-7); Z=-3.45, p=.001. They were also less motivated in the control condition than in the textual condition (Mdn=6.5, r=1-7); Z=-2.95, p=.003. There was no significant difference between the nudge and textual conditions; Z=-1.36, p=.175.

For a target cadence of 60RPM, the motivation question again showed statistical significance; χ^2=21.00, p<.001. Players were less motivated in the control condition (Mdn=4.5, r=1-7) than in the nudge condition (Mdn=7, r=4-7); Z=-3.69, p<.001. Players also felt less motivated to slow down in control than in textual (Mdn=6, r=2-7); Z=-2.79, p=.005. No significant difference was found between nudge and textual; Z=-1.83, p=.067.

For the presence score, the Friedman test showed no significance on a target cadence of 40RPM; χ^2=4.69, p=.097. However, there was a significant difference at 60RPM; χ^2=7.57, p=.022. Wilcoxon signed-rank tests showed no significant difference between the control (Mdn=68, r=51-75) and nudge (Mdn=69.5, r=50-76) conditions; Z=-0.56, p=.594. There was no significant difference between control and textual (Mdn=68, r=51-73); Z=-1.20, p=.237. No significance was found between the nudge and textual condition; Z=-1.31, p=.196.

In an effort to understand the incongruity between the Friedman and Wilcoxon tests, we also conducted sign tests for presence at 60RPM. The sign tests revealed no significant difference between the control and nudge conditions, p=.824; and no significant difference between control and textual, p=.052. There was an apparent difference between the nudge and textual conditions, p=.035; however there was no significant difference at the Bonferroni-corrected α=.05/3 level.

C. *Interviews*

During the concluding semi-structured interview, participants were asked questions about the different study conditions they experienced. These conditions were referred to descriptively rather than by name (for example, the nudge condition was "the version with the smoke") to avoid influencing the participants' answers.

Asked whether the nudge condition distracted them from the gameplay, eight participants said "no", ten said "a little", and six said "yes". The textual condition was described as not distracting for 11, a little distracting for six, and distracting for seven.

All participants found the feedback in both the nudge condition and textual condition to be clearly understandable.

Asked which condition they felt was "a more natural fit for the game", 15 participants chose the nudge condition, five chose textual, three chose control, and one thought all were equally natural.

Players were asked to choose their favourite of the three game conditions; ten participants preferred the nudge condition, eight preferred textual, and six preferred control. Of those participants who chose the nudge condition as their favourite, five found it more fun or interesting, four liked the binary nature of the nudges (either present or not), and one found it easier to stay within the target range. The participants whose favourite condition was textual preferred it because it was easier to stay within the target range. Of those who preferred the control condition, three did so because of the lack of distraction, one because they felt there was no need to slow down, one for both the preceding reasons, and one because it was more challenging to stay within the target range.

Players were also asked to choose a least favourite condition. The control and textual conditions were each chosen by eight, six chose the nudge condition, and two had no preference beyond their single favourite (textual in both cases). Of the participants who disliked the control condition, four did so because of the lack of feedback to help them stay within the target range and four because it made the game simpler and less interesting. For the textual condition, four participants disliked it because they found it fit poorly with the gameplay, three because they felt compelled to match the target cadence exactly and it was very difficult, and one because it was similar to the nudge condition, but less intimidating. Of those who disliked the nudge condition, four did so because they found it stressful or uncomfortable, and two because it was the most distracting.

The slower target cadence (40RPM) was seen as too slow to be a comfortable cycling cadence by 11 participants, the faster target cadence (60RPM) was reported as uncomfortable by two, and the other 11 found both to be comfortable.

VII. Discussion

As expected, players did a much better job cycling within the target range in both the nudge and textual conditions than in the control condition. However, we saw no significant difference between nudge and textual in terms of keeping within the target range. The only performance difference we saw between the two was in game score, where players had lower scores in the nudge condition, but only for the lower target cadence of 40RPM.

It is slightly curious that nudge-condition scores were lower than either control or textual scores. But since the number of rainbows collected does not depend on not exceeding the target range, it is possible that players were over-correcting in response to the nudges, and therefore oscillated around the target cadence. This would result in sometimes pedaling slowly enough that fewer rainbows had time to spawn or enemy birds were able to take some. Oscillating like this is easier to avoid in the textual condition, since the player knows exactly how close they are to the target.

The data for immersion are mixed. We expected to find that immersion was highest in the control condition and lowest in the textual condition, with the nudge condition in the middle. Our primary measure of immersion, the Presence Questionnaire [16], showed no significance between the conditions, suggesting there is no difference. Players found the control condition less motivating than the other two, but most also found the nudge and textual conditions at least a little distracting.

However, in the interviews, participants said they found the nudge condition to be the most natural fit for the game. When asked to choose favourite and least favourite conditions, their reasons supported this result. Four participants explicitly disliked the textual condition because it was a poorer fit for the game play. Conversely, many players who liked or disliked the nudge condition did so for game-related emotional reasons: they found the nudge either fun and interesting if they liked it, or stressful and uncomfortable if they disliked it.

One possible reason that players do not feel more immersed, despite stating the nudge condition suits the game best, is that we set the target cadence values deliberately low. This was to try to avoid exhausting players and thereby affecting their responses. We also wanted to increase the likelihood that players would experience feedback, thus giving them more opportunity to correct their performance and yield more data points. However, the need to avoid pedaling too quickly came up much more often at these lower cadences, and was always on players' minds. It is possible that if the target were set higher, as it would be to control over-exertion in actual exercise conditions, players would have fewer encounters with the feedback, and would be less distracted by it.

One peculiarity is that the Friedman test for presence at 60RPM shows significance ($p=.022$), but the paired tests do not. However, the sign test between the nudge and textual conditions did show significance before the Bonferroni correction. A study with more participants might reveal the lack of significance to be a type II error, consistent with our hypothesis that the slow cycling speeds in this study made participants feel less immersed, since only the faster speed showed the potential difference.

VIII. Conclusion

An exergame is a helpful fitness tool only if people are willing to play it in the first place, and then use it in a way that supports their fitness needs and goals. We created a cycling-based exergame and used it to examine techniques for correcting player cycling cadences at two target speeds to achieve a target level of exertion. Test conditions included a control condition without feedback, and two feedback conditions, one using nudges and one using a textual display.

We expected that players would find any type of feedback to change their performance at least somewhat intrusive, and our results confirmed that. However, while we expected that textual feedback would be more effective than nudges at keeping players within the target range, and thereby controlling player exertion, our results showed that the nudges were equally effective, and both were, as anticipated, more effective than no feedback.

As one tool to support exergame acceptance, designers might want to consider including nudge techniques, which are valuable to reduce the player's sense of dissonance with the game world, without creating significant performance penalties. Even if there does not appear to be an increase in immersion, players preferred the nudges, saying they felt more natural to the game.

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