Converting Sedentary Games to Exergames: A Case Study with a Car Racing Game

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***Abstract*—One of the major challenges in designing exercise games (exergames) is maintaining engagement and motivation over time. Previous research has shown that games can increase the motivation exercise. However, these games are typically developed with limited set of specific exercises in mind, which limits genre choices, and potentially long term motivation. To address this critical issue, we are interested in employing any exercise as an interface to common, existing, sedentary games, such as a car racing game. Specifically, in this paper, we aim to take initial steps toward this goal. As a proof of concept, we developed 2 exercised based interfaces for a car racing game – a game genre minimally used for exergames. We present the evaluation of our novel exercise interfaces to the racing game, and offer general guidelines for converting common classes of sedentary games to exergames.**

Keywords— Virtual Reality; 3D user interfaces; exergames; exercise; motivation; physiological measures; user studies

I. Introduction

Can traditionally sedentary game genres (e.g., car racing) be used for effective exergames? Previous research has largely focused on games that were designed for specific exercises [1-5]. For example, Kinect sports includes a track and field game in which the user must run to make the character run in the game. However, focusing on designing exergames for specific exercises potentially limits the genres of exergames, which could impact motivation for many users. Many exercise programs focus on repetitive movements and thus can quickly become boring and monotonous. Similarly even though exercise games like Kinect Sports or Wii Sports are able to motivate players to exercise, gameplay may start to feel monotonous after playing the same game repeatedly. What if the users could choose any game to play, but still reap the health benefits of exergames? That is, people could play different games with the same exercise or play the same game with different exercises. To investigate these issues in a case study, we modified a common sedentary (non-exercise) video game (i.e., a racing game) to be controlled with two exercise-based interfaces and evaluated the impact on exercise effectiveness and motivation. Our long term goal is to derive general guidelines for employing traditionally sedentary games as effective exergames.

However, it is unclear how to most intuitively map exercises to game missions, especially since there seem to be innumerable types of missions. Thus, the present research focuses on two types of common missions found in many in sedentary video games: 1) Time-locked missions – the time of playing the games is fixed, and the advancement is primarily based on performance. Taking Need for Speed (i.e., a common racing game) as an example, the career mode is a performance-based mission. In the game, every track has a time limit depending on how difficult it is to complete. The players have to pass the finish line before the time ends. If the players drive well and thus finish on time, they progress in the game; 2) Time-open missions – there is no time limitation of playing the games, and the primary score metric is the length of time taken. For example, in the Plants vs. Zombies game there is a Survival Endless mode. In this mode, the players need to attempt to survive as many rounds of zombies' attacks as they can. The better players will survive more rounds.

Similarly, we found that time-locked and time-open missions are the common types of missions in both exergames and real physical exercises.. Such as the boxing game in the Wii-Sports, this is a time-locked mission. The players need to get enough points before the time ends or knock the opponent out to win the game. Using a real physical exercise as another example, doing push-ups could be either a time-locked mission, doing as many push-ups as fast you can in 60 seconds or a time-open mission, doing as many push-ups as you can without a time limit. Thus, time-locked and time-open missions are prevalent in exercise, exergames and non-exergames, which motivate the use of them in our research on converting non-exergames to exergames.

Fig. 1. Crouching and Rising Exercise with the Game. Left: bottom position; Right: top position

To begin to address these issues, we performed a case study in which we modified a 3D car racing game with a Microsoft Kinect [10] and we mapped exercises to the acceleration of the car. We implemented two different types of crouching exercises as interfaces to the game: 1) Half-crouching exercise (time-open mission) and 2) Crouching and rising exercise (time-locked mission, shown in Fig. 1), we performed two user studies that compared the crouching exercises both with and without the game. This enabled us to perform a controlled comparison and effectively study unusual couplings of game and exercise interfaces and their impact on user motion, motivation, behavior, and physiological response. Based on this, our conclusions include general guidelines for these types of couplings for other games..

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II. BACKGROUND AND RELATED WORK

In general, previous research has shown that games can increase motivation and enjoyment and may lead to better adherence to exercise and rehabilitation programs. That is games have the potential to effectively improve health, fitness and rehabilitation [1-9]. However, the available selection of most exergames is limited. Here, we review existing exergames and rehabilitation games, general design guidelines for exergames and rehabilitation games, and identify current limitations in game choice that our research aims to address.

A. Existing Exergames

Exergames are becoming more and more popular on the market. There are increasingly more commercial exergames such as Kinect sports, Wii sports, and WiiFit balance board games. Whitehead et al. did a survey of exergames with Nintendo Wii, Sony's EyeToy and traditional sedentary games in 2010 [10]. They found that exergames may help to minimize the threat of childhood obesity and sedentary related diseases. They also provided suggestions for designing effective exergames. They suggested that sensor systems need to be used to get the information from the entire body to avoid cheating. Current exergame interfaces, such as the WiiMote, can only really sense one part of the body, which limits feedback and interaction based on good form. Moreover, most of the current exercise games are designed for a specific exercise, which constrains the user's choices in the types of games and exercise that can be performed.

B. Existing rehab games

Much of the research that is relevant to exergames comes from the field of rehabilitation. Many of the goals in rehabilitation games and games are similar to exergames (e.g., [1-9, 11-15]) in that they are trying to increase motivation and maintain adherence to a rehabilitation program. Flores et al. compared six different games for stroke rehabilitation in 2008 [6]. From a usability perspective it is suggested that rehabilitation games should take advantage of affordances - "an object's sensory characteristics intuitively imply its functionality and use." (see the discussion on affordances in Shneiderman et al. [16] and http:// www.usabilityfirst.com /glossary/affordance/), That is, the mapping between an exercise and game should be intuitive and expected based on the user's prior experience. For example in Wii bowling, in order to propel the bowling ball down the lane, the user performs an exercise that is very similar to bowling in real life. Although ensuring intuitive affordances between an exercise and a game interaction is consistent with the current suggestions found in the literature and traditional UI design principles, we propose that constraining interaction design to these affordances limits game and exercise choice, which may also limit the motivational impact of exergames.

C. Design Guidelines for Exercise and Rehabilitation Games

Sinclair et al. proposed design guidelines for exergames [17]. An exergame needs engaging and intuitive gameplay, which includes concentration, challenge, control, feedback, immersion, player skills, clear goals and social interaction. There has been recent research on deriving design guidelines for rehabilitation games based on results of empirical studies [6]. Alankus et al.'s guidelines include: simple games should support multiple methods of user input, calibrate through example motions, ensure that users' motions cover their full range, detect compensatory motion, and let therapists determine difficulty [1]. There have been many other guidelines derived, which suggest there is a need for more focused game design research and development for specific populations. However, there is relatively minimal research on how to most effectively map exercises to games that are not developed for exercise (e.g., car racing). This is what our research aims to address and if successful, will greatly expand the genres of games that can be considered for exergames.

D. Our Contributions

The previous work has shown that exergames can increase the users' motivation[6, 18], which can be further increased by adhering to the proposed exergame design guidelines – design games to fit the exercise. This has been very successful. However, this severely limits game choice, which could have negative long term implications for maintaining motivation.

Thus, we ask the question "How can we enable any exercise to be used effectively as an interface to any game?" This paper represents the first strides towards answering this question by investigating the motivational and physiological impact of a sedentary game turned exergame. Although this paper focuses on an initial case study with a car racing game, the results can be generalized to any game with time-locked and time-open missions – two types of missions that occur in most games.

Specifically, our contributions are:

- Insight into the types of exercises that are effective with two types of common game missions.
- Two novel exercise based 3D interaction techniques for an existing car racing game.
- The physiological and motivational impact of a sedentary game turned exergame as compared to the exercise alone as a baseline.

III. CONVERTING A CAR RACING GAME TO AN EXERGAME

A 3D car racing game was chosen for this research because it was challenging to convert - its existing interaction style is totally unrelated to exercise. Specifically, we modified a tutorial car racing game downloaded from the Unity website (http://unity3d.com/). It has one track on a loop.

Originally, the game was played through keyboard interaction. For example, the up and down arrows controlled the acceleration and the left and right arrows controlled steering. We replaced the keyboard user interface with exercises tracked through a Microsoft Kinect. In order to effectively isolate the differences between doing exercise with the game and without the game, we had to constrain the interaction. That is, performing the exercises correctly increased the speed of the car, while the car steered automatically (based on pre-recorded data) around the track.

A. *Exercise-Based Interfaces for the car racing game*

We developed two exercise-based interfaces for the car racing game that were different types of crouching exercises: 1) a stability exercise (time-open mission) and 2) a frequency of motion exercise (time-locked mission).

1) *Half crouch stability exercise (HCSE)*

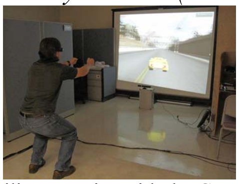

Fig. 2. Half Crouch Stability Exercise with the Game (HCSE-G).

The Half Crouch Stability Exercise (Fig. 2) is designed to match the "time-open missions" in video games. The users have to keep their half crouch position inside a small, predefined half couch range as long as possible. When they are inside the range, the car will keep accelerating until it reaches full speed. If they are outside the range, the car will decelerate very quickly and will eventually stop.

In the top left corner of the screen, the game displays a hint – either lower, higher, or keep - that indicates if the user needs correct their pose. The hint suggests to crouch down more (i.e., 'Lower') or stand up more (i.e., 'Higher') or to maintain the correct position (i.e., 'Keep').

2) *Crouch and rise frequency exercise (CRFE)*

The Crouch and Rise Frequency Exercise (Fig. 1) is designed to match the "time-locked missions" in video games. The users must do the exercise as fast as possible and must reach the predefined (i.e., through a prior per user calibration) top position and bottom position. Otherwise, it will not be counted as an effective crouching and rising exercise. The car speed depends on how fast the user can do the CRFE. During the exercise, if users maintain their frequency, the car speed will be maintained.

In the top left corner of the screen, the users can see how many successful CRFEs they have completed. The counter will only be increased by when they perform a correct CRFE.

B. *Equipment and Technology*

The game was developed in Unity. A Microsoft Kinect is used as our whole body tracking device. We used the Flexible Action and Articulated Skeleton driver (FAAST, Available at http://projects.ict.usc.edu/mxr/faast/) for Microsoft Kinect under Microsoft Windows. We also used Virtual-Reality Peripheral Network (VRPN)[19] and Unity Indie VRPN Adapter (UIVA, Available at http: // web.cs.wpi.edu/~gogo/ hive/UIVA/), which is a plug-in of Unity for using VRPN, to develop the virtual environment. The environment is rendered in stereoscopic 3D by an NVIDIA graphics card, and projected onto a projection screen with a 3D projector.

IV. STUDY 1: HALF CROUCH STABILITY EXERCISE (HCSE)

We conducted a within-subjects study comparing HCSE without the game to the HSCE with the game during a time open mission. The study included two sessions. The second session occurred approximately 48 hours after the first one so as to minimize the effects of fatigue. The two sessions were for two different conditions, 1) half crouch stability exercise with the game (HCSE-G) and 2) half crouch stability exercise without the game (HCSE-NG). Participants were randomly assigned to conditions to counter-balance any learning effects.

A. *Differences Between HCSE-G and HCSE-NG Conditions*

The only difference between the conditions was the presence of the interactive visual feedback of the car driving along the track (i.e., the game). Otherwise, the conditions were the same. For both HCSE-G and HCSE-NG, participants were asked to keep their arms pointing to the front, as shown in Fig. 1. The goal for both conditions was to hold the half crouch position as long as possible while keeping their body inside the correct half crouch range as long as possible. All users received the same interactive 'Lower', 'Keep', and 'Higher' hints that indicated how to correct or to maintain their crouch position.

B. *Hypotheses*

We expected participants to experience advantages with the game even though the interface did not share affordances with the game.

HCSE-H1 – Participants can perform HCSE-G for a longer period of time than HCSE-NG.

HCSE-H2 – Participants will drive the car further in HCSE-G than in HCSE-NG (i.e., driving distance is recorded in both conditions).

HCSE-H3 – The percentage of time in good form, which is defined as how long the participants keeping their bodies inside the good half crouch range of HCSE-G over the total time of HCSE-G is greater than the percentage of time in good form of HCSE-NG's.

HCSE-H4 – Participants' maximum heart rates during HCSE-G are greater than in HCSE-NG.

HCSE-H5 – Participants will be more motivated to do the in HCSE-G than in HCSE-NG.

HCSE-H6 – The time estimation of HCSE-G will be less than the HCSE-NG's.

C. *Environment*

The study was conducted in a quiet, air-conditioned laboratory environment. Only the participant and experimenter were present. If a participant was under 18, their parents were present, but they remained quiet.

D. *Participants*

Out of the 27 participants, only 24 are used as the effective data, because of 3 of them couldn't finish the whole study for some personal reasons. There are 6 females and 18 males. The age range is from 13 to 39. The average age is 24.89.

E. *Metrics*

1) *Game*

Total time – The time from the start of the game to the end.

Percentage of time in good form – How long the participants kept their body inside the good half crouch range over the total time.

2) Physiological Measures

Heart Rate – we used a Bluetooth physiological sensor called Bioharness BT (Available at http://www.zephyr-technology.com/bioharness-bt) to monitor the heart rate, breath rate, skin temperature, and other metrics, although in this study we only analyzed the heart rate data. The participants had to wear it touching the skin on the chest before starting the study. The Bluetooth device transfers all of the data it captures to the computer and shows the data on the screen in real time. At the same time, the Bluetooth device records the data into its own memory.

3) Questionnaires

Motivation – We used Likert scales to assess motivation for 1) performing the exercises with the game; 2) performing the exercises without the game; 3) exercising regularly. We presented a scale bar from 1 to 7 under the question and commented 1 represented the lowest, 4 represented the moderate and 7 represented the highest. We also asked them how frequently they exercised.

Time Estimation – We asked the participants to estimate an average time that they took to perform the exercise.

F. Procedure

The whole procedure is as shown in Fig. 3. This study includes two sessions, one for HCSE-G and the other for HCSE-NG. The second session took place approximately 48 hours after the first session finished.

1) Session 1

i. Informed Consent and Introduction – When the participants arrived, they were asked to read the informed consent and signed it if they didn't have questions. We also briefly introduced the study to them.

ii. Bioharness, Calibration and Initialization – This is a series of preparation procedures. The participants had to wear the Bioharness physiological sensor before starting the study. Then they were requested to stand at a marked position for Kinect camera calibration so that the Kinect could recognize their body. Then they were asked to crouch down to the bottom and stand up in normal speed to finish the initialization. This last initialization calibrated the good half crouch range to each participant.

iii. Trial Round Exercises – We explained how to do the exercise to the participants, and randomly assigned the participants to a condition – either HCSE-G or HCSE-NG. The unpicked one for the first session will be finished in session 2. We gave them a trial round to make sure they understand how to do the exercise or how to play the game. There was a break after the trial round.

iv. 3 Rounds Exercises – In this step, the participants need to do the same exercise for three rounds. They self-rated their fatigue level after each round. Between every round, they had a 3-5 minutes break. There was no time limitation for this exercise. The participants choose the time to stop. The total time for the HCSE was recorded for each round, along with the total moving distance of the car, the total time the participants kept their position inside the range, and also logged the whole body motion data.

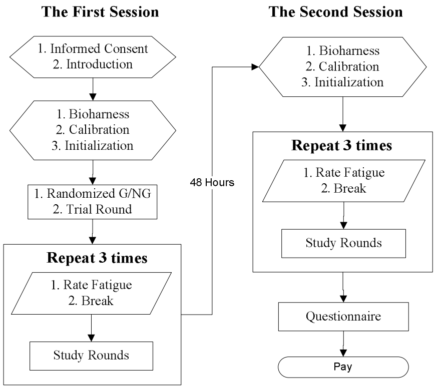

Fig. 3. The flowchart of the study procedure.

2) Session 2

The second session began approximately 48 hours after the first.

i. Bioharness, Calibration and Initialization – This series procedure is the same as in the first session.

ii. 3 Rounds Exercises – Depending on which condition, was assigned (i.e., HCSE-G or HCSE-NG) in session 1, participants will be assigned to the other one in this session. They perform the exercise for 3 rounds. Participants rated their fatigue as soon as they finished each round of the exercise, and had a short break between each of the 3 rounds.

iii. Questionnaires and pay – After finishing the exercise, the participants were asked to answer a questionnaire. Lastly, the participants were paid $20 for their time and effort.

G. Results and Discussion

1) Time Estimation

We hypothesized that the time estimation represented the motivation. The participants might feel the time went faster with the game, if they were motivated by the game. About 60% of participants estimated that the time was longer without the game. We ran a Paired-Samples t-Test with the time that people estimated from the questionnaire. The P value ($0.726 > 0.05$) was not significant. This suggests that HCSE-H6 cannot be accepted.

2) Motivation

As expected, participants were more motivated by the game. We ran the Wilcoxon Signed Ranks Test with the level of motivation participants reported from the questionnaire. The data is given as ordinal data. The P value is < 0.001. The Z value is $-4.047 < -1.96$. Except one participant, all of the other participants thought the game would increase their motivation to do the exercise. The HCSE-H5 is strongly supported by this result. The P value of pair HCSE-NG and Regular Exercise (i.e., their motivation to regularly exercise in general) is 0.044 < 0.05, and the Z value is -2.013 < -1.96, which is based on negative ranks. And the P value of pair HCSE-G and Regular Exercise is 0.015 < 0.05, and the Z value is -4.286 < -1.96 which is based on positive ranks.

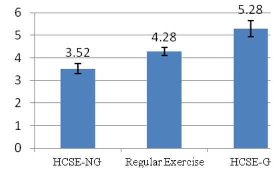

Fig. 4. Means of motivation with Standard Errors.

3) *Total Time*

Total time represented the ability that how long the participants could do the half crouch exercise. Participants were able to perform the exercise longer with the game. See Fig. 5. We ran the two-way Repeated Measures ANOVA analysis with the total time for three sessions of both HCSE-G and HCSE-NG. The F value is 16.467, and the P value is < 0.001 for each of the four different statistical methods. From the differences of the total time between HCSE-NG and HCSE-G we can say that the game makes the people do the exercise much longer. This result strongly supports HCSE-H1.

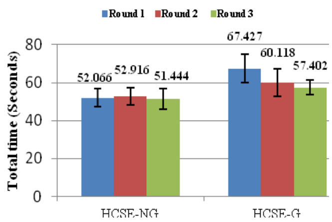

Fig. 5. Means of total time with Standard Errors.

4) *Total Moving Distance*

Total moving distance represented the ability of how well the participants could perform the half crouch exercise. The better they performed, the further the car could go. The participants were able to make the car travel a further distance in the game.

We ran the two-way Repeated Measures ANOVA analysis with the total moving distance for the three rounds of both HCSE-G and HCSE-NG. The F value is 5.126, and the P value is 0.033 < 0.05. This result strongly supports the HCSE-H2.

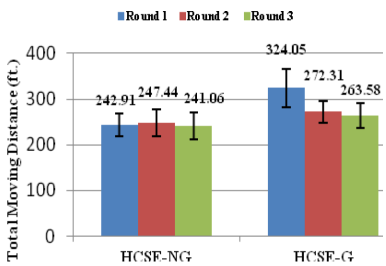

Fig. 6. Means of total moving distance with Standard Errors.

Observationally, it is likely that the game motivated the participants to try their best to make the car go further. Participants are always trying their best for every round, because the total moving distance from the first round to the third round keeps decreasing because of increasing fatigue.

5) *The Percentage of Time in Good Form*

The percentage of time in good form represented how stable the participants could keep their half crouch during the exercise. We also ran the two-way Repeated Measures ANOVA analysis for the percentage of time in good form. The P value is 0.083.

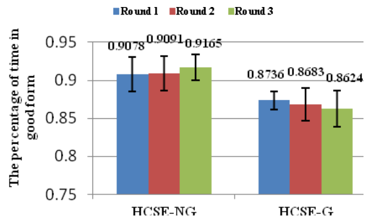

Fig. 7. Means of the percentage of time in good form with Standard Errors.

From the Fig. 7, the percentage of time in good form of HCSE-G is lower HCSE-NG's. Thus we cannot accept HCSE-H3.Although the P value is not significant at 0.083, which is greater than 0.05, we consider this a trend in the data. From the observational and verbal feedback of participants, it seems that the game distracted their attention during the exercise so they feel it is harder for them to consistently maintain the correct position.

6) *Maximum Heart Rate*

We assumed the maximum heart rate could represent how hard the participants pushed themselves during the exercise. We ran the two-way Repeated Measures ANOVA analysis with the maximum heart rate for three sessions of both HCSE-G and HCSE-NG. We could not find any significant differences (P = 0.345) from the heart rate and thus cannot accept HCSE-H4.

V. STUDY 2: CROUCH AND RISE FREQUENCY EXERCISE (CRFE)

We conducted a within subjects study comparing CRFE without the game to the CRFE with the game. The study included two sessions. The second session occurred approximately 48 hours after the first one so as to minimize the effects of fatigue. The two sessions were for two different conditions, 1) crouch and rise frequency exercise with the game (CRFE-G) and 2) crouch and rise frequency exercise without the game (CRFE-NG). Participants were randomly assigned to conditions to counter balance any learning effects.

A. *Differences Between CRFE-G and CRFE-NG Conditions*

Similar to the previous study, the only difference between the conditions was the presence of the interactive visual feedback of the car driving along the track (i.e., the game). Otherwise, the conditions were the same. All users received the same interactive CRFE count that indicated how many correct CRFEs were performed. The goal of both conditions was the same – perform as many correct CRFEs as possible in 20 seconds.

B. *Hypotheses*

Based on previous exergame and virtual reality research, we generally expected that the game would distract users from discomfort, increase motivation, and push them to work their body harder than without the game. However, contrary to previous research, we expected the advantages of the game even though the interface did not share affordances with the game.

CRFE-H1 – Participants will drive the car further in CRFE-G than in CRFE-NG (i.e., driving distance is recorded in both conditions).

CRFE-H2 – Participants will demonstrate a higher crouch and rise frequency in CRFE-G than in CRFE-NG.

CRFE-H3 – Participants' maximum heart rates during CRFE-G are greater than in CRFE-NG.

CRFE-H4 – Participants will be more motivated to do the exercise in CRFE-G than in CRFE-NG

CRFE-H5 – The time estimation of CRFE-G will be less than that of CRFE-NG.

C. Environment

It was the same environment as the previous study.

D. Participants

We recruited 30 participants who did not participate in the previous study (HCSE). Out of the 30 participants, only 28 are used as the effective data, because 2 of them couldn't finish the whole game for some personal reasons. They were all males. The age range is from 15 to 30. The average age is 24.14. The main reason we did not have any female participants for this study is that all of the participants were recruited from Computer Science Department, which has proportionally fewer female students.

E. Metrics

1) Game

Total moving distance – The total distance that the car moved in 20 seconds.

Frequency – How long it took the participants to finish a whole crouch and rise procedure on average.

2) Physiological Measures

Heart Rate – The same as the previous study.

3) Questionnaires

Motivation – The same as the previous study.

Time Estimation – The same as the previous study.

F. Procedure

The procedure of the CRFE study is the same as the procedure of HCSE study (Shown in Fig. 2) except CRFE was performed instead of HCSE. It also includes two sessions 48 hours apart - one for CRFE-G and the other for CRFE-NG.

G. Results and discussion

1) Time estimation

The same to the HCSE study, we hypothesized time estimation represented the motivation. The participants might feel the time went faster with the game, if they were motivated by the game. We ran the Paired-Samples t-Test with the time that people estimated from the questionnaire. Similar to the HCSE study, the P value is not significant (P = 0.469 > 0.05). Thus, CRFE-H5 cannot be accepted.

2) Motivation

Similar to the previous study, participants were more motivated by the game. We ran the Wilcoxon Signed Ranks Test with the motivation people rated from the questionnaire. The data is given as ordinal data. The P value of pair CRFE NG and CRFE-G is < 0.001. The Z value is -4.587 < -1.96. All of the participants thought that the game increased their motivation to do the exercise. Thus the CRFE-H4 is strongly supported by this result. The P value of pair CRFE-NG and Regular Exercise (i.e., their motivation to regularly exercise in general) is 0.004 < 0.05, and the Z value is -2.843 < -1.96, which is based on negative ranks. And the P value of pair CRFE-G and Regular Exercise is < 0.001, and the Z value is -3.494 < -1.96 which is based on positive ranks.

3) Frequency

Frequency represented the ability that how fast the participants could perform the crouch and rise exercise. In general, participants moved their body at a higher frequency in the game. We ran the two-way Repeated Measures ANOVA analysis with the frequency for three sessions of both CRFE-G and CRFE-NG. The F value is 7.477, and the P value is 0.011 < 0.05, which strongly supports CRFE-H2.

Fig. 8 demonstrates that people tried to move their body faster with the game than without the game. The column of each round from CRFE-G is higher than the corresponding one from CRFE-NG.

There is other feedback from the participants. Because we randomized the CRFE-NG and CRFE-G for the two sessions for the study, the reactions from the participants were different between those who did the CRFE-NG first and those who did the CRFE-G first. The participants who did the CRFE-G for their first session really tried their best to do the exercise, but when they came back for the second session, they felt pain from their thighs and did the exercise much slower than the first session. It was more like finishing the task, but not doing the exercise. But the participants who did the CRFE-NG for their first session still tried to do the exercise better during the second session even they felt the pain from their thighs.

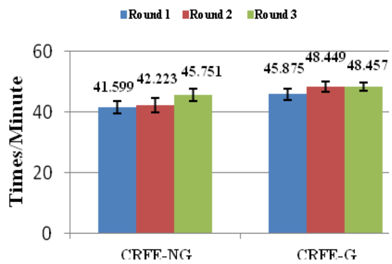

Fig. 8. Means of frequency with Standard Errors.

4) Total moving distance

Total moving distance also represented the ability of how fast the participants could perform the half crouch exercise. The better they performed, the further the car could go. In the game, participants were able to get the car to drive faster and thus travelled significantly (F = 30.124, P < 0.001 – two-way repeated measures ANOVA) further in the game.

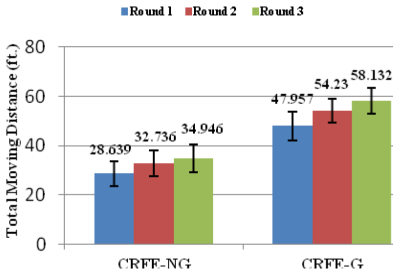

Fig. 9. Means of total moving distance with Standard Errors.

5) *Maximum Heart Rate*

The same as in the HCSE study, we assumed the maximum heart rate could represent how hard the participants pushed themselves during the exercise.

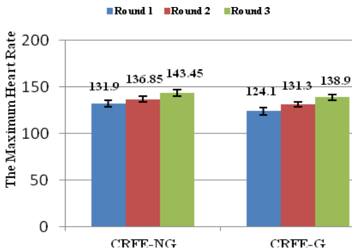

Fig. 10. Means of maximum heart rate with Standard Errors.

Contrary to what we expected, performing the exercise without the game resulted in a higher maximum heart rate than performing the exercise with the game.

We ran the two-way Repeated Measures ANOVA analysis with the maximum heart rate for three sessions of both CRFE-G and CRFE-NG. The F value is 4.890, and the P value was 0.039 < 0.05. From the Fig. 10, the maximum heart rate was higher in the CRFE-NG condition. The CRFE-H3 cannot be accepted.

We do not know the reason for the higher the maximum heart rate in CRFE-NG. It is possible that the participants were unknowingly trying to find the path of least resistance to advance in the game. We tried to take measures to prevent this type of outcome, but it is possible that participants found a way to circumvent those measures in order to save their energy while still moving at a higher frequency. We still cannot find a way to 'cheat', but we are still looking.

The other possibility is that the game somehow served to calm participants down and lower their heart rate. It is especially interesting that participants were able to maintain a lower heart rate at a higher frequency of movement. We plan to investigate this with further study, but we have not seen this type of conflicting result duplicated in the literature - exercise with the game was more vigorous, but the heart rate was not indicative of the increased vigorousness.

VI. IMPLICATIONS FOR EXERGAMES BASED ON RESULTS FROM BOTH STUDIES

From both the HCSE and the CRFE studies, we learned the game could distract people from the exercise since the percentage of time in good form was lower in-game (HCSE) and the heart rate was lower in-game (CRFE). However, in both studies, participants were consistently highly motivated, even when they were not as motivated to regularly exercise.

Observationally, it seemed that the exergame engendered a sense of self-competitiveness in the participants. Each time they played the game, they tried to outperform their previous attempts. In contrast, this was not the case when participants performed the exercise without the game. Ultimately, even doing exercises with a car racing game, the participants experienced many of the same advantages and disadvantages as a traditional exergame that is developed for specific exercises.

In terms of guidelines for converting existing games to exergames, one question that arises is: which types of exercises should be mapped with which types of mission? Using our studies as an example, frequency exercises (e.g., CRFE) can be mapped effectively to time-locked missions and stability exercises (e.g., HCSE) can be effectively mapped to time-open exercises. From a practical perspective, frequency exercises may often be tiring to muscles over a long period of time, and thus users can focus on frequency over a shorter period of time. Whereas, stability exercise focuses more on maintaining a form, which often is not as strenuous and can be held over a longer time. We hypothesize that these guidelines will help to maintain motivation in sedentary games converted to exergames.

VII. CONCLUSIONS

One of the grand challenges of exergame design is maintaining motivation and engagement over time. A potential solution to this is to simply offer users a wider selection of exergames, but there are many logistical barriers preventing rapid development of new exergames, such as funding and time. Instead, we propose that exergame designers should be able take advantage of the wide array of existing sedentary games and convert them to exergames. However the question is: can existing sedentary games be converted to effective exergames?

As a test case to investigate the motivational and exercise effectiveness implications of this idea, we converted an open source sedentary racing game to an exergame. We chose a car racing game because there was no physical exercise that maps realistically to a car racing game, and thus the racing game represents one of the more challenging conversion to exergame scenarios. For generalizability of our results, the car racing game can be considered an example with the common time-open and time-locked missions that are in most video games. We conducted two studies, each of which investigates a different type of exercise: 1) Half Crouch Stability Exercise (HCSE) for time-open missions and 2) Crouch and Rise Frequency Exercise (CRFE) for time locked missions.

We learned that converting sedentary games to exergames results in a similar experience as a standard exergame in that 1) the game motivates users to try harder when they are doing exercises. Even if users are not motivated to exercise regularly, they will still be motivated to play the exergame; 2) users can be distracted by game specific feedback, which can hinder effectiveness of the exercise.

Based on our studies, we hypothesize the following guidelines about converting a sedentary video game into an exergame:

Guideline 1: When mapping exercises to game interactions, effective mappings can be enabled through matching the goals of an exercise (e.g., crouch and rise as frequently as possible in 20 seconds) to the goals of the game's missions (e.g., drive as far as possible in 20 seconds), rather than focusing on natural affordances.

That is, to enable effective exercise, it is not necessary that the mapping between game interaction and the exercise has natural affordances. Although, not having these affordances may cause the resulting mapping to be less intuitive, matching the goals of the game to the goals of the exercise may be a viable way to mitigate this issue. For example, frequency exercises may be intuitively mapped to time-locked missions and stability exercises can be intuitively mapped to time open missions.

Guideline 2: Even through sedentary games were not developed with exercise in mind, they can be converted to effective exergames. Consider converting existing sedentary games before developing a new exergame.

Although the racing game was not originally for exercise, users still experienced many of the same advantages and disadvantages of typical exergames. Our study provided a proof of concept that a sedentary video game can be converted to an effective exergame.

VIII. FUTURE WORK

We plan to convert other types of games to exergames, develop a generic interface framework to enable the mapping of exercises to games, and conduct longitudinal studies to find out the long term physical and motivational benefits of user-defined game-exercise interface mappings.

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REFERENCES

[1] G. Alankus, *et al.*, "Towards customizable games for stroke rehabilitation," in *CHI*, 2010, pp. 2113-2122.

[2] A. Bardack, *et al.*, "EMG Biofeedback Videogame System For The Gait Rehabilitation Of Hemiparetic Individuals," 2010.

[3] K. Brütsch, *et al.*, "Influence of virtual reality soccer game on walking performance in robotic assisted gait training for children," 2010.

[4] J. Burke, *et al.*, "Serious Games for Upper Limb Rehabilitation Following Stroke," 2009, pp. 103-110.

[5] J. Burke, *et al.*, "Optimising engagement for stroke rehabilitation using serious games," *The Visual Computer,* vol. 25, pp. 1085-1099, 2009.

[6] E. Flores, *et al.*, "Improving patient motivation in game development for motor deficit rehabilitation," 2008, pp. 381-384.

[7] J. Halton, "Virtual rehabilitation with video-games: A new frontier for occupational therapy," *Journal of Occupational Therapy Now,* vol. 10, 2008.

[8] G. Jung, *et al.*, "Timed automata-based rehabilitation training game design for the affected lower extremity of hemiparetic patient," 2008, pp. 17-27.

[9] G. Yavuzer, *et al.*, ""Playstation eyetoy games"improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial," *European journal of physical and rehabilitation medicine,* vol. 44, p. 237, 2008.

[10] A. Whitehead, *et al.*, "Exergame Effectiveness: What the Numbers Can Tell Us," in *the 5th ACM SIGGRAPH Symposium on Video Games* Los Angeles, CA, USA, 2010.

[11] S. Flynn, *et al.*, "Virtual reality rehabilitation–what do users with disabilities want?," 2008.

[12] R. Armiger and R. Vogelstein, "Air-Guitar Hero: A real-time video game interface for training and evaluation of dexterous upper-extremity neuroprosthetic control algorithms," 2008, pp. 121-124.

[13] M. Jannink, *et al.*, "A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study," *Cyberpsychology & behavior,* vol. 11, pp. 27-32, 2008.

[14] B. Maurer, *et al.*, "Improving rehabilitation process after total knee replacement surgery through visual feedback and enhanced communication in a serious game," in *Proceedings of the 30th ACM international conference on Design of communication*, 2012, pp. 355-356.

[15] J. Doyle, *et al.*, "The effects of visual feedback in therapeutic exergaming on motor task accuracy," in *Virtual Rehabilitation (ICVR), 2011 International Conference on*, 2011, pp. 1-5.

[16] B. Shneiderman, *Designing the user interface*: Pearson Education India, 1998.

[17] J. Sinclair, *et al.*, "Considerations for the design of exergames," in *the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia* Perth, Westen Australia, 2007.

[18] T. Morelli, *et al.*, "VI-Tennis: a vibrotactile/audio exergame for players who are visually impaired," in *the Fifth International Conference on the Foundations of Digital Games* Monterey, California, USA, 2010.

[19] R. M. Taylor II, *et al.*, "VRPN: a device-independent, network-transparent VR peripheral system," in *Proceedings of the ACM symposium on Virtual reality software and technology*, 2001, pp. 55-61.