Effects of Commercial Exergames on Motivation in Brian Injury Therapy

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Abstract
Brain injuries (BI) are a major public health concern. Many therapists who focus on BI use commercial video-exergames (CVEs) to motivate patients to perform the repetitive exercises required for rehabilitation. However, there is relatively little work examining the effects of CVE use on BI patient motivation to perform rehabilitation exercises. In this paper, we report on a randomized controlled study with 35 outpatients; we examined how including CVEs was associated with intrinsic motivation using Self-Determination Theory as a framework. We found using CVEs was associated with an increased perceived competence over a four-week study period when compared to a control group receiving only standard care. However, there was very little indication that games were more intrinsically motivating than standard care. Our work represents a much-needed study to investigate motivational aspects of CVE use in therapies for people who have had a BI.

Author Keywords
Intrinsic motivation; brain injury; physical rehabilitation; commercial exergames; games

ACM Classification Keywords
K.4.2. Computers and Society: Social Issues (Handicapped persons/special needs); K.8.0. Personal Computing: Games

Introduction

The Centers for Disease Control (CDC) in the United States recognizes brain injuries (BI) as a major public health concern [5]. The CDC estimates that 6.4 million children and adults in the US live with a lifelong disability as a result of a traumatic BI (e.g. falls, car accidents – 5.3 million) or a stroke (1.1 million) [5]. Previous research has established the commonalty of using commercial video-exergames (CVEs) in physical therapies for people who have had a BI [29]; CVEs are motion-based games that involve standing and physical exertion of players. A common reason cited for including CVEs in physical therapies has been to increase patients' motivation to perform the repetitive exercises that are required for rehabilitation (e.g., [3, 4]). Motivation has been defined as "*the forces acting on or within an organism to initiate and direct behavior*" [27]. In the context of games for BI rehabilitation, motivation is a driving force that initiates gameplay and keeps players engaged in rehabilitation.

While recognized as important, there is relatively little work examining the effects of CVE use on patient motivation when engaging in BI therapy activities. In this spotlight paper, we report on a randomized controlled study with 35 patients in which we examined how including two CVEs were associated with intrinsic motivation (i.e. performing an activity based on the characteristics of the activity itself) when compared to standard care in physical therapy for BI patients. Specifically, we asked the following research questions:

- RQ1: Can CVE use result in an increased motivation over multiple sessions compared to standard care?
- RQ2: Can CVE use result in higher overall motivation to engage in rehabilitation in BI physical therapies when compared to standard care?
- RQ3: Are there mitigating patient factors (e.g. age, physical abilities) associated with perceived motivation when comparing the two types of care?

We used Self-Determination Theory (SDT) as a framework of examining intrinsic motivation [11]. SDT is an empirically derived theory of human motivation that is widely adopted in game studies [11].

Related work

Multiple studies have examined the effectiveness of CVEs for BI physical therapies; projects have included case studies [6. 12, 14, 25] and controlled designs [9, 10, 15, 17, 18, 21, 37]. In an example of the former (i.e. case studies), Paavola et al. [25] reported using Microsoft 'Kinect Adventures!' [19] for 10 sessions over a month with a single patient with a BI. The participant showed improvements in clinical outcomes, including balance and gait. In an example of the latter (i.e. controlled studies) Cho et al. [9] used the Nintendo Wii Fit with 11 participants (plus a 11-person control group) for six weeks. The game group performed significantly better than the control group in measures of dynamic balance, e.g., 'Time Up and Go' test [28]; however, there were no differences in static balance [9]. The researchers in these studies focused on efficacy, but did not examine how the games were related to increased motivation to perform rehabilitation exercises.

Previous work has also examined the appropriateness of CVEs for people who have had a BI; for example, Burke et al. [7] discussed an informal evaluation of

games designed for the Sony Eye Toy and Nintendo Wii, and found that CVEs were difficult to use for many people rehabilitating from a stroke. Because CVEs are not tenable for many people who have had a BI, some researchers have also examined the creation of custom games for BI. For example, Alankus [1-3] created nine adjustable mini-exergames for stroke rehabilitation focused on upper body rehabilitation. The researchers tested the games with five people who had stroke with hemiparesis over two studies, and found that their games helped participants meet targeted therapeutic goals [1-3]. Additionally, they assessed motivational aspects through interviews. Most of their participants expressed an increased willingness to perform rehabilitation exercises through their games when compared to standard care; however, their participants were varied in their level of interest in their games [3].

While the effectiveness, appropriateness, and creation of both custom and commercial exergames to support BI physical therapy continues to be vibrant areas of research and design, measures of motivation in controlled studies has not been addressed in the context of BI physical therapies. When designing this study, we referenced controlled studies that used survey instruments based on SDT to measure levels of motivation; we summarize major aspects of SDT and present a sample of studies in the following section.

Self-Determination Theory

SDT is an empirically derived concept based on the assumption that human motivation is regulated by the need of "psychological freedom" or self-determination [30]. SDT differentiates intrinsic and extrinsic motivation; the former denotes "*the doing of an activity for its inherent satisfactions*" while the latter refers to "*the performance of an activity in order to attain some separable outcome*" [34]. Originating in 1970s from the work of Deci and Ryan, the researchers proposed that a perceived locus of causality will enhance intrinsic motivation [34]. That is, intrinsic motivation is based on the satisfaction of three basic psychological needs: (1) autonomy, which concerns "*a sense of volition and willingness*" and can be enhanced by a sense of choice; (2) competence, which describes a balance between challenge and the belief of being able to overcome the challenge; and (3) relatedness, which describes the need to be connected with others [34].

SDT has framed many research studies that have focused on intrinsic player motivation in games (e.g., [22, 24, 26]) including some focused on exergames. For example, Peng et al. [26] conducted controlled experiments with 372 college students who played an exergame that the authors created (in one 15-minute session); they manipulated the levels of autonomy and competence in the game. They found that the conditions of greater autonomy and competence were motivational but did not influence self-reported physical effort to play the game. Osorio et al. [24] also investigated player motivation in a controlled study examining exergames through a survey framed by SDT; they found that (1) autonomy and relatedness were the two needs most satisfied through exergame play and (2) intrinsic regulation (enjoyment) and identified regulation (a feeling of being in a better mood and health condition) were the major reasons why people played exergames. In this work we did not manipulate psychological needs; instead we leveraged the Intrinsic Motivation Inventory (IMI) which is a questionnaire based on SDT exploring multiple

constructs that are associated with intrinsic motivation [35].

In research closely related to our work that also used the IMI Fitzgerald et al. [13] conducted a study with 28 healthy adults to measure motivational aspects of an exergame compared to standard care. The exergaming group reported statistically higher levels of one construct (interest and enjoyment) when compared to the control group who received standard care. In another similar study, Smeddinck et al. [37] explored motivational aspects of their custom-designed physical therapy games with 29 patients in treatment for chronic spine afflictions. Like Alankus [1-3], their games were designed with the capability of adjustment; participants were randomly assigned to (1) adjustable game group, (2) non-adjustable game group, and (3) standard care. The motivational findings were mixed; they found higher level of interest and enjoyment for both game groups when compared to standard care.

While these studies informed our methods, we were not able to find reports of controlled studies that compared motivational aspects of CVEs to standard care with BI patients; BI patients are arguably different than average players because of health conditions and/or special needs that can affect gaming preferences/ motivations. We contend that this is an important topic to examine because (a) CVEs are and probably will continue to be commonly used in BI therapies because of their ready availability, and (b) there is an assumption in many studies investigating exergaming with BI patients that CVEs increase motivation to engage in physical therapy.

Methods

The Internal Review Boards (IRBs) from DePaul and Rosalind Franklin Universities and the Captain James A. Lovell Federal Health Care Center (Lovell FHCC) in Illinois approved this study; all participants signed an informed consent form.

Participants

One physical medicine and rehabilitation (PMR) physician and three physical therapists (PTs) who worked with outpatients at the Lovell FHCC identified participants for the study. Between May 2015 and August 2016, 36 participants were recruited and 35 completed the study. Among the 35 participants, 28 were male, seven were female; the average age was 42.4 years (*SD* = 12.5).

We examined two additional attributes of patients and their association with motivational aspects of CVE use in BI therapies: (1) body-mass index (BMI) and (2) level of mobility calculated by the therapists using the locomotion dimension of FIM® instrument [38]. Average BMI of our participants was 30.2 (*SD* = 5.1), which is considered moderately obese; the CDC estimates the average BMI in the US at 28.6 [8]. FIM is a common rehabilitation measure that ranks patients' abilities to perform 18 tasks, which include 13 motor tasks (e.g., stairs, grooming) and five cognitive tasks (e.g., problem solving, memory). We used only part of the FIM; PTs assessed the ability to complete the locomotion tasks on a seven-point scale whereas a score of 7 is complete independence and a score of 1 is complete dependence. We decided that patients needed a FIM mobility score of at least 3 to participate in the study; mean FIM score among our participants was 4.83 *(SD* = 1.01); scores ranged from 3 – 7.

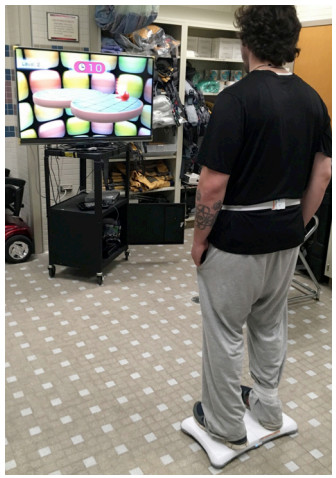

Figure 1 Participant playing Table Tilt on Balance Board

Table 1 Demographic Summary

Group	Age	FIM	BMI
Table Tilt (n = 8)	49.9	3.89	29.1
Super Saver (n = 9)	40.0	5.63	29.2
Combined Games (n = 17)	39.9	4.76	29.2
Control (n = 18)	45.4	4.85	31.2

Study Design

Outpatient participants were first randomized into the game or control group. Two motion-based mini-games were chosen based on consultation with the PTs and previous work with 29 other therapists in the Chicago area who work with people who have had a BI [30]. Both games addressed static and dynamic balance, respectively: (1) Nintendo Wii U Fitness 'Table Tilt' [23] and (2) Microsoft Kinect Sports Season 2 "Super Saver' [20] which is a soccer-based game.

The 'Table Tilt' mini-game uses a pressure balance board (about 2 inches high) that is included in the Wii Fit U game; the mini-game requires the player to move balls into holes by tilting a virtual table through shifting his/her center of mass on the balance board (see Figure 1). The game does not require any upper body mobility. The game increases in difficulty, starting with one hole and one ball, building to multiple balls and multiple holes with quicker tilting at the higher levels. Players have a limited time at each level; the game ends when the timer runs out on a level.

The Kinect Sports Season Two 'Super Saver' is a soccer mini-game that uses the Xbox 360 Kinect system, which captures whole-body movement of the players. The mini-game requires the player to block oncoming balls like a soccer goalkeeper. It is played over specific lifeline limits and requires players to have the capability to move both upper and lower extremities to block the virtual balls from going into the net.

The therapists determined that the Super Saver game was more strenuous and would require a higher FIM score than that of Table Tilt. As such, participants selected for the game group were further divided based on their FIM measure at the day of enrollment. Participants with FIM scores of 5 to 7 played Super Saver, while those with FIM scores of 3 and 4 played Table Tilt. The reason for this arrangement was to afford all game-group participants exposure to a game that the therapist felt appropriately challenged their functional abilities; see Table 1 for demographics.

For outpatients at Lovell FHCC the standard of care was half an hour therapy session, for two days a week for four weeks. In addition to standard of care, outpatients in the game group received two sessions of gaming consisting of two episodes of 15 minute gaming with 10-minute break in-between; as such, they received 30 additional minutes of care.

To assess participant motivation, we leveraged a shortened version of the 'Intrinsic Motivation Inventory' (IMI), developed by Ryan, Mims, and Koestner, which is based on the SDT motivational theory [35]. The instrument has been established as reliable over multiple lab-based studies to assess constructs associated with intrinsic motivation [36]. Specifically, we asked participants to assess their level of agreement using a 5-point Likert scale to assess five constructs of intrinsic motivation. (While the original IMI uses 7-point scales we used 5-point scales recommended by Revilla et al. [31] for the general public). The five constructs were:

1. Enjoyment and interest (e.g., "I enjoyed doing this activity very much" and "This activity did not hold my attention at all" (Reversed));
2. Perceived competence (e.g., "I think I am pretty good at this activity" and "This was an activity that I couldn't do very well" (Reversed));

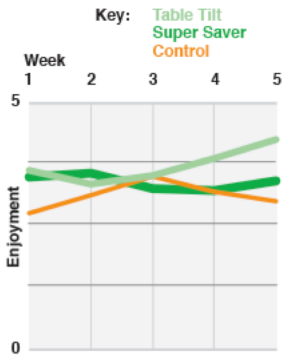

Figure 2 Interest/Enjoyment

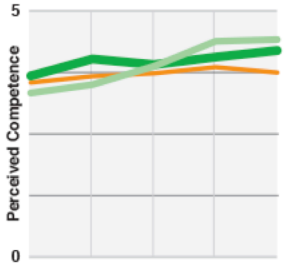

Figure 3 Perceived Competence

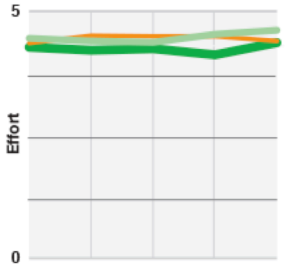

Figure 4 Effort Exerted

3. Effort exerted in the activity (e.g., "I put a lot of effort into this activity" and "I didn't try very hard on this activity" (Reversed));
4. Perceived value/usefulness of the activity (e.g., "I believe this activity could be of some value to me" and "I think this is an important activity");
5. Pressure and tension (e.g., "I felt very tense while doing this activity" and "I was very relaxed in doing these" (Reversed)).

Questions were asked after therapy sessions for all groups; after standard care for the control group and after a gaming session for the game groups. We assessed base scores after the first session and then once a week after the last session of the week for a total of five measurements for each construct.

Data Analysis

We first re-scored all the reversed Likert-scale questions to be positive. We explored and analyzed the motivational data using three approaches that aligned to our research questions: (1) trend analysis; (2) group comparisons; and (3) ordinal regression using the PLUM procedure to examine how individual differences affected motivation in the game group versus the control group. All statistical tests were conducted using SPSS version 22; we used non-parametric tests because our data did not meet the assumptions (e.g. normality) for parametric tests.

To answer RQ1 (i.e. the effect of CVE use over time), we examined trends of the five SDT constructs from base measurement to week 4. We used Wilcoxon tests (for related samples) to compare scores (from base-to-4th week) for each participant group (Table Tilt, Super Saver, and Controls) along each motivational construct.

To answer RQ2 (i.e. overall effect of CVE compared to standard care), we first averaged each participant's scores; as a result, each participant had a single overall mean for each construct. We then examined three-group (Table Tilt versus Super Saver versus Controls) comparisons using Kruskal Wallis tests and two-group (Combined game groups versus Controls) comparisons using Mann-Whitney U tests for each of the five constructs.

To answer RQ3 (i.e. potential patient individual differences in relation to motivation), we first created an overall positive motivation score for each participant by combining (adding) the scores from the first four constructs (enjoyment, competence, effort, value). We conducted the ordinal regression using the PLUM procedure to examine how age, gender, FIM score (recoded binary into low that included scores of 3-4 and high that included scores 5-7) and BMI predicted the overall positive motivation score for (a) the combined game group and (b) the control group.

Findings

We organized the findings sections to parallel our research questions: (1) trend analysis; (2) group comparisons; and (3) regression models to examine individual differences in the control and games groups.

Trend Analysis

We examined the three groups (Table Tilt versus Super Saver versus Control) by each construct over the five data collection sessions.

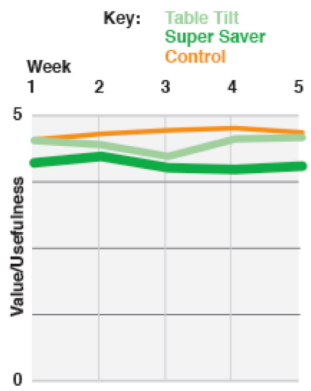

Figure 5 Value/Perceived Usefulness

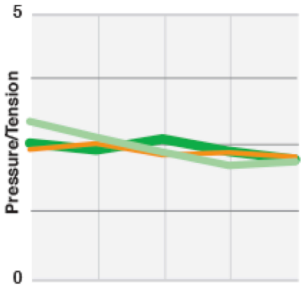

Figure 6 Pressure/Tension

- Construct 1: Interest/enjoyment: Participants perceived both games as more enjoyable than the control by the end of the study. The Table Tilt group reported the largest increase in enjoyment while the Super Saver and the standard therapy groups both remained somewhat steady; see Figure 2. There was no statistical significance in trends for any of the groups when comparing week one measurements to the week five measurements using a Wilcoxon test at alpha level .05; however, Table Tilt narrowly failed significance, Z = -1.873, p = 0.061, with a medium effect size (r= -0.47).
- Construct 2: Perceived Competence: Participants had a very similar level of perceived competence at the first session, but their perception of competence continued to increase for both game groups while the control group remained somewhat steady; see Figure 3. The trend for the Table Tilt group was significant, Z = -2.668, p = 0.008 with a large effect size (r= -0.67) and the Super Saver changes narrowly failed significance, Z = -1.778, p = 0.075, with a medium effect size (r= -0.42); see Figure 3.
- Construct 3: Effort exerted: Participants reported that they exerted very similar (high) levels of effort throughout the four weeks, regardless if they were game or control sessions; see Figure 4. There was no statistical significance in trends for any of the groups when comparing the first and last sessions.
- Construct 4: Value/perceived usefulness: Participants had a high perception of the usefulness of the therapy regardless of the type. There was no statistical significance in trends for any of the groups, see Figure 5.
- Construct 5: Pressure/tension: Participants reported moderate to low levels of pressure and tension, see Figure 6. There was no statistical significance in trends for the Super Saver and Control groups; however, the pressure and tension significantly decreased for the Table Tilt group, Z = -2.371, p = 0.018, with a large effect size (r= -0.59).

In sum, when considering the five constructs of intrinsic motivation over the five data collection sessions, the Control group did not show any trend of change. However, we observed an increased perceived competence in both Game groups. The Table Tilt group had also demonstrated an increased interest/enjoyment and decreased pressure/tension.

Group Comparisons

Recall, we compared the three groups (Table Tilt versus Super Saver versus Controls) by each Construct using Kruskal Wallis tests and the two-groups (Games versus Control) through Mann-Whitney U tests.

- Construct 1: Interest/enjoyment: All groups reported a high level of enjoyment and interest; Table Tilt scored the highest. There were no significant differences among the groups; see Figure 7.
- Construct 2: Perceived Competence: All three groups reported a high level of perceived competence. While both game groups reported a higher level of perceived competence, the differences were not significant; see Figure 8.
- Construct 3: Effort exerted: All groups reported that they exerted a very high level of effort in the activity. While the Super Saver group reported a slightly lower level of effort, the differences were not significant; see Figure 9.

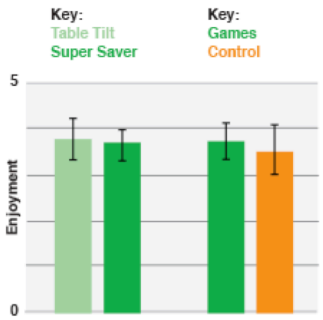

Figure 7 Interest/Enjoyment

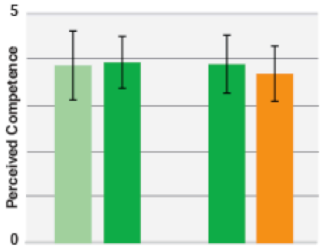

Figure 8 Perceived Competence

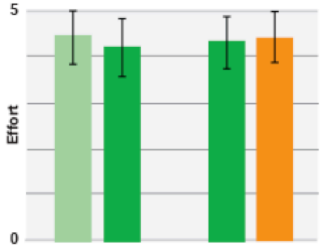

Figure 9 Effort Exerted

- Construct 4: Value/perceived usefulness: All groups reported a high level of perceived usefulness; the differences were significant among the three-groups $\chi^2(2) = 8.24$, $p = 0.016$ and between the combined game groups versus the Control group, $U = 83$, $Z = -2.32$, $p = .020$ with a medium effect size (r=-0.39). In both tests participants perceived standard therapy as *more* useful than games therapy; see Figure 10. The Super Saver scored the use of their game therapy lowest among the three groups.

- Construct 5: Pressure/tension: All three groups reported a similar (medium) level of pressure and tension; see Figure 11.

In sum, the only significant difference among the treatment and control groups was observed in the value/usefulness construct of SDT. While participants from all groups reported a high level of value/usefulness, the ranking of this construct is higher in the control group.

Table 2 Regression models examining individual differences

	$\chi^2_{(4)}$	*Pseudo* R^2	*Estimate*	*(SE)*	*Wald(1)*	*Sig*	*Exp B*	*95% CI*	
Model: Game Group	*6.93*	*.34*							
Age			-0.8	(0.04)	1.92	0.17	0.95	*.88*	*1.02*
BMI			0.0	(0.09)	0.02	0.88	1.01	*.86*	*1.19*
Gender			-2.4	(1.07)	5.01	0.03**	0.09	*.01*	*.74*
FIM			1.3	(0.89)	2.13	0.14	3.68	*.64*	*21.19*
Model: Control Group	*4.93*	*.24*							
Age			0.0	(0.03)	0.02	0.88	1.00	*.94*	*1.07*
BMI			-0.1	(0.09)	1.53	0.22	0.89	*.75*	*1.07*
Gender			-1.1	(1.40)	0.55	0.42	0.32	*.02*	*4.97*
FIM			-2.0	(1.03)	3.82	0.05**	0.14	*.02*	*1.01*

Notes. Both FIM and Gender were entered as binary categorical predictors. ** $p \leq .05$

Individual Differences

We conducted an ordinal regression to examine how age, gender, FIM score and BMI affected the overall positive motivation score for (a) the game group and (b) the control group. Neither model was a good fit (game group = χ^2 (4) = 6.93, $p = .140$, control group = χ^2 (4) = 4.93, $p = .295$); however, both models had a predictor that contributed significantly to the model, see Table 2.

In the game group (n = 17) the model predicted 34% of the scores correctly (Nagelkerke R^2). Gender contributed significantly to the model. As motivation increased, participants were statistically more likely to

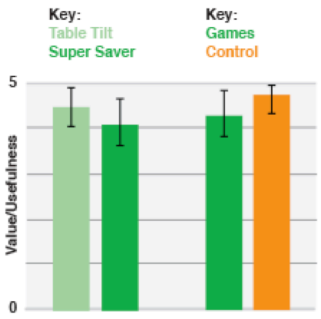

Figure 10 Value/Usefullness

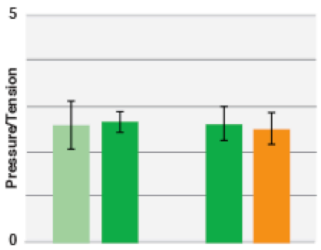

Figure 11 Pressure/Tension

be male. For males (n = 12) the average motivation score across the four constructs was 4.35/5 while for females (n = 6) the average score was 3.78/5. The odds of females having a higher intrinsic motivation score was 0.09 (95% CI, .01 to .74) times that of males (i.e. lower odds), a statistically significant effect, Wald $\chi^2(1) = 5.01$, $p = .03$.

In the control group (n = 18) the model predicted 24% of the scores correctly (Nagelkerke R^2). FIM's scores contributed significantly to the model. As scores for the four combined constructs increased, participants were statistically more likely to have a higher FIM score. For people who had a FIM score of 5-7 (n = 12) the average motivation score across the four constructs was 4.25/5 while people who had a low FIM score of 3-4 (n = 6) the average score was 3.96/5. The odds of people who had lower FIM scores having higher intrinsic motivation in the Control group was .14 (95% CI, .02 to 1.01) times of people with a higher FIM score (i.e. lower odds), a statistically significant effect, Wald $\chi^2(1) = 3.82$, $p = .05$.

Together, these findings indicated that while gender may be something therapists should consider when deciding to use CVEs in BI therapies; but patients with a range of FIM scores, age, and BMI appear to be somewhat equally motivated in the game group (unlike the control group where FIM appeared to play a role).

Discussion

We framed the following discussion around the three research questions that drove this study.

RQ1: Can CVE use result in an increased motivation over multiple sessions?
A qualified yes: when considering both the enjoyment and perceived competence motivation trends, there appeared to be a positive relationship indicating that some outpatients might view game therapy initially with trepidation, but that after four weeks their enjoyment increases (significantly in the case for Table Tilt) as their perceived competence to succeed playing the games increase. Additionally, the Table Tilt group reported decreased pressure and tension as competency increased. All of the significant findings had a medium or large effect size.

Together these trend findings have implications for both game therapy and the design of games to address BI therapies. First, therapists might expect (a) lower initial enthusiasm for game therapies when compared to standard care and (b) higher intrinsic motivation as their patients improve and build confidence. Second, the design of therapeutic exergames for BI needs to focus on games with appropriate and/or adjustable challenge ramps that allow patients to build their confidence in playing the game. This finding supports previous work by Alankus et al. [1-3] and Smeddinck et al. [37] in which adjustability of game challenge was an important consideration in their designs of custom games. However, the effect of adjustability on motivation still needs more exploration; Smeddinck et al. did not find consistent higher motivation when comparing adjustable games to non-adjustable games.

RQ 2: Can CVE use result in higher overall motivation?
A qualified no: when considering the overall motivation across multiple sessions there was very little indication that games were more intrinsically motiving than

standard care. This is partially due to the lower initial enthusiasm towards game therapies. While participants reported slightly higher levels of enjoyment, interest and perceived competence, they reported slightly lower levels of exerted effort and significantly lower levels of perceived value. This result indicated that for patients to find game therapy more intrinsically motivating than standard care they needed to believe that the games are helping them with their rehabilitation. This suggests there is a need for therapists to clearly communicate a game's contributory value to their therapies. Game designers should also consider the importance of clearly indicating how a game can improve the players' therapeutic outcomes.

RQ3: Are there mitigating patient factors associated with perceived motivation?
A qualified yes: when considering individual differences (FIM, age, gender and BMI) only gender uniquely contributed to the game model. Specifically, males had significantly higher combined intrinsic motivation scores than females in the combined gaming groups (and this was not true for the standard care group). This finding suggests that therapist may need to scaffold their female patients more in exergame therapies. Conversely, patients with a range of FIM scores, age, and BMI appear to be somewhat equally motivated in exergame therapies. However, regression findings should be interpreted with care because of (a) poor model fit and (b) gender bias in the study.

Conclusions, limitations and future work
Our findings indicated that CVE use is promising at increasing patients' motivation over time, throughout BI therapy periods. However, when considering how exergames might result in overall intrinsic motivations to engage in BI therapy, our findings were somewhat mixed. Because of the challenge of recruiting from this population, our sample sizes were often too small to see statistical significance in the group differences. Additionally, the differences between the two exergames groups (Table Tilt versus Super Saver) were confounded by the need to put patients with lower FIM scores in the former group. This study had several other limitations that should be addressed in future work:

- Working with Lovell FHCC introduced a limitation of gender; most of our population was male because of the large population of veterans.
- We only used two exergames; it is possible that individual game preferences would contribute to intrinsic motivation. For example, if a patient was a golfer, then a golf game might contribute more to intrinsic motivation than either of the exergames that the therapists choose.
- While the study was fairly long (4 weeks) we did not witness significant changing trends (first up then down) in the motivation constructs. We hypothesize that a reduced novelty of any exergame will lead to lowered intrinsic motivation over time. In other words, there might be a 'peak' time of motivation. This would be an important consideration for therapists when considering using exergames in BI therapies and should be explore in future work.

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