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Body in the interactive game: How interface embodiment affects physical activity and health behavior change

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ABSTRACT

Does the delivery platform for a health behavior game contribute to its effectiveness? With the growing popularity of interactive video games that combine physical exercise with gameplay, known as "exergames," there has been a burgeoning interest in their impact on users' exercise attitudes and behavioral outcomes. This study examines how the level of user interface embodiment, the degree to which the user's body interacts with the game, affects the user's experience, game behavior, and intention for behavior change. We conducted a between-participants experiment in which participants ($N = 119$) played an exergame under one of the three levels of user interface embodiment (low, medium, and high). Our results revealed a significant positive main effect of user interface embodiment on user experience (i.e., the sense of being in the game, "presence," and enjoyment); level of energy expenditure (change in heart rate); and intention to further engage in exergame-play exercise but not necessarily to increase exercise in the physical world. A further analysis revealed the mediating roles of user experience in the association between user interface embodiment and intention to repeat exergaming and a potential link between heart rate change and level of presence in the game. We conclude that type of interface is a key variable in this health communication environment, affecting user experience, behavior, and some intention for behavior change.

1. Introduction

Playing certain computer games can affect our behavior (Anderson & Dill, 2000; Lieberman, 2006; Squire, 2003). Taking advantage of this, within the class of serious games there are several games that attempt to change health behavior during the game or in real life after the game is played (Garn, Baker, Beasley, & Solmon, 2012; Lieberman, 2012; van Schaik, Blake, Pernet, Spears, & Fencott, 2008). One single behavior, level of exercise, is associated with many different disease outcomes. Not only is exercise good for general health and fitness, but also, in recent years, research has shown that exercise can increase neurogenesis (Rhodes et al., 2003). Despite this knowledge and despite recommendations by health professionals to increase physical activity, many people do not exercise. With recent advances in video game technology, however, we now have access to a variety of interactive video games that combine physical exercise with gameplay, called "exergames."

Exergames virtually guide players through various exercise regimens based on a player's level of ability and interest in various types of exercise. In most exergames, a virtual coach teaches and leads players as they perform exercises. Performance feedback is provided to the players to help them understand how well they are exercising. For example, video of player activity may be superimposed onto the game screen or 3D data about player activity may be integrated into the game in the form of a virtual avatar. Sound effects are used in some games to indicate when a player has the correct posture and balance, while in others, a virtual coach provides voice feedback to encourage the players or help them do a better job. Exergames can be deployed on many platforms, from mobile phones to virtual reality systems. Increasingly exergames involve the user's body in the game by using more embodied interfaces, such as augmented virtuality and augmented reality (Azuma et al., 2001; van Schaik et al., 2008).

This study addresses the following guiding research questions: (1) Do exergames and other health-related behavior games become more effective as interaction approximates actual physical activity by involving more of the user's body? (2) Does the interface

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platform itself, specifically the level of user interface embodiment, influence the psychology of the game and users' physical behavior, and does it contribute to greater persuasion and behavioral change?

More specifically, this study explores the following:

(a) Does the level of user interface embodiment associated with a game alter users' experiences in the virtual environment?
(b) Does the level of user interface embodiment significantly affect users' physical activity; in this case, exercise intensity (i.e., energy expenditure)?
(c) Will increased user interface embodiment lead to stronger intentions to engage in the modeled behaviors (i.e., exercise) in the future?
(d) What are the key mediators in a user experience that augment users' intentions to engage in behavioral change after the game?

2. Using computer games to change health behavior

2.1. Media in health behavior interventions

Since the rise in obesity cases over the past few decades (Boughter, 2006), there has been a growing interest in creating effective health communications that increase physical activity, improve diets, and change overall negative health behaviors. Studies have looked at past efforts to bring about change through a variety of media, including print, telephone, television, Internet, and mass media campaigns.

All of these media have had moderate success in the short term with participants who are already motivated, but generally failed to stimulate and affect long-term behavior change (Marshall, Owen, & Bauman, 2004). For example, Marcus, Owen, Forsyth, Cavill, and Fridinger (1998) showed that while recall was high with mass media, there was a lack of significant behavior change. Further studies showed that tailoring messages specifically to an individual's own current behavior was more effective than typical, general health communications (Bock, Marcus, & Pinto, 2001; Kreuter & Strecher, 1996).

Immersive and interactive virtual environments have the ability to influence learning by offering situated learning and applicable lessons (Dede, 2009). Thus, while traditional media often fail to provide effective messages for behavioral change (Schooler, Chaffee, Flora, & Roser, 1998), virtual environments afford interaction with (not just observation of) specific, targeted messages that can reach a massive audience (Fox, 2010). They provide the necessary elements outlined by social cognitive theory (Bandura, 1977) to bring about change.

2.2. Getting the body into the game: user interface embodiment and cognition

Does the interface platform matter in experience? There is a big difference in user experience between a book that describes how to play to tennis and a full body simulator that takes the user's body through the experience, and there is ample evidence in the psychological and neuroscience literature on the role of the body in cognition. Embodied cognition research indicates that the sensory disposition, movement, and extension of the body can affect user's perceptions, experience, decisions, and learning (e.g., Bohil, Alicea, & Biocca, 2011; Klemmer, Hartmann, & Takayama, 2006; Wilson, 2002).

There is a current trend to make gaming interface platforms increase the level of sensory immersion and motor immersion. For example, some games utilize common technologies like picture-in-picture video or sound effects while others use highly sophisticated techniques to record and interpret players' full body motions and nonverbal behaviors (Won, Yu, Janssen, & Bailenson, 2013). Biocca (1997) calls this variability in interface sophistication "progressive embodiment" and defines it as the "steadily advancing immersion of sensorimotor channels to computer interfaces through a tighter and more pervasive coupling of the body to interface sensors and displays" (section 2, para. 3).

User interface embodiment refers to the degree to which the user's body is coupled to the interface. This is influenced by three aspects: sensory immersion, motor immersion, and the representation of the user's body. By sensory immersion we mean the range of sensory modalities (i.e., vision, auditory, touch, etc.) and the sensory richness within each modality (i.e., fidelity and sensory range such as amount of the visual field). Motor immersion is the degree to which the body (motor system) is engaged by the interface. For example, a mouse pointing device only engages one hand within a very limited range of 2D interaction. By contrast, some virtual reality systems can record and respond to the full range of a user's body motions.

2.3. Augmented virtuality in exergames

Within the class of interfaces that enhance user embodiment are so-called "augmented virtuality" (AV) interfaces. These are part of an emerging suite of technologies (including interactive user interfaces, photorealistic 3D graphics, motion input devices, and hands-free input devices) that inject elements of the real world into virtual reality spaces to create mixed reality environments (Milgram, Takemura, Utsumi, & Kishino, 1994; Simsarian & Akesson, 1997). Such environments can produce a strong sense of interactivity, presence, and feedback for the player (Kim, Lee, Gramzow, & Biocca, 2012).

Modern exergames exemplify the idea of AV, and normally consist of a virtual environment that is augmented in various ways by elements of the real world. Exergames often combine real and virtual images by enabling video capture or real-time 3D sensing of whole body motions and nonverbal behaviors (Won et al., 2013). Furthermore, the ability to analyze and interpret body movements in real time allows body motion to be used as player input in many exergames. This can be done with motion input devices like balance boards and accelerometer-based hand controllers, as well as with infrared (IR) camera systems. These input systems introduce real-world events (not just images) into the virtual environment and allow exergame systems to understand and respond to player gestures and exercise movements (Won et al., 2013). Feedback to the player can include visual, auditory, and sometimes even tactile feedback, injecting some aspects of the virtual environment back into real space.

3. Effects of user interface embodiment on gameplay outcomes

3.1. Sense of being in the game: presence

It is widely argued that one goal of immersive technologies like virtual reality and augmented virtual reality is to create the illusion that one is "there" in the virtual environment, a psychological illusion called *presence*. Zeltzer (1992) suggests that presence reflects a match between the human senses and virtual inputs or outputs such as visual displays, sound reproduction, and haptic or tactile input. In this way, presence is "a rough, lumped measure of the number and fidelity of available sensory input and output channels" (Zeltzer, 1992, p. 128).

Presence is a central concept for research on virtual environments and is concerned with both the sense of "being there" (spatial presence) and the sense of "being with someone" (social presence) (Heeter, 1992; Lombard & Ditton, 1997). Spatial presence refers to a state of consciousness in which users attribute the source of their sensations to the virtual environment, whereas social presence refers to the degree to which users feel access to the intelligence, intentions, and sensory impressions of others (Biocca, 1997). Substantial research has shown that realistic visual and auditory cues incorporated into video games, such as lifelike in-game characters, can enhance users' feeling of presence (Bracken & Skalski, 2009; Ivory & Kalyanaraman, 2007; Jeong, Biocca, & Bohil, 2012; Kim, Sears, Costa, & Biocca, 2013).

Because multi-sensory cues are a key feature of AV exergames, they are likely to increase a player's sense of presence. For example, Persky et al. (2009) employed two distinct virtual environments accommodating different learning modalities (self-driven vs. interactive learning activity) and showed that different configurations of the content and form in these environments influenced the user's sense of presence. Following from the logic of this research, we posit the following hypothesis regarding the users of exergames:

H1. Users of systems with higher levels of interface embodiment will experience higher levels of presence.

3.2. Immersed in the game: enjoyment

Enjoyment is another central concept in evaluating virtual environments, especially video games. A substantial body of research has explored enjoyment from a standpoint of Csikszentmihalyi's (1990) notion of "flow," the idea that enjoyment, a balancing act between challenge and ability, will put users into an engaged state where long periods of time seem to pass quickly as their attention becomes focused on the activity at hand.

Sweetser and Wyeth (2005) modified the original flow theory to create a general analysis tool for enjoyment in games. Their "GameFlow" measurement instrument includes various criteria for game enjoyment, including level of concentration required, level of challenge, and support for varying levels of player skill, control, clear goals, feedback, immersion, and social interaction. Krcmar and Renfro (2005) and others have developed similar measurement instruments over the years.

AV exergames achieve many of these flow-like criteria through their design. For example, they often include varying exercise difficulties, immersive control affordances, clearly delineated exercise routines and reward structures, and detailed feedback to the player about their performance. However, as has been noted, modern exergames vary in their level of interface embodiment and thus, in their potential to create feelings of enjoyment in players. Accordingly, we posit that:

H2. Users of systems with higher levels of interface embodiment will experience higher levels of enjoyment.

3.3. Effects of interface differences on physical activity

Interfaces that vary in their level of user interface embodiment usually differ in how they engage the user's body. For example, a mouse and keyboard-based tennis game engages only a few player behaviors (clicks and mouse movements). On the other hand, a tennis simulator affords many more physical behaviors (swinging, jumping, running, etc.). Therefore, interfaces that have higher user interface embodiment may draw more energy output from the user.

Sell, Lillie, and Taylor (2008) showed that in games designed to induce exercise, players with more playing experience expended more energy, had higher heart rates, and showed a higher level of exercise intensity than those with low playing experience. Similarly, Leatherdale, Woodruff, and Manske (2010) and Graves et al. (2010) concluded that participants who played games that required more active participation predictably resulted in more energy expenditure (measured by heart rate monitor) than those who played games that were inactive.

Though exergames at varying levels of interface embodiment may ask players to perform exactly the same physical exercises (in theory, asking them to expend exactly the same amount of energy), differences in the coarseness of user inputs and feedback suggest that higher levels of interface embodiment may lead to greater effort on the part of players and correspondingly more energy expenditure (e.g., a higher heart rate). Thus, the following hypothesis is proposed:

H3. Users of systems with higher levels of interface embodiment will yield greater energy expenditure.

3.4. Effects of interface differences on attitudes and behaviors in the real world

Attitudinal and behavioral changes can result from playing games, either as an intended outcome of the design (e.g., health or education games) or as an unintended side effect (e.g., aggressive behavior) (Anderson & Dill, 2000; Kim et al., 2013; Lieberman, 2006; Lieberman, 2012; Whitaker & Bushman, 2012). So-called serious games are a category of games specifically designed to change psychological states, attitudes, and/or behaviors (Ritterfeld, Cody, & Vorderer, 2009).

One possible route for attitudinal and behavioral change is related to the user's representation in the virtual environment (Lomanowska & Guitton, 2012). Seeing oneself, specifically one's virtual body, engaged in a behavior can facilitate changes in attitudes and behavior through modeling, rehearsal, and identification. For example, Kim et al. (2013) reported that participants who customized their own avatars showed less aggressive thoughts and behavior, and more prosocial behaviors than participants who played with an avatar that looked like them (created using photo capture of the player him/herself) or a generic character. Rosenberg, Baughman, and Bailenson (2013) found that players in a virtual reality game who were provided a "superhero" identity, given the ability to fly throughout a virtual city, and instructed to take on the search for a missing child were more likely to exhibit prosocial behaviors after play than those who were assigned to the more passive condition of riding as a passenger in a helicopter touring the city. Furthermore, Ahn, Bailenson, and Park (2013) found an impact on real-world behaviors after virtual interactions. For example, study participants who virtually chopped down a tree went on to reduce their paper usage in the real world.

Following from the logic of this research, we posit the following hypothesis regarding the users of exergames:

H4. Users of systems with higher levels of interface embodiment will show higher levels of intention to change behaviors: (a) increased intention to engage in exergame-play exercise; and (b) intention to engage in physical exercise.

3.5. Mediating roles of presence and enjoyment on behavioral intentions

Although many of hypotheses in this study are framed in terms of the technology, technology may not be the immediate factor in affecting behavioral change. It is more likely that the technology, specifically the level of user interface embodiment, shapes user experiences that can go on to change behavioral intentions and actual behaviors.

More specifically, to be "there" and engage in the virtual environment – to hold feelings of presence – is usually to have a more intense and memorable experience. The more present the user is in the virtual environment, in our case an exercise game environment, the more likely the experience might contribute to changes in behavioral intentions towards exercise.

Several studies have also demonstrated that users' level of enjoyment in a virtual environment can facilitate effective learning or healthy behavior change (Kirkley & Kirkley, 2005; Lieberman, 2006; Squire, 2003). A research study by Sell et al. (2008) supported this view by showing that there was a high correlation between enjoyment in the game and continued playing. This is indicative of the usefulness of video games in exercise. If exergames are enjoyable, players will be more likely to continue playing them or to seek enjoyment from non-game versions of the game activity, leading to healthy behavior outcomes from their play. If exergames enhance feelings of presence, players may similarly feel more engaged with the game and may exercise on their own outside of the game. Accordingly, two final hypotheses are proposed in this study:

H5. Participants who experience more presence will have (a) higher intention to engage in exergame-play exercise and (b) higher intention to engage in physical exercise.

H6. Participants who experience more enjoyment will (a) have higher intention to engage in exergame-play exercise and (b) higher intention to engage in physical exercise.

4. Method

4.1. Participants

A total of 119 participants from a large, urban university were recruited to voluntarily participate in the study. The participants consisted of 67 males and 52 females aged 18–42 ($M = 24.39$, $SD = 3.56$).

4.2. Stimuli

We created three levels of user interface embodiment using three types of exergaming systems (*Nintendo Wii*, *Nintendo Wii Fit*, and *Microsoft Xbox* 360 *Kinect*), resulting in three experimental conditions for low, medium, and high interface embodiment, respectively (Fig. 1; see the subsections below for details). We operationalized user interface embodiment by the level of sensory immersion (i.e., visual, auditory, and other perceptual cues) and motor immersion (i.e., sensing of the body and behavioral feedback). In all conditions, the games asked the same behavior from the user: to carry out an exercise based on instructions from a virtual personal trainer.

4.2.1. Low level of user interface embodiment: video feedback only

In the low interface embodiment condition, participants played the *Wii* personal training program which showed players a video of themselves on the screen (captured with a webcam installed on the *Wii* system). A virtual personal trainer instructed the player, and players used the video of themselves to judge how well they were exercising by comparing their own movements to those of the virtual trainer. Note that this was not a zero interface embodiment condition because the player video introduced elements of the real world into the game space.

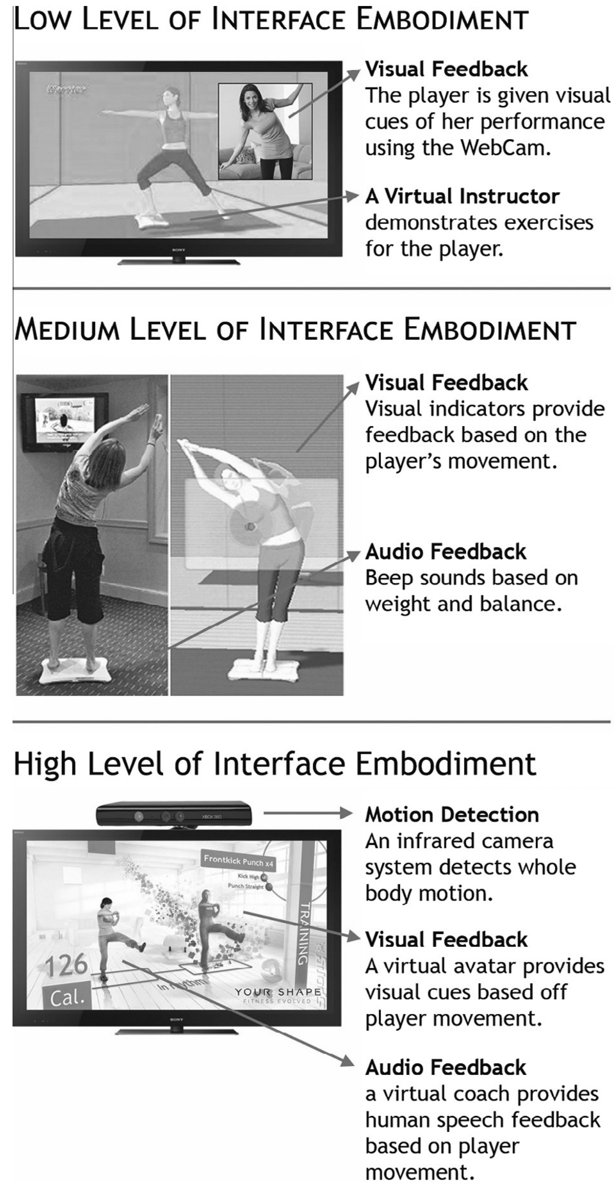

Fig. 1. Three different levels of user interface embodiment associated with the exergame considered.

4.2.2. Medium level of user interface embodiment: video feedback + single-point motion detection + (beep sound)

The *Wii Fit* personal training program (the *Wii* console plus a *Wii Balance Board* input device) was used for the medium interface embodiment condition. This configuration of the *Wii* provided players with a webcam-captured, self-body image as well as motion detection feedback based on their balance and weight. The game used a balance board device to measure the player's weight distribution and determine how balanced they were. The balance board also supported one-point motion detection. A 'beep' sound would tell players when they had achieved the level of balance requested by a virtual trainer, providing a fundamental "perceptual interface" (Reeves & Nass, 2000).

At the same time, captured webcam video helped players to match their body position to that of the trainer's. The posture balance and motion detection capabilities helped players avoid and correct misbehavior during gameplay. However, the balance board input device could not sense the player's true body position, so it remained up to the player to follow the virtual personal trainer as best they could, deciding for themselves with only beep feedback and the webcam image as a guide, if they were performing the on-screen exercises properly.

4.2.3. High level user interface embodiment: integrated avatar feedback + whole-body motion detection + (human speech sound)

The *Kinect* personal training program was used in the high interface embodiment condition. This system captures whole body motion and nonverbal behaviors using an IR camera system, providing players with integrated visual and auditory feedback, as well as real-time, whole-body motion feedback, through verbal prompts (e.g., providing human speech sound to adjust the player's behavior) and visual instructions (e.g., highly specific visual indicators on the player's avatar that compare the player's movements to the correct exercise movements).

Though the *Kinect* personal training program is a different game than the *Wii* personal training program, these two games are extremely similar in their design. The instructed exercises were uniform across all conditions, regardless of the specific game played, and the researchers configured each game before the study began to ensure that the participant experience was as identical as possible between conditions other than controlling for interface embodiment. The *Kinect* personal training program was selected for the high interface embodiment condition because it was able to do something the *Wii* could not: capture and analyse digital body position data using IR cameras. The *Kinect* game used captured video and 3D data to place a virtual avatar that looked just like the player into the game environment.

Unlike the video in the low and medium interface embodiment conditions, in the high interface embodiment condition the player's character was presented as an integral part of the virtual game space, and not as a breakout video box. In addition, the player's body position data were analyzed from the IR data and the game provided feedback based on the player's actual activity (not just balance or weight distribution). Voice prompts and visual cues (rather than simple beeps) helped participants to adjust their activities.

In summary, the high interface embodiment condition integrated the player's visual appearance and actual exercise activity directly into the game's virtual space, using technologies that allowed player feedback to be presented in a way that made it seem like "part of the game" and not simple video layered "on top of" the game. It is an acknowledged limitation to use two different games for this study, but great care was taken to ensure that the participant experiences, regardless of the game played, were as similar as possible.

4.3. Procedure

We conducted a between-subjects experiment with one factor (level of user interface embodiment) having three levels (low, medium, and high). Prior to the experiment, participants were asked to complete a pre-questionnaire which collected data such as age and gender, as well as the frequency of engaging in physical exercise (rated on 7-point scale). Participants were randomly distributed among three approximately equally-sized experimental groups: low ($n = 41$; age $M = 23.85$, $SD = 3.18$; male/female = 23/18), medium ($n = 38$; age $M = 25.42$, $SD = 4.77$; male/female = 24/14), and high ($n = 40$; age $M = 23.98$, $SD = 2.22$; male/female = 20/20).

Upon entering the laboratory, participants were asked to read and sign an informed consent form. Before the actual experiment, the participants' baseline heart rate was measured. The experimenter provided a basic gameplay tutorial to ensure they held a minimum level of gameplay competence. Participants then played the exergame for about 20 min. During gameplay, the experimenter was stationed outside the laboratory and visually monitored the participant through a window. The participants' heart rate was continuously recorded throughout the experiment. After finishing the gameplay session, participants were asked to complete a post-questionnaire. They were then debriefed and thanked for their participation. The complete experiment took approximately 50 min to 1 h.

4.4. Measures

4.4.1. Presence

The feeling of presence in the game was measured by one of its core sub-dimensions: spatial presence. In this study, spatial presence (Cronbach's $\alpha = .96$) was assessed using the 20-item questionnaire of the spatial presence factor used in the ITC-Sense of Presence Inventory (Lessiter, Freeman, Keogh, & Davidoff, 2001). Items were scored using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

4.4.2. Enjoyment

The level of enjoyment (Cronbach's $\alpha = .71$) was assessed using the 10-item questionnaire developed by Krcmar and Renfro (2005). Items were scored using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

4.4.3. Energy expenditure

The level of energy expenditure was assessed by measuring the change in heart rate using a Biopac system with the AcqKnowledge 4.2 software (Biopac Systems Inc.). Participants' baseline heart rate was measured for about 5 min before beginning the gameplay session, and their heart rate was continuously measured throughout the duration of the gameplay session. While there are several ways to determine the relative change in heart rate from the baseline (e.g., see Wainer, 1991), in this study the change in heart rate (i.e., the level of energy expenditure) was determined by subtracting the mean baseline heart rate from the mean heart rate measured during gameplay.

4.4.4. Exergaming intention and exercise intention

The study adapted the questionnaires used in the study by Jin (2010) to assess exergaming intention (Cronbach's $\alpha = .90$) and exercise intention (Cronbach's $\alpha = .84$). Both measures were scored using a 5-point Likert scale ranging from 1 (*lowest*) to 5 (*highest*).

5. Results

The three experimental groups did not statistically significantly differ in age ($F(2,116) = 2.38$, $p = .10$, partial $\eta^2 = .04$), gender (male-to-female ratios; $\chi^2 = 1.37$, $df = 2$, $p = .50$), and the frequency of prior physical exercise ($F(2,118) = 1.71$, $p = .19$, partial $\eta^2 = .03$). An analysis of variance (ANOVA) was conducted to examine the effects of user interface embodiment on participants' presence, enjoyment, and energy expenditure, as well as exergaming intention and exercise intention while playing the exergame. In addition, Preacher and Hayes' (2008) SPSS macro was utilized to test the mediation effects of presence and enjoyment on exergaming intention and exercise intention.

5.1. Effects of interface differences on presence and enjoyment

H1 predicted that higher levels of user interface embodiment would produce more presence than lower levels. The results of ANOVA indicated that there was a very significant main effect of user interface embodiment on presence, $F(2,112) = 28.11$, $p < .001$. As shown in Fig. 2(a), post hoc comparisons using the least significant difference (LSD) test revealed that the mean score for the high user interface embodiment group was very significantly greater than those for the medium embodiment group ($p < .001$) and for the low embodiment group ($p < .001$). These comparisons also showed that the mean score for the medium embodiment group was very significantly greater than that for the low embodiment group ($p = .002$). Therefore, H1 was fully supported.

H2 predicted that higher levels of user interface embodiment would produce more enjoyment than lower levels. The results of the ANOVA indicated that there was a significant main effect of user interface embodiment at the $p < .01$ level on enjoyment, $F(2,72) = 6.97$, $p = .002$. As shown in Fig. 2(b), post hoc comparisons using the LSD test revealed that the mean score for the high user interface embodiment group was very significantly greater than those for the medium embodiment group ($p = .006$) and for the low embodiment group ($p = .001$); however, the difference in the mean score between the medium and low embodiment groups was not statistically significant ($p > .05$). Therefore, H2 was partially supported.

5.2. Effects of interface differences on energy expenditure

H3 tested the effect of user interface embodiment on participants' energy expenditure, which was assessed by the increase in average heart rate from before the exergame to during the exergame. Recall that participants were instructed to perform identical exercise routines in each condition. Despite this similarity in instructed physical effort, results showed that there was a very significant main effect of user interface embodiment on energy expenditure, $F(2,108) = 9.68$, $p < .001$. As shown in Fig. 2(c), post hoc comparisons using the LSD test revealed that the change in heart rate for the high user interface embodiment group was significantly higher than that for the medium embodiment group ($p = .040$) and very significantly higher than that for the low embodiment group ($p < .001$). These comparisons also showed that the change in heart rate for the medium embodiment group was significantly higher than that for the low embodiment group ($p = .025$). Therefore, these results supported H3, which predicted that higher levels of user interface embodiment would yield higher energy expenditure during playing the exergame than lower levels.

5.3. Effects of interface differences on behavioral intentions

H4a predicted that higher levels of user interface embodiment would produce a higher exergaming intention than lower levels. The results of the ANOVA indicated that there was a significant main effect of user interface embodiment at the $p < .01$ level on exergaming intention, $F(2,115) = 5.67$, $p = .004$. As shown in Fig. 2(d), post hoc comparisons using the LSD test revealed that the mean score for the high user interface embodiment group was significantly greater than that for the medium embodiment group ($p = .018$) and very significantly greater than that for the low embodiment group ($p = .002$); however, the difference in the mean score between the medium and low embodiment groups was not statistically significant ($p > .05$). Therefore, H4a was partially supported.

H4b predicted that higher levels of user interface embodiment would produce higher exercise intention than lower levels. The results of the ANOVA indicated no significant main effect of user interface embodiment on exercise intention, $F(2,114) = .28$, $p > .05$ [also see Fig. 2(e)]. Therefore, H4b was rejected.

5.4. Mediating effects of presence and enjoyment

H5 predicted that participants who experienced more presence would have (a) higher exergaming intention and (b) higher exercise intention. Results from the mediation analysis indicated that the sense of presence was a mediator of user interface embodiment on exergaming intention [i.e., its bias-corrected 95% confidence interval (CI) did not contain zero, as presented in Table 1], but not on exercise intention. Thus, only H5a was supported.

Fig. 3(a) shows a path model illustrating the associations among user interface embodiment, presence, and exergaming intention. As can be seen in this model, user interface embodiment significantly accounts for variability in presence, which, in turn, significantly accounts for variability in exergaming intention when controlling for embodiment level.

H6 predicted that participants who experienced more enjoyment would have (a) higher exergaming intention and (b) higher exercise intention. Similar to the case of presence, the results for enjoyment indicated that there was a mediating effect of enjoyment on the relation of user interface embodiment with exergaming intention (see Table 1), but not with exercise intention. Thus, only H6a was supported.

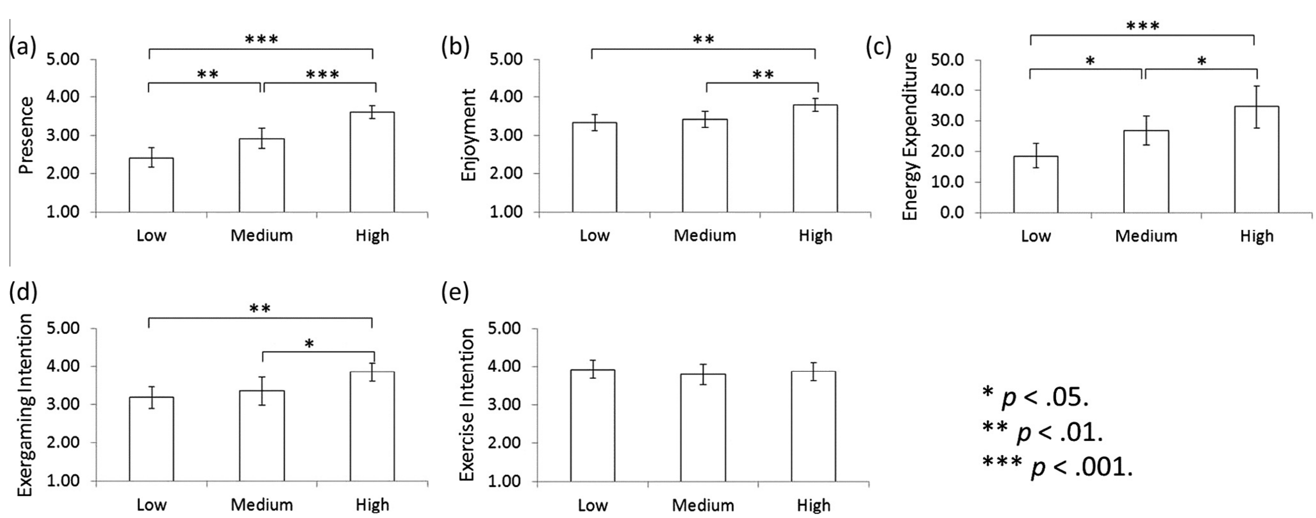

Fig. 2. Means (and 95% confidence intervals for the means) of the dependent variables at different levels of user interface embodiment: (a) presence, (b) enjoyment, (c) energy expenditure, (d) exergaming intention, and (e) exercise intention.

Table 1
Indirect effects of user interface embodiment level on exergaming intention: (a) through presence and (b) through enjoyment.

	Point estimate	Product of coefficients		Bias-corrected 95% CI	
		SE	Z	LL	UL
(a)	.47	.09	5.39	.31	.66
(b)	.28	.09	3.14	.13	.48

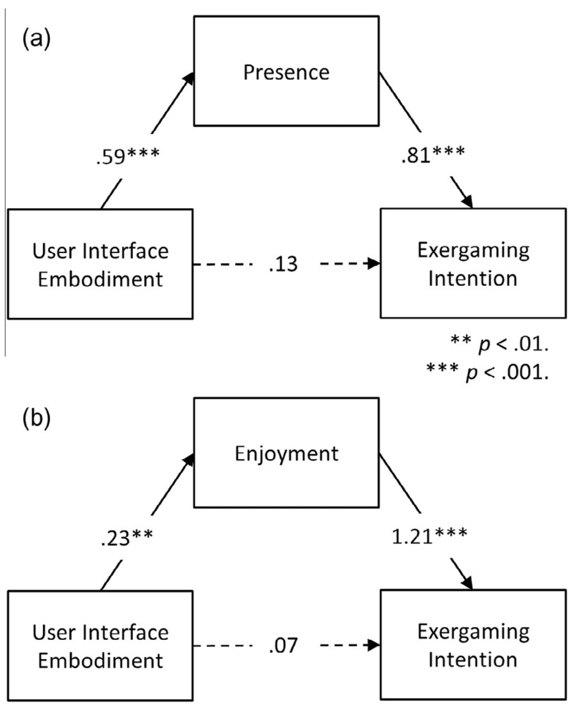

Fig. 3. Mediation models: (a) presence and (b) enjoyment.

Fig. 3(b) shows a path model illustrating the associations among user interface embodiment, enjoyment, and exergaming intention. As indicated in this model, user interface embodiment significantly accounts for variability in enjoyment, which, in turn, accounts for variability in exergaming intention; however, when enjoyment was included as a predictor, the effect of user interface embodiment on exergaming intentions was significantly attenuated.

6. Discussion

6.1. User interface embodiment impacts player experience and energy expenditure

The type of interface appears to significantly influence the modeling and experience of mediated behaviors (in this case, exercise). Notably, the sophistication of the high user interface embodiment technology made the experience more realistic and enjoyable for participants.

More embodied interfaces change user experience, the sense of realism, and enjoyment. Our results revealed that the level of user interface embodiment increased the degree to which participants felt they were "in the game," that is they were positively engaged with the virtual environment. When the technology included more interactivity such as whole-body motion detection rather than single-point motion detection, participants felt more present in the virtual environment. In addition, higher levels of interface embodiment (e.g., integrated avatar feedback) made the game more pleasurable, maybe motivating participants to exercise more rigorously. It is also likely that the higher levels of feedback helped participants to feel more engaged with and interested in the exercise routine.

The level of interface embodiment affects real-world behavior. Results showed that the level of user interface embodiment associated with the exergame increased real-world energy expenditure, as measured by change in heart rate. Participants' cardiovascular arousal was higher as the level of interface embodiment increased, with single-point motion detection and simple 'beep' audio feedback resulting in lower energy expenditure than full-motion body detection with avatar and voice feedback, despite the fact that each user interface embodiment condition asked participants to do the same exercise routine. Simply put, greater user interface embodiment through higher fidelity input and feedback channels led participants to exercise harder.

Ultimately, differences in user interface embodiment significantly altered the physiological state of the user (i.e., increased heart rate), with cardiovascular reactivity increasing linearly as the technology engaged the body more directly and became more sophisticated in the interaction.

6.2. User interface embodiment has limited effects on behavioral intentions

Do changes in user interface embodiment transfer to behavior change inside and outside the game? This was measured using self-reported behavioral intention, and results indicated that more immersive interface features increased participants' intentions to engage in exercise inside the virtual world (i.e., to play the exergame again in the future). However, this did not translate into intentions to increase their exercise activity outside of the game environment.

This may be because the technology itself, no matter the level of user interface embodiment, does not contribute to changes in behavior or it may be that the sophisticated user interface embodiment of the exergame caused players to look upon the game as a desirable alternative to "real world" exercise. Another possibility is that the time participants spent inside the virtual environment (i.e., the dosage) was not sufficient to translate into better exercise habits and intentions that might translate in time to exercise in the physical world.

In other words, when looked at from the point of view of gross energy used (as measured by change in heart rate), participants did exercise harder inside the virtual environment and formed stronger intentions to exercise again using the technology when user interface embodiment was high. However, these behavioral and behavior–intention effects did not generalize beyond the exercise game environment to impact broader intentions to exercise in the real world.

6.3. Presence may be associated with increases in heart rate

Feeling that you are inside a realistic virtual environment increases your physical response (heart rate) to the experience. Results showed that participants who experienced more presence in the game were more likely to exert greater effort in the game [compare Fig. 2(a) with Fig. 2(c)]. This may suggest that physiological arousal during gameplay is correlated with the participants' reported experience of being present in the virtual environment: i.e., their sense of being spatially there in the environment, being engaged with the content, and perceiving the environment as realistic.

This finding is consistent with previous studies (Grigorovici, 2003; Meehan, Insko, Whitton, & Brooks, 2002) that indicate that heart rate change can serve as an objective indicator of presence in virtual environments, where these environments are intended to be physically or emotionally stimulating (i.e., most games and simulations). Measures of heart rate have been in widespread use in the social sciences for studies of the relationships between physiological and psychological states (Berntson et al., 1997; Ravaja et al., 2006). In a seminal review, Grigorovici (2003) highlighted the relationship between presence and physiological responses, stating that, "emotional responses mediate increases in heart rate," (p. 197). Meehan et al. (2002) also found that there was a possible relationship between heart rate change and presence in a stressful virtual environment.

6.4. Feeling present in and enjoying the virtual world are related to behavior intentions

In this study, the participants' experience of being present in and having fun with the virtual environment was related to the intention to repeat the behavior (i.e., intention to play the exergame again), but not to the intention to increase exercise in real life. In other words, the more participants felt present in and enjoyed the virtual environment the more likely they were to report intentions to exercise again inside the game environment. It appears that both presence and enjoyment are mediating variables related to these behavioral-intention outcomes.

The present study suggests that user interface embodiment is likely to affect user behaviors within the virtual environment. Specifically, we saw that a game intended to stimulate exercise did increase physical effort (i.e., an increase in energy expenditure), as well as the perception of being inside a realistic virtual environment. These effects predicted the intention to repeat the gameplay experience (along with its attendant exercise activities), but not necessarily the intention to exercise more broadly outside the virtual space.

Previous research has shown that exergaming can be more enjoyable than walking or jogging on a treadmill (Graves et al., 2010), which has important implications for users' enjoyment and for reducing the economic burden of exercise. By replacing treadmills, expensive weight and exercise machines, and rising gym membership costs with relatively inexpensive gaming consoles and games, exergames provide greater ease of access to exercising. Using this emerging media to increase people's fitness levels may be one way to improve preventative healthcare services by making them more fun and economical.

7. Conclusions

This study illustrates how level of interface embodiment is a key design variable in the creation of successful serious games and simulations, especially those that model physical behavior. Findings suggest that the level of user interface embodiment improves user experience, energy expenditure, and intention to repeat the experience inside the game (i.e., exergaming intention), but not necessarily to change one's behavior outside the game (i.e., exercise intention). Further analysis reveals that perceived realism (presence) and enjoyment mediate the desire to repeat the experience, but there was no supporting evidence for the transfer of this perceived experience to a desire to increase "real world" exercise. On the other hand, some augmented virtuality exergames could become an adequate substitute for players lacking the motivation to engage with exercise outside of a game environment. Generalizing to other games that simulate physical behavior, it is likely that some of these effects are likely to be found in the design and effectiveness of different genres of serious games. The role of the interface has implications for the design and effectiveness of serious games in general and health games specifically.

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