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Physiological Responses to Perceived Exergame Task Demands


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by


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This thesis is dedicated to the movers, shakers, and dreamers. They make the world go 'round.

ABSTRACT


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Exercise videogames are increasingly popular as individuals seek to increase daily exercise. This study assessed physiological reactions to perceived task demands from a virtual exercise game and their influence on exercise during the following week. Participants completed a biking task in a virtual environment with an avatar that they were told would slim if they cycled fast enough (low task demand manipulation). Only half of participants' avatars actually slimmed (high task demand manipulation). Individuals with high exercise self-efficacy (ESE) showed similar results in both task demand conditions with high levels of work output and cardiovascular reactivity patterns indicative of threat. However, individuals with low ESE with an avatar that remained constant (high task demand) worked less hard and completed less exercise than those with low ESE who observed their avatar slimming. Results confirm that high task demands for those with low ESE levels can be particularly damaging by reducing future exercise levels.

The United States is facing an obesity "epidemic" (Callahan, 2013) with many

clinicians, researchers and doctors citing the lack of regular exercise as a leading contributor

(Kaminsky et al., 2013). According to the Centers for Disease Control (CDC), adults should

complete 2.5 hours of exercise per week, but only 48% of adults meet this guideline (Centers

for Disease Control, 2012). While many people know exercise is important for maintaining a

healthy weight and lifestyle, many do not perform the recommended amount because they

find it difficult, boring, or hard to schedule (Johnston, Massey, & DeVaneaux, 2012). To

make exercise more enticing and enjoyable, companies like Microsoft and Sony have

designed exercise based videogames that mentally and physically engage the user. Although

these exergames have proven to be popular and lucrative for their respective companies,

research on the effectiveness of using these exergames has been mixed, with some actually

showing negative consequences of use (Song, Kim, & Lee, 2011). In the current research, we

tested the hypothesis that perceived task demands during an exergame interacts with an

individual's exercise self-efficacy level to influence cardiovascular responding and future

exercise levels (see Figure 1).

We first provide a review of exercise self-efficacy and self-efficacy more broadly,

followed by a review of the literature on exergames and how the outcome of exergame use is

influenced by exercise self-efficacy. Finally, we present an overview of the biopsychosocial

model of challenge and threat (Blascovich, Mendes, Vanman, & Dickerson, 2011) as a

means for assessing reactions to perceived exergame task demands.

### Self-Efficacy and Exercise Self-Efficacy (ESE)

Most people strive to see themselves as generally good, efficacious, and able to effect

change in the world around them (Taylor & Brown, 1988). An individual's belief that he or

she has the ability to successfully complete tasks and accomplish goals reflects high self-

efficacy (Bandura, 1982). According to Self-Efficacy Theory, an individual must believe he/she is capable of performing a task well to perform well (Bandura, 1982). Many factors are considered by individuals when assessing their own efficacy level including the appraisal and integration of past accomplishments, social and verbal persuasion and feedback, vicarious experiences, and physical and emotional states (Samson & Solomon, 2011). Although many factors influence efficacy levels, research indicates that an individual's general efficacy level is relatively stable over time (Strecher, McEvoy, Becker, & Rosenstock, 1986; Chen, Gully, & Eden, 2001). However, if individuals are faced with information that calls into question their efficacy for a given task, one way they may maintain high self-efficacy is to re-evaluate task demands and available resources such that the level of demands is equal to or lower than available resources (Chemers, Hu, & Garcia, 2001; Feltz, Short, & Sullivan, 2008).

Even as individuals have a general level of efficacy, Bandura (2006) clearly stated that individuals also have specific efficacy levels for a variety of tasks, including exercise. Exercise self-efficacy (ESE) is an individual's belief that he or she can complete an exercise routine even in the face of stressors or detractors (Bandura, 2006). Hence, ESE levels are generally associated with perceptions of greater resources relative to situational demands, allowing for adaptive coping with potentially stressful stimuli (Chemers et al., 2001). High ESE levels are also associated with a host of daily positive outcomes and behaviors including persisting longer at physical tasks, exercising more, being more likely to pursue challenging goals, cope with pain, and persevere through setbacks (Chuang, Chang, Lee, Chou, & Doong, 2003; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Llewellyn, Sanchez, Asghar, & Jones, 2008; Hankonen, Absetz, Ghisletta, Renner, & Uutela, 2010). Importantly, since past accomplishments and physical states from daily experiences can

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influence ESE levels, perceiving or receiving negative feedback while playing an exergame could result in lower ESE levels and subsequently less exercise.

### ESE and Exergames

Exergames, or exercise video games, come in many forms including Dance Dance Revolution, the Wii Fit suite, Zumba for PlayStation, and many more (see Cornick & Blascovich, in press for a review). Exergame platforms vary widely in the type of user input used to track movement from joystick to infrared camera to weight sensitive pressure pad. What is common among all types of exergames however is that game progress is measured by the amount and type of movement generated by the user.

Even though exergames have only recently become commonplace in American homes, much research points to their benefits over more traditional exercise routines (Rizzo, Lange, Suma, & Bolas, 2011). For example, exergames allow users to review their movements for accuracy as well as obtain different perspectives of their avatar allowing for review of their own movements from multiple angles. These inherent exergame functions have been shown to increase the accuracy of newly learned exercise movements (Bailenson et al., 2008). Use of exergames has also been shown to increase intense exercise, intrinsic motivation, energy expenditure, positive mood, and energy levels (Chuang et al., 2003; Fox & Bailenson, 2009; Ijsselsteijn, de Kort, Westerink, de Jager, & Bonants, 2006; Legrand, Joly, Bertucci, Soudain-Pineau, & Marcel, 2011; Lyons, Tate, Komoski, Carr, & Ward, 2012; Porcari, Zedaker, & Maldari, 1998; Plante, Aldridge, Bogden, & Hanelin, 2003; Plante, Cage, Clements, & Stover, 2006; Russell & Newton, 2008). Researchers have posited that exergames influence these health outcomes because of the "Proteus Effect," or the idea that avatar behavior can inform a user's attitudes, motivations, and goals, and ultimately change the user's behavior in everyday life (Yee, Bailenson, & Ducheneaut,

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2009). For example, users whose avatars engage in healthy behaviors in Second Life are more likely to engage in exercise and other active behavior than users who have avatars that are less physically active (Dean, Cook, Keating, & Murphy, 2009).

Research during the last decade suggests that using exergames can also influence ESE levels. For example, Katula and McAuley (2001) conducted a study in which healthy participants exercised in front of or in the absence of a mirror. Compared to the no mirror condition, participants in the mirror condition reported increases in ESE immediately post exercise and twenty minutes later. However, a similar study found that women who exercised in front of a mirror had a maladaptive cardiovascular response pattern and decreased work output relative to women who exercised without the mirror (Cornick & Blascovich, 2015). Similarly, Song and colleagues (2014) found that visual reflection does not affect everyone positively. In their study of normal and slightly overweight individuals, participants played an exercise video game while seeing themselves on a television screen. Participants who were dissatisfied with their weight experienced decreased ESE, and decreased enjoyment following exercise (Simonavice, 2008; Song, Kim, & Lee, 2014; Song, Peng & Lee, 2011).

Although these results appear contradictory, the results can be explained by the presence or absence of heightened self-awareness in the user. The self directed awareness elicited by mirrors, exergames, and standing in front of a crowd can increase levels of self-evaluation by making the discrepancy between an individual's "ideal" and actual self more salient (Mead, 1934; Wickland & Duval, 1971). Discomfort is associated with awareness of the disparity between current and ideal selves and the discomfort grows proportionally with the discrepancy, motivating individuals to reduce the discrepancy (Higgins, 1989). Such motivation may consequently make the demands associated with reaching the goal more

salient. Therefore, individuals with increased self-awareness during performance tasks should perceive increased demands when compared to less self-aware individuals. Evaluations of situational demands and personal resources play a central role in CV reactivity to stressful tasks that ultimately influences an individual's ESE level.

**Biopsychosocial Model of Challenge and Threat**

The biopsychosocial model of challenge and threat (BPSCT) states that individuals exhibit varying patterns of psychophysiological reactions to stimuli based on their implicit and explicit evaluations of task demands and personal resources to meet those demands (Blascovich, 2008; Blascovich & Mendes, 2010). When individuals ascertain (either consciously or unconsciously) that they have greater resources than a performance task demands, they exhibit patterns of cardiovascular (CV) reactivity indicative of challenge. Conversely, if they ascertain that they do not have enough resources to meet task demands, they exhibit CV reactivity patterns indicative of threat. States of challenge and threat can be differentiated using four CV measures: heart rate (HR), ventricular contractility (VC), cardiac output (CO), and total peripheral resistance (TPR; cf. Blascovich et al., 2011).

Electrocardiography (ECG), continuous mean arterial blood pressure (MAP) measurement, and impedance cardiography (ICG) are used to quantify these four measures In addition to the four standard metrics, the current study also assessed rate pressure product (RPP) which is a metric of both energy consumption of the heart and stress in the cardiac muscle (Smith & Fernhall, 2010). Unnecessary effort and strain placed on the heart can have negative consequences for the CV fitness of threatened/stigmatized individuals (Kelsey, 2004; Blascovich, Mendes, Hunter, Lickel, & Kowai-Bell, 2001).

The BPSCT specifies that in a motivated performance situation (i.e., one requiring active coping), sympathetic neural activation results in increases in myocardial ventricular

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contractility (VC i.e., pre-ejection period (PEP)*-1) and HR. This reactivity pattern is common to both challenge and threat motivational states demonstrating that the individual is engaged in the motivated performance task. Given task engagement, when an individual's resources meet task demands (state of challenge), increases in released epinephrine cause decreases in arterial contractility resulting in lower TPR and increased CO. During a state of threat (evaluation of fewer resources compared with demands), cortisol is released in addition to the epinephrine resulting in little change or an increase in TPR and little change or decrease in CO (Blascovich, 2008; Mendes, Blascovich, Lickel, & Hunter, 2002). Although this pattern of physiological responding may be relatively harmless in the short term, the pattern of physiological responding to stressful stimuli is a significant predictor of an individual's future CV disease risk and CV health (Kelsey, 2004). Additionally, changes in these indexes have been shown to predict concurrent and future physical and cognitive performance in a variety of domains (see Blascovich, 2008; Blascovich & Mendes, 2010; Tomaka, Blascovich, Kelsey & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997).

Crucial to the current study, research testing the BPSCT during metabolically demanding tasks has shown that the CV system works harder but less efficiently for individuals experiencing greater task demands (Rouselle, Blascovich, & Kelsey, 1995). In their study, participants pedaled a stationary bike while simultaneously doing serial subtraction aloud showed greater CV response (CO, VC and HR) than during either task conducted alone (Rouselle et al., 1995). Similarly, when participants were asked to ride a stationary bike in front a mirror (versus no mirror), they exhibited threat reactivity profiles in reaction to the increased task demands and decreased personal resources associated with exercising in front a mirror (Cornick & Blascovich, 2015).

Combining knowledge from the BPSCT and exercise physiology literature, we predict that individuals exercising in a physiologic state of threat would exhibit a simultaneous increase in TPR and a decreases in CO, resulting in active muscles receiving less oxygenated blood. When muscles do not receive enough oxygen needed to produce adenosine triphosphate energy, lactic acid is produced, which accumulates in the blood stream signaling the need for anaerobic metabolism (Rowell, Taylor, Wang, & Carlson, 1964). Periods of anaerobic metabolism can be maintained for short periods of time (around a minute) before the individual fatigues, and during anaerobic metabolism carbohydrate stores are metabolized instead of fat stores in order to use available blood oxygen most efficiently (Wasserman et al., 2004). Therefore, individuals who exercise while in a state of threat place more stress on the heart, derive fewer CV and fat burning benefits, and cannot exercise as long as individuals in a state of challenge (Kelsey, 2004).

### Overview: ESE, Exergames, and BPSCT

Exercise self-efficacy levels are known to predict a host of positive daily outcomes by increasing perceived available resources. Individuals with high ESE levels perceive more available resources than individuals with low ESE levels (Chemers et al., 2001; Samson & Solomon, 2011). Additionally, although exergames are useful in that they encourage individuals to exercise, research on exergames and ESE suggests that increased self-awareness brought on by use of the exergame can make task demands more salient (Katula & McAuley, 2001; Song et al., 2011; Song et al., 2014). When tasks are relatively easy, an individual perceives low task demands; the opposite is true of more difficult tasks. The perceived ratio of personal resources and task demands determines whether an individual experiences positive or negative outcomes from exercise via the BPSCT (Blascovich, 2008).

The current study explored the interaction of ESE and perceived exergame task demands on BPSCT indices and completed strenuous exercise in a sample of women who reported being heavier than their ideal weight. In the lab, participants cycled on an ergometer in a digital virtual environment with an avatar that either appeared to slim down (fewer task demands) or not (more task demands) during the cycling while physiological responses were recorded. One week later, participants reported their average amount of exercise completed during the intervening week.

We hypothesized that individuals in the avatar slimming condition (fewer task demands) would show no differences in CV responding and future exercise as task demands stay low regardless of whether the participant has low or high ESE (low or high perceived resources respectively). However, for those in the avatar constant condition (more task demands) with low ESE, we hypothesized that they would exhibit a CV reactivity profile of threat and would show low levels of exercise (low resources and high task demands). Finally, for those in the avatar constant condition (more task demands) with high ESE, we hypothesized that they would exhibit a CV reactivity profile of challenge and would show high levels of exercise (high resources and high task demands; see Figure 1 for a theoretical model).

Importantly, due to the metabolically demanding nature of the task, the threat pattern of CV responses was expected to occur during the latter minutes of the task (minutes 3-5; Rouselle et al., 1995). Additionally, in typical BPSCT studies in which the participant is doing a task that is cognitively based, threat is indexed by no change or an increase in TPR values. However, when the task is metabolically demanding (as is the case with riding a stationary bike), BPSCT research shows that all individuals show a reduction in TPR and threat now becomes indexed by smaller reductions in TPR values (Tomaka et al., 1997).

**Method**

**Participants**

Eighty nine female undergraduates (44% White, 22% Hispanic/Latino, 19% Asian American, 15% Other or multiple ethnicities) from the Introductory Psychology and Experimental Psychology subject pool at the University of California, Santa Barbara (UCSB) were recruited to participate in exchange for course credit. The sample was restricted to women as weight stigma is more prevalent among women, and women are stigmatized at lower weights than men (Azarbad & Gonder-Frederick, 2010; Major, Hunger, Bunyan, & Miller, 2014). Importantly, participants were selected based on their perceived weight (versus their actual weight) because perceived weight normality is often more important in determining mental states than actual weight (Muennig, Jia, Lee, & Lubetkin, 2008). Therefore, only women who initially rated their current weight as above "ideal" were recruited to participate in the current study.

Participants ranged in age from 18 to 21 ($M$=18.74, $SD$=1.05) and their average BMI fell within the normal to obese range ($M$=23.34, $SD$=3.63, range= 14.42-35.41). Based on the Centers for Disease Control guidelines, 3.6% ($n$=3) were underweight, 65.9% ($n = 56$) were normal weight, 25.9% ($n = 22$) were overweight, and 4.7% ($n = 4$) were obese. Participants were screened for major heart conditions, medications, pregnancy, and other serious medical conditions.

**Design**

The current study involved two between-subjects factors -- perceived exergame task demands (low or high task demands) and ESE level (continuous) – and one within-subjects factor, time (5 min baseline 1, 5 min baseline 2, and 5 min task). During the task, each

participant cycled on an ergometer while immersed in a virtual environment. The two dependent measures were CV patterns and strenuous exercise completed the following week.

**Procedure**

Prior to arrival at the laboratory, participants completed a measure of perceptions of ideal body weight and ESE. In order to avoid influencing the physiological measures, participants were also asked to abstain from caffeine for at least two hours prior to the study (Astrup et al., 1990). Upon arrival at the laboratory, participants' height and weight were measured and CV leads and sensors were attached. Subsequently, the participant completed a seated, resting five-minute baseline period. The participant then sat on the ergometer and was immersed in the virtual environment (an exact replica of the laboratory). A second baseline period was conducted while participants sat on the ergometer without pedaling. The virtual world was then refreshed and participants were shown an avatar standing in the middle of the laboratory. Participants were told that the avatar "represents you and will reflect your hard work during the biking task. If you continue to pedal fast enough, she will lose weight." In actuality, only half of the participants completed the cycling task with an avatar that slimmed. The other half were assigned an avatar whose apparent weight remained constant throughout. Participants exercised at a constant 100-Watt workload for five minutes on an electronically-controlled upright pedacycle ergometer (Kettler Model E3; Rouselle et al., 1995). Finally, all sensors and leads were removed and participants were partially debriefed. One week later, participants were emailed a follow up survey that assessed daily average physical activity (Aahdahl & Jorgensen, 2003). Participants' were then fully debriefed.

**Measures**

**Weight Perception.** Perception of ideal body weight was measured via a single item during the pre-screening process. Participants were asked to rate themselves on a 1 to 7 scale, with "much thinner than ideal weight" at 1, "at my ideal weight" at 4, and "much heavier than my ideal weight" at 7. All participants rated themselves as a 5 or above (5: $n$= 45; 6: $n$= 26; 7: $n$= 11). Participant's BMI and perceptions of ideal body weight were significantly correlated ($r(80)$=.61, $p$ <.001).

**Exercise Self-Efficacy.** The Self-Efficacy to Regulate Exercise Scale (Bandura, 2006) required participants to rate how certain they were that they could perform their exercise routine three or more times per week given a number of common obstacles. All responses were given on an 11-point scale ranging from 0 (*Cannot do at all*) to 10 (*Highly certain can do*) after completing the stationary biking task. Reliability among items was (Cronbach's $\alpha$=.94). An average ESE value was calculated by taking the mean value of all 18 items (ESE $M$= 5.27, $SD$=1.81). Participant's ESE and BMI were significantly correlated ($r(83)$=-.24, $p$<.05), such that participants with higher BMI reported lower levels of ESE.

**Physiological Measures and Apparatus.** Physiological responses including heart rate (HR), stroke volume (SV), cardiac output (CO), pre-ejection period (PEP), and blood pressure (BP) were measured continuously and noninvasively throughout baseline and task period via a Biopac MP150 system with an Impedance Cardiograph and CNAP Monitor 500. Impedance cardiograph (ICG) and electrocardiograph (ECG) recordings provided continuous measures of cardiac performance (SV, HR, and CO). Two pairs of mylar tape band electrodes (separated by at least three centimeters) encircled the participant's neck and torso (thorax at the xiphisternal junction; Sherwood et al., 1990). These provided basal trans-thoracic impedance (Z0) data and the first derivative (dZ/dt) of pulsatile changes in transthoracic impedance, sampled at 1kHz. The electrocardiograph recordings were obtained

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with a Modified Lead II configuration (the right lead below the clavicle and the left lead on the left side of the torso below the ribcage). A 400 μA (rms) DC 50 kHz current passed through the two outer electrodes and measured impedance from the two inner electrodes.

The CNAP Monitor enabled collection of continuous noninvasive recordings of BP from the participants' left thumb. Data was integrated via the MP150 and displayed and stored with Acqknowledge software (Biopac; Goleta, CA). Mindware software (Gahanna, OH) was used to edit artifacts and ensemble and score the CV data in 60-s intervals. Four measures of cardiac performance: VC (PEP), HR, TPR (derived from BP and CO), and CO were used to distinguish between states of challenge and threat while RPP was assessed for its correlational strength with these four original measures. Scoring was performed blind to other participant data.

**Physical Activity Questionnaire.** One week after completing the exergame in the virtual environment, participants completed the Physical Activity Questionnaire (PAQ; Aadahl & Jorgensen, 2003) describing the total time spent on each of nine physical activity levels on an average day in the past week (24 hour total): 1-sleep or rest; 2- sitting quietly or watching television; 3- working at a desk or eating; 4- standing or driving a car; 5- light cleaning or walking downstairs; 6- biking to work or brisk walking; 7- gardening or carrying light objects upstairs; 8- aerobics or health club exercises; 9- running or racing at higher intensity than level 8. Responses were reported in 15 minute increments. Although all nine levels were collected, the levels of most importance were levels eight and nine that correspond to high-energy expenditure behavior, so a composite score was created by adding level eight and nine activity.

**Results**

**Preparation of Physiological Measures**

**Baseline Periods.** To ensure there were no differences in participants' physiological responses during the rest periods as a function of experimental condition, multiple t-tests were performed comparing minutes 4 and 5 of baseline 1 and 2 across all five physiological indicators (HR, VC (PEP), CO, TPR, and RPP). Across all 30 comparisons, 11 reached statistical significance (with baseline 1 values being lower). Because the baseline represents the lowest resting point, baseline 1 values were created by averaging baseline 1 minute 4 and baseline 1 minute 5 for each index (five baseline values were created, one for each index).

**Reactivity Values.** CV reactivity values were calculated by subtracting the baseline 1

value from each of the five biking task physiologic values, for a total of five reactivity values per index (25 total). Values exceeding $\pm$ 2.6 *SDs* from the mean ($p=.01$ in a normal distribution) were identified as extreme and were winsorized by assigning them a value 1% higher (or lower) than the next-highest value (Tabachnik & Fidell, 2013). Among the thousands of CV data points collected for this study, only 11 data points were winsorized.

**Task Engagement.** As task engagement is a pre-requisite for challenge and threat, we first examined whether participants were engaged in the biking task prior to testing for CO and TPR differences. Single-sample *t*-tests were used to assess whether HR and PEP reactivity values, which index task engagement (Blascovich, 2008), differed significantly from zero. In all task minutes in both exergame task demand conditions, task engagement was evidenced by significant increases in HR and VC reactivity (i.e., decreases in PEP from baseline) (all *t* tests significant at $p< .05$).

**Hypothesis A- ESE and exergame task demands interact to influence CV reactivity**

To test the interaction outlined in Figure 1 (ESE and exergame task demands condition on CV reactivity), moderated regressions were conducted on the last three task

minute values for the five physiological indices, with ESE values and exergame task demands condition entered on step 1 and the interaction (product term) entered on step 2. It was hypothesized that participants in the low task demand condition (avatar slimming) would exhibit BPSCT reactivity profiles of challenge, while participants with low ESE in the high task demand condition (avatar constant) would display a threat response and participants with high ESE in the high task demand condition (avatar constant) would display a challenge response.

### Analysis of Physiologic Measures to Test Hypothesis A

**Cardiac output.** At step 1 there was no main significant main effect of exergame task demands condition ($b$=.18, $p$=.97) or ESE ($b$=1.69, $p$=.27).Together these two predictors explained 1.7% of the variance in CO reactivity, $F(2,72)$=.62, $p$=.54.

At step 2, the interaction term ($b$=-1.97, $p$=.52) was non-significant and explained an additional .6% of the variance in CO reactivity, $F(1,71)$=.42, $p$=.52.

**Total peripheral resistance.** There was a significant main effect of exergame task demands condition on TPR, ($b$=170.91, $p$<.05). Participants in the high task demand condition (avatar constant) showed TPR reactivity in line with a challenge response [simple $b$= 58.41, $t(69)$=1.66, $p$=.10] while those in the low task demand condition (avatar slimming) showed TPR reactivity values in line with a threat response [simple $b$= -23.10, $t(69)$=-.67, $p$=.50]. There was no main effect of ESE level of TPR values, ($b$=16.84, $p$=.50). Together these two predictors explained 5.9% of the variance in TPR reactivity, $F(2,70)$=2.20, $p$=.12.

At step 2, there was a marginally significant interaction of exergame task demands and ESE level on TPR, ($b$=-81.51, $p$=.10), which explained an additional 3.6% of the variance in TPR reactivity, $F(3,69)$= 2.42, $p$=.10. To follow up on this marginal interaction,

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we computed the simple slopes relating ESE to TPR for those in the high task demand (constant weight avatar) or low task demand (slimming avatar) conditions. The differing exergame task demands impacted TPR reactivity values differed depending on levels of ESE. Participants with low ESE were strongly influenced by task demands - in the low task demand condition (avatar slimming) they had smaller reductions in TPR (indicating a state of threat) compared to the high task demand condition (avatar constant) [simple $b$=313.46, $t(69)$=2.58, $p<.01$] contrary to our hypothesis. No such relationship emerged for individuals with high ESE [simple $b$=28.13, $t(69)$=.23, $p=.82$] (see Figure 2).

**Rate pressure product.** There was a significant main effect of exergame task demands on RPP reactivity values, ($b$=1832.17, $p<.01$). Participants in the low task demand condition (avatar slimming) showed higher cardiac workload than participants in the high task demand condition (avatar constant). There was no main effect of ESE level on RPP reactivity, ($b$=97.56, $p=.51$). Together these two predictors explained 10.2% of the variance in RPP reactivity, $F(2,70)$= 3.99, $p=.02$.

At step 2, there was a significant interaction between exergame task demands and ESE level ($b$=-1080.54, $p<.01$; see Figure 3), which explained an additional 10.3% of the variance in RPP reactivity, $F(3,69)$=5.94, $p<.001$. Exercise self-efficacy level was an important factor for participants in the high task demand condition (avatar constant) [simple $b$= 648.71, $t(69)$=2.51, $p=.01$] such that participants with high ESE had higher cardiac workload than participants with low ESE. Exercise self-efficacy levels were marginally related to RPP reactivity for individuals in the low task demand condition (avatar slimming) [simple $b$= -431.83, $t(69)$=-1.71, $p=.09$]. Participants with low ESE had higher cardiac workload than participants with high ESE.

Finally, exergame task demands significantly impacted RPP reactivity values differently for participants with low ESE. Participants with low ESE in the low task demand condition (avatar slimming) had significantly higher cardiac workloads than participants in the high task demand condition (avatar constant) [simple *b*=3721.99, *t*(69)=4.18, *p*<.001]. No such relationship emerged for individuals with high ESE [simple *b*=-60.70, *t*(69)=-.07, *p*=.95].

**Hypothesis B- Relationship between ESE and exercise mediated by CV reactivity**

To test the model outlined in Figure 1, moderated mediation models were conducted using the SPSS package PROCESS (Hayes, 2012). We hypothesized that the relationship between ESE and strenuous exercise would be mediated by CV reactivity, and that this mediated relationship would be moderated by exergame task demands condition. We hypothesized that individuals with threat CV reactivity patterns (smaller reduction in TPR and lower CO) would show reduced strenuous exercise in the week following the experiment. We were also interested in how RPP reactivity values may influence exercise levels. As such, we also tested RPP in a moderated mediation model. We modeled three separate moderated mediation models: CO, TPR, and RPP (Hayes, 2015).

**Analysis of moderated mediations models to Test Hypothesis B**

**Cardiac output.** The indirect effect of ESE on follow-up exercise through CO reactivity was not moderated by exergame task demands condition, slope= -.01(.04) CI: -.11, .07 (Hayes, 2015). Additionally, CO reactivity did not significantly predict strenuous exercise (*b*=.01, *p*=.19), and the relationship between ESE and strenuous exercise (total effect: *b*=.28, *p*<.05) was not mediated by CO reactivity (remaining indirect effect*: b*=.25, *p*<.05).Taken together, these results suggest that CO reactivity alone does not explain exercise in the week after the experiment.

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**Total peripheral resistance.** The indirect effect of ESE on follow-up exercise through TPR reactivity was not moderated by exergame task demands condition, slope= -.10(.06) CI: -.22, .01 (Hayes, 2015). Additionally, TPR reactivity did significantly predict strenuous exercise in the following week ($b$=.001, $p$<.05). Participants with more negative TPR reactivity (state of challenge) exercised more in the following week. Finally, the relationship between ESE and strenuous exercise ($b$=.28, $p$<.05) was not fully mediated by TPR reactivity ($b$=.24, $p$<.05).

**Rate pressure product.** The indirect effect of ESE on follow up exercise through RPP reactivity was not moderated by exergame task demands condition, slope= -.04(.08) CI: -.19, .12. Additionally, RPP reactivity did not predict strenuous exercise in the following week ($b$=.0001, $p$=.59). Finally, the relationship between ESE and strenuous exercise ($b$=.28, $p$<.05) was not mediated by TPR reactivity ($b$=.26, $p$<.05).

## Discussion

We hypothesized that individuals in the low task demands condition (avatar slimming) would show no differences in CV responding or exercise levels. However, for those in the high task demands condition (avatar constant) with low ESE, we hypothesized that participants would exhibit a CV reactivity profile of threat and would show low levels of exercise (few perceived resources and high task demands due to increased perceived task demands). Finally, for those in the high task demands condition (avatar constant) with high ESE, we hypothesized that participants would exhibit a CV reactivity profile of challenge and would show high levels of exercise (many perceived resources and high task demands due to increased perceived task demands). Results deviated from our hypotheses but yielded interesting results. Individuals with high ESE (high perceived resources) had similar outcomes regardless of exergame task demands: higher threat response (TPR), and a modest

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amount of cardiac work (RPP). In contrast, participants with low ESE (fewer perceived resources) were significantly influenced by exergame task demands. Participants with low ESE in the low task demands condition (avatar slimming) had highest levels of threat responding (TPR) and the highest cardiac workload (RPP) while those in the high task demands condition (avatar constant) had the largest reduction in TPR (signaling challenge) and lowest levels of cardiac workload (RPP).

Our findings support previous research that self-awareness (and therefore task demands) during exercise and exergames is not beneficial for all. For individuals with high ESE in our study, the exergame task demands did not influence their physiological responding, similar to Katula and McAuley's (2001) findings that ESE increased after exercising in the mirror among healthy participants. However, our differential findings for those with low ESE support the findings of Cornick and Blascovich (2015) and Song, Kim, and Lee (2014), which outlined negative effects for those with body dissatisfaction. Going forward, the design of exergames should account consider demands being placed on the user and strive to ensure that users at all skill and resource level will be able to complete the game demands. Our findings support the assertion that perceived exergame task demands can have negative outcomes for those with body image dissatisfaction by influencing perceptions of task demands and resources.

Additionally, as shown by in previous research assessing BPSCT outcomes in metabolically demanding tasks (Cornick & Blascovich, 2015; Rouselle et al., 1995), exercising while in a CV state of threat puts additive stress on the CV system while not providing more beneficial outcomes (such as increased oxygen intake or calorie expenditure). In the current study, participants in the low task demands condition (avatar slimming) with low ESE (low perceived resources) exhibited a CV profile of threat during

the cycling task. While it was initially hypothesized that these individuals would exhibit a CV profile of challenge, perhaps they were in a state of threat because even low task demands are still higher than their available resources due to their low ESE levels. Given that ESE and BMI negatively correlate and one-third of American adults are obese (Ogden, Carroll, Kit, & Flegal, 2014), many Americans could be influenced by the design and implementation of future exergames.

Although the current study represents a distinctive combination of physiological indices, trait ratings, and behavioral measures, there are limitations that must be addressed. First, the physiological indices of RPP and CO did not significantly predict exercise completed in the following week even though self-efficacy theory argues that physiological and psychological states are used to assess and modify self-efficacy levels (Samson & Solomon, 2011). We believe that this predicted relationship was not borne out in the data as the biking task completed in the lab was only one of many experiences the participants have had with exercise and so therefore could potentially be easily discounted when evaluating current ESE levels. In future work, we are planning a longitudinal study where participants return to the lab over many weeks in order to see if we can more definitively influence exercise levels via physiological response patterns.

Second, the data was collected on a university campus on mostly normal weight individuals. In future studies, we would like to have a sample with more weight variability so as to determine if weight influences the relationships between ESE, physiological response patterns, and exercise. We would also like to seek out more members from the community so as to utilize a more representative and diverse sample for future work.

Finally, the avatar that was used in the exergame was generic and not customized to each participant. It is thus possible that each participant identified to a different degree with

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the avatar. In future studies we would like utilize software such that each avatar could be completely customized to the participant, thereby increasing identification with the avatar and potentially enhancing the avatar's influence on the participant (Yee et al., 2009). Level of identification with the avatar could provide a new approach to understanding the downstream consequences of exergame use.

As long as the obesity epidemic remains a part of the US social landscape, weight loss techniques such as exercising with exergames will remain popular. The results of the current research suggest that while these games may be more entertaining and engaging for users, for those with low ESE, the downstream consequences of playing these games may be harmful. As exercise is a key component to maintaining a healthy lifestyle, finding ways for individuals with body dissatisfaction to exercise without increasing self-awareness will be critical. Given that over one third of US adults are obese, the need to find these solutions is urgent.
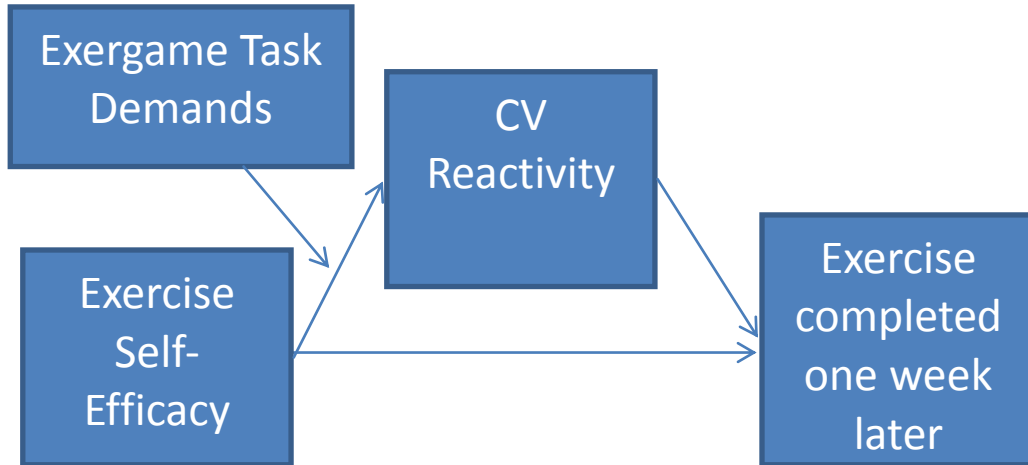
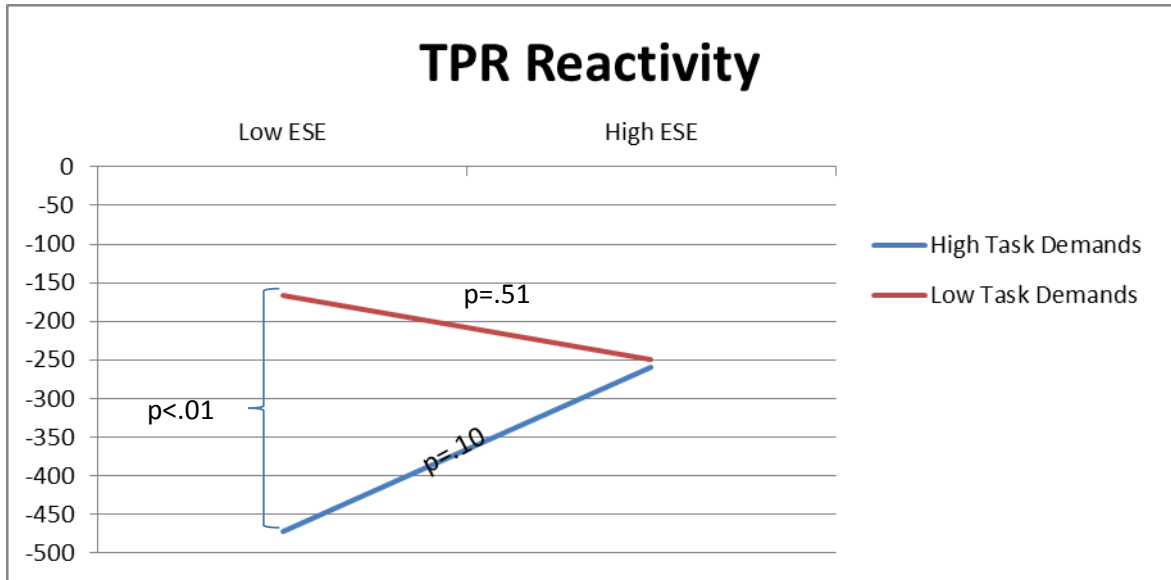*Figure 1*. Theoretical model for the current study.

*Figure 2.* TPR reactivity values by exergame task demands condition and high and low

exercise self-efficacy (ESE). More negative values indicate a challenge state of

cardiovascular responding with an equal or greater amount of resources compared to task
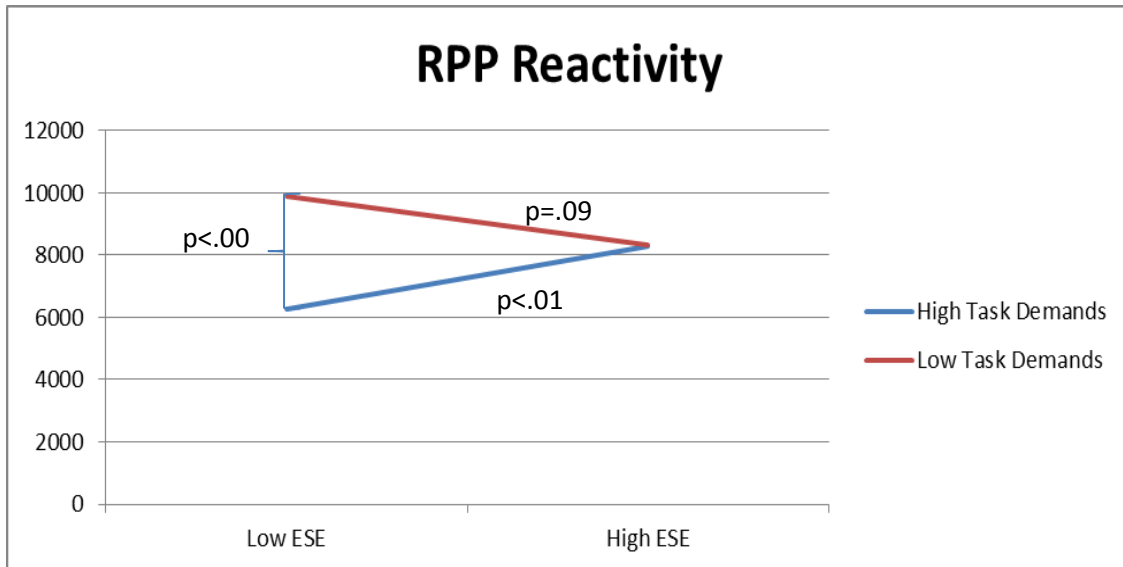
demands.

*Figure 3.* RPP reactivity values by exergame task demands condition and high and low exercise self-efficacy (ESE).

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