EXAMINING THE EFFECTS OF VALENCE AND AROUSAL ON PAIN PERCEPTION USING VIRTUAL REALITY MOOD INDUCTION

by

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ABSTRACT

ANNE MARIE PORTER. Examining the effects of valence and arousal on pain perception using virtual reality mood induction. (Under the direction of DR. PAULA GOOLKASIAN)

Virtual reality (VR) distraction has successfully decreased chronic and acute pain perception in clinical and experimental settings, but the precise elements of VR that optimize distraction have not been fully explored. Research has suggested that increasing "presence" can diminish pain reports. The current literature has used head mounted displays (HMD) to increase presence, but HMDs are costly and their effects on pain and presence are inconclusive across VR studies. Mood induction with a VR could be a more effective, inexpensive way to increase presence and optimize VR distraction benefits. The first study developed and tested the validity of four experimental VR mood induction conditions manipulating emotional valence and arousal, and examined the effect of the four conditions on heart rate and heart rate variability. Self-report ratings of valence and arousal showed the conditions induced the intended emotions. There were no differences in heart rate measures across the conditions. The second study compared pain intensity and unpleasantness ratings across the four VR conditions and a baseline control. There were no differences in pain intensity ratings, but there were significant differences in pain unpleasantness ratings across conditions. A calm background environment seemed to have the most beneficial effect on pain unpleasantness. Possible methods and protocols to increase pain intensity measurement validity are discussed.

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INTRODUCTION

Pain conditions are the most prevalent and expensive medical problems in the United States today. Over 100 million people suffer with chronic pain, and these pain conditions cost the U. S. 560-635 billion dollars annually in health care costs and lost work productivity (Institute of Medicine, 2011). Unfortunately, current pharmacological treatments are not sufficient to treat these conditions for two reasons. First, pharmacological treatments could be more effective. Medications decrease in efficacy over time due to tolerance, and have not consistently demonstrated long-term effectiveness for chronic conditions (Manchikanti, Fellows, Ailinani, & Pampati, 2010). Of those taking medications for chronic pain conditions, only 23% believe opioids are highly effective in managing their pain (American Pain Foundation, 2006). This is especially important because effective pain management is crucial to health outcomes. Poor pain treatment has been linked to cardiovascular issues, immune dysfunction, and an increased risk of mortality (Kehlet, 1997). Second, pharmacological treatments have the potential for serious side effects, which could drive up medical costs even further (Manchikanti et al, 2010). Clearly, less dangerous and more effective pain management techniques are needed to improve patient quality of life and decrease U.S. medical costs.

To address this, researchers have examined the effectiveness of non-pharmacological distraction techniques that may better manage pain conditions. Attention is thought to be an important cognitive process involved in pain perception. During a pain experience, attention is used to focus the individual on pain sensations to motivate escape from a noxious stimulus (Eccleston & Crombez, 1999). By using distraction to divert an individual's attention towards a goal other than pain evasion, pain perception will decrease. This occurs because the brain is theorized to have limited attentional resources. An individual's brain cannot focus on pain processing and a competing distraction simultaneously, reducing performance in one or both tasks (McCaul & Mallot, 1984). Thus, the more attentional resources a distraction tasks consumes, the less attentional resources will be available for pain processing, and the more pain perception will decrease. A contemporary technique using this theory is Virtual Reality (VR) distraction, which allows the user to interact with a computer-generated environment in three dimensions (Shahrbanian, Ma, Korner-Bitensky, & Simmonds, 2009). Because VR allows complex, multi-modal interactions in a virtual world, VR has the potential to consume a large amount of attentional resources, making it a highly effective distraction method in theory.

VR distraction has significantly decreased pain ratings in multiple published studies, showing effective pain management pain during a wide variety of medical procedures and in several different populations, with little to no known side effects (Botella et al., 2008). VR distraction has decreased pain ratings during chronic pain treatment (Oneal, Patterson, Soltani, Teeley, & Jensen, 2008), burn wound debridement (Hoffman et al., 2011), phantom limb treatment (Cole, Crowle, Austwick, & Slater, 2009), chemotherapy (Gershon et al., 2003), and dental procedures (Furman et al., 2009). VR distraction has inhibited activity in pain related areas of the brain such as the thalamus, insula, and anterior cingulated cortex (Hoffman et al., 2006), and also has more effectively reduced pain ratings when compared to other non-pharmacological techniques, specifically, hypnosis (Patterson, Hoffman, Palacios, & Jensen, 2006) and passive distraction techniques, like watching a movie (Furman et al., 2009).

Now that the literature has demonstrated the effectiveness of VR distraction, research needs to investigate how to optimize this distraction technique in order to guide future pain interventions using this technology. Presence, the subjective experience of being in one environment when physically situated in another (Witmer & Singer, 1998), may be an important optimizing factor in VR pain management. Research has suggested that higher presence in a VR can decrease pain ratings, and the influence of VR presence on pain could be maximized by having a participant wear a head mounted display (HMD) during gameplay, since it would block out external stimuli (Hoffman et al., 2004). However, this method of increasing presence has its limitations: (1) HMDs range from $ 2000-5000 per unit, and may not be economical for widespread clinical use. (2) The effects of HMDs on pain ratings are inconsistent within the literature. When comparing VR conditions with and without an HMD, some studies found HMDs to be more effective in decreasing pain perception, while others found no difference between HMD and non-HMD conditions (Hoffman et al., 2004; Gordon, Merchant, Zanbaka, Hodges, & Goolkaisan, 2011). Based on these limitations, a less expensive and more consistent method of increasing presence may have notable benefits.

Research has shown that inducing emotions in a VR can increase a player's perceived presence (Riva et al., 2007). This suggests presence may have an emotional component that could optimize VR pain distraction. However, the exact emotional component that affects VR presence is unclear. Riva et al. (2007) only used two affective conditions (a relaxed and an anxious affective state) that were not matched on arousal level. Perhaps lower arousal in the relaxing condition predicted greater presence than the anxious condition, not positive valence. To address these limitations, we used core affect theory in our experimental design (Russell, 1980; Russell, 2003). According to this theory, affective states exist along continuous scales of valence and arousal, and are categorized within four quadrants based on arousal and valence level. In the high arousal-negative valence quadrant, individuals feel “tense”, “upset”, or “distressed.” In the low arousal-negative valence quadrant, individuals feel “sad”, “tired”, or “lethargic”. In the high arousal-positive quadrant, individuals feel “excited” or “elated”, and in the low arousal-positive quadrant, individuals feel “serene” or “calm.” Previous pain studies have found that the arousal and valence of the induced emotion have differential effects on pain perception: positive emotions decreased pain ratings more than negative emotions, and higher arousal levels magnify these pain ratings differences (Roy, Lebuis, Peretz, & Rainville, 2010). These studies used pictures to induce emotional states, not virtual technology. Thus, the present study applied Core Affect Theory in the context of VR pain distraction and used a VR to induce different emotional states.

Two experiments examined how VR mood induction can affect participant self-report ratings. The first experiment developed and tested the validity of this mood induction method. Following Core Affect Theory (Russell, 2003), there were four VR mood induction conditions: negative valence-low arousal (Gloomy), negative valence-high arousal (Anxious), positive valence-low arousal (Calm), and positive valence-high arousal (Exciting). Emotions were manipulated by changing the background music and physical environment in a video game.

To validate arousal differences across conditions in Experiment 1, cardiovascular variables were measured in addition to emotional valence and arousal ratings. Research has suggested that heart rate and heart rate variability can be used to identify distinct emotional states (Kragel & LaBar, 2013). Emotions are tied to goals that require differing levels of sympathetic and parasympathetic activity to prepare for appropriate actions (Stemmler, 2004). Increased heart rate is related to higher sympathetic and lower parasympathetic activity (Grassi et al., 1998), while increased heart rate variability is related to lower sympathetic and higher parasympathetic activity (Task Force of the European Society of Cardiology, the North American Society of Pacing Electrophysiology, 1996). Therefore, heart rate and heart rate variability, indicators of sympathetic and parasympathetic activity, would change depending on the emotion induced. Based on these findings, we expected that high arousal emotions would increase heart rate and low arousal emotions would increase heart rate variability.

However, when emotion induction studies have used these cardiovascular measures, the relationship between emotions and arousal is unclear. When using images or sounds as mood inductors, some studies demonstrate that heart rate increases with high arousal stimuli (Cuthbert et al., 2003), while others show heart rate decreases with high arousal stimuli (Brouwer, Van Wouwe, Muhl, Van Erp, & Toet, 2013.). The findings on heart rate variability are just as unclear. Certain studies have found that heart rate variability increases with high arousal images (Brouwer et al., 2013; Ritz, Thons, Fahrenkrug, & Dahme, 2005), which contradicts other evidence that shows heart rate variability decreases in when people experience high arousal states like fear (Srinivasan, Ashkok, Vaz, & Yeragani, 2002). The mixed findings in the literature could be due to several possible limitations. Most of this research used either pictures or sounds as emotion induction stimuli. These stimuli last a few seconds in duration, and cardiovascular protocols recommend that a stimulus lasting at least one minute in duration is necessary to interpret heart rate variability measures properly (Task Force, 1996). Thus, an emotion induction stimulus of longer duration is needed. Since a video game can be played over several minutes, using VR for mood induction may provide an opportunity to better understand the relationship between emotion and arousal.

In Experiment 1, we hypothesized that: 1) The four emotion induction conditions would show differences in participants' responses to numerical rating scales of valence and arousal. For example, the high-arousal-positive valence condition would be rated with high arousal and positive valence ratings. 2) Heart rate would be higher in the two high arousal conditions compared to the two low arousal conditions and baseline. 3) Heart rate variability would be higher in the two low arousal conditions compared to the two high arousal conditions and baseline.

In Experiment 2, we compared the effects of the four VR mood induction conditions on pain perception. A thermal pain stimulator device was used to administer hot thermal sensations, and self-reported pain intensity and unpleasantness were the primary outcome measures. A baseline condition without a VR was used as the control. We hypothesize that: (1) All four VR conditions would have lower pain intensity and unpleasantness ratings compared to the no-VR, baseline condition. (2) Positive valence VR conditions would have lower pain intensity and unpleasantness ratings than negative valence conditions. (3) Valence differences in pain intensity and unpleasantness would be greater in high arousal conditions. In other words, the high arousal-positive condition would have the lowest pain ratings and the high arousal-negative condition would have the highest pain ratings. Moreover, since research has not yet examined VR presence differences in different arousal and valence conditions, we examined variations in self-reported presence scores across the four emotion conditions.

EXPERIMENT 1: VALIDATING THE MOOD INDUCTION CONDITIONS

Method

Participants

Thirty-five volunteers were taken from undergraduate students at the University of North Carolina at Charlotte. Participants ranged from 18-47 years of age (*M* = 22.12 *SD* = 5.12) and were mostly female (60%). On average, participants rated moderate prior experience with video games on a 1-5 scale (*M* = 3.15, *SD* = 1.35), and most (91%) had never played the video game, *Skyrim,* before the experiment. The sample reported relatively low levels of depressive symptoms (*M* = 14.55, *SD* = 10.62), and no participant data was excluded based on depressive symptomology. Informed consent was obtained before participation and the students received extra credit points towards their psychology class grade.

Emotion Induction Conditions

The VR conditions consisted of four different areas in a game called *The Elder Scrolls V: Skyrim*. The emotion induced in each condition was manipulated based on the type of background environment the participant explores and the type of background music. Figure 1 below presents a visual depiction of each game area by valence and arousal level. In order to tailor the virtual environments to match the intended mood, we programmed the game areas with “mods”, drawn from the word modifications, which are codes or sets of codes that modify the contents of the game. These mods can create new environments/items within the game, alter existing environments/items, and change character abilities. Mods for *The Elder Scrolls V: Skyrim* are legal and encouraged by the game’s creators, *BethesdaSoft*. Using mods, we created the background environments (including scenery, creatures and weather), assigned the background music, designed the in-game task, and made the players character invincible so death during gameplay was not possible.

The music was selected from the "Skyrim" soundtrack. Sixteen music pieces from the Skyrim soundtrack were rated on emotional valence and arousal scales by five volunteers. The four pieces used in the mood induction conditions were selected based on the outcome of the emotion scale scores. The in-game task was a scavenger hunt. Participants were required to collect glowing orbs located within each game area.

Gloomy Area (low arousal; low valence). To induce a lethargic emotion, participants explored a foggy area with a greyscale background. “Silent Footsteps” was used as the background music.

Anxious Area (high arousal; low valence). To induce an anxious environment, participants explored a cave with large spiders. These spiders move but do not attack the game character. “Night Without Stars” was the background music.

Calm Area (low arousal; high valence). To induce a relaxed, peaceful feeling, the participant explored a meadow environment with sunny weather. “Secunda” was the background music.

Exciting Area (high arousal; high valence). To induce an exhilarating feeling, the participant explored the top of the tallest mountain in the game. In Roy et al. (2011), the researchers used images of skydiving and other activities involving heights in this condition, so this environment was thought to create a similar emotional effect. “Watch the Skies” was the background music.

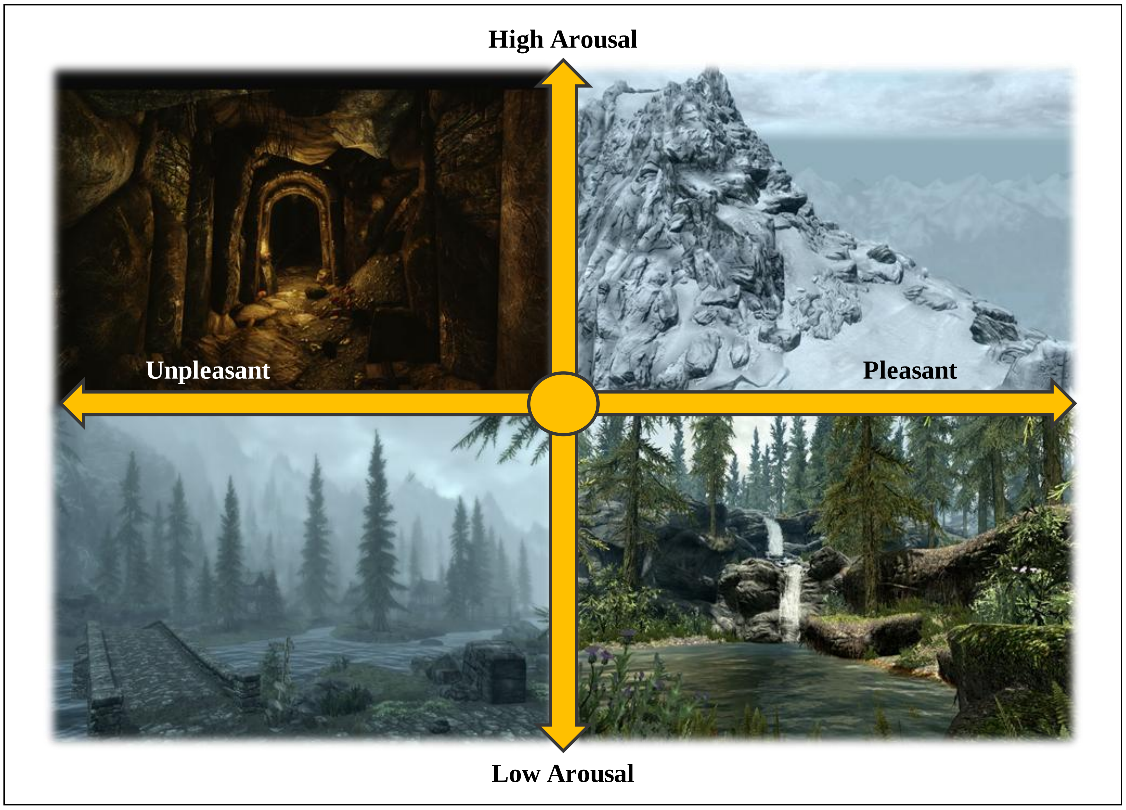

Figure 1: Emotion inductions conditions by arousal and valence level.

Measures

Emotion Scales: Two numerical rating scales were used to determine if the conditions induced the intended affective state. On a scale of 1 to 9, participants rated the degree of pleasantness (1= unpleasant, 5= neutral, 9=pleasant) and arousal (1=calm, 5=neutral, 9=aroused) during each of the gameplay conditions. These scales have been successfully used in experiments testing emotional components (Kron et al., 2013). In addition, participants rated the degree to which each condition was anxious, calm, exciting, and gloomy on a 1 to 5 unipolar scale (1=Not at all, 5=A lot).

Heart Rate**:** Heart rate (bpm) and heart rate variability was measured with a Polaris RS800CX heart rate monitor to assess physiological arousal during gameplay. Heart rate variability was assessed using the square root of the mean squared difference of successive beat intervals (RMSSD), which is associated with parasympathetic function

(Malik et al., 1996). Data was analyzed using the ProTrainer 5 and Kubios programs on a Windows 7 PC.

CES-D (Radloff, 1977): The Center for Epidemiological Studies of Depression Scale (CES-D) was used to measure depression. It is a 20-item questionnaire that asked participants how often during the past week they have experienced depression symptoms. Responses range from 0 to 3 (0=Rarely or none of the time, 1=Some or little of the time, 2=Occasionally or a moderate amount of time, and 3=Most or all of the time). Possible scores ranged from zero to 60, with higher scores indicating greater depression symptoms. This measure has an internal consistency (Cronbach's alpha) of .84-.85.

Demographic Form: This form collected demographic data that described the sample population and examine the effects of these factors on pain perception. Specifically, it collected information on gender and ethnicity since studies suggest there may be differences in how these groups experience and express pain (Greenspan et al., 2007; Thomas & Rose, 1991). It also asked how experienced the participant feels they are at playing video games (From "A little to no experience" to "Very experienced"), and if they have ever played *The Elder Scrolls V: Skyrim* before.

Procedure

Participants were run individually in 45-minute sessions. To record heart rate, a Polaris watch was strapped to the participants' wrist and a sensor strap was strapped around their chest. Participants completed the demographics and the CES-D on Survey Share, an online survey software. Participants' heart rate during questionnaire completion was used as a baseline. Participants were introduced to the game and informed that they would be searching for glowing orbs in a scavenger hunt. They were instructed on how to walk, look around, and pick up the orbs. They were also told they cannot die at any point during gameplay. As a reminder, the game controls were listed on a sheet of paper attached to the monitor. To become familiar with the controls, participants used the keyboard and mouse to walk around a circular room three times before they started the game. Participants played each of the four video game conditions for five minutes and after each condition was completed, they filled out two emotion rating scales assessing perceived arousal and valence and the four unipolar scales. Order of the conditions was randomized. The experimenter recorded the number of orbs collected, and the start and stop time of each condition.

Results

Figures 2 and 3 present the mean ratings of valance and arousal (with 95% confidence intervals) across the four emotion induction conditions. Repeated measures analyses of variances (*ANOVA*s) were conducted on arousal and valance ratings to test whether there were differences among the four conditions. A significance level of .05 was used for all statistical tests and, where appropriate, a Greenhouse Geisser correction was used when necessary to protect against possible violations of the sphericity assumption.

An *ANOVA* determined that there were significant differences in arousal ratings across conditions, $F(2.36, 78.17) = 16.56$, $p < .001$, $\eta^2_p = .33$. Follow-up Bonferroni comparisons (at the $p < .05$ level) showed that the Exciting ($M = 6.34$, $SD = .28$) and Anxious conditions ($M = 6.14$, $SD = .22$) had significantly higher arousal ratings than the Calm ($M = 3.91$, $SD = .38$) and Gloomy ($M = 4.67$, $SD = .28$) conditions. The two high arousal conditions induced more arousal than the two low arousal conditions as hypothesized and shown in Figure 2.

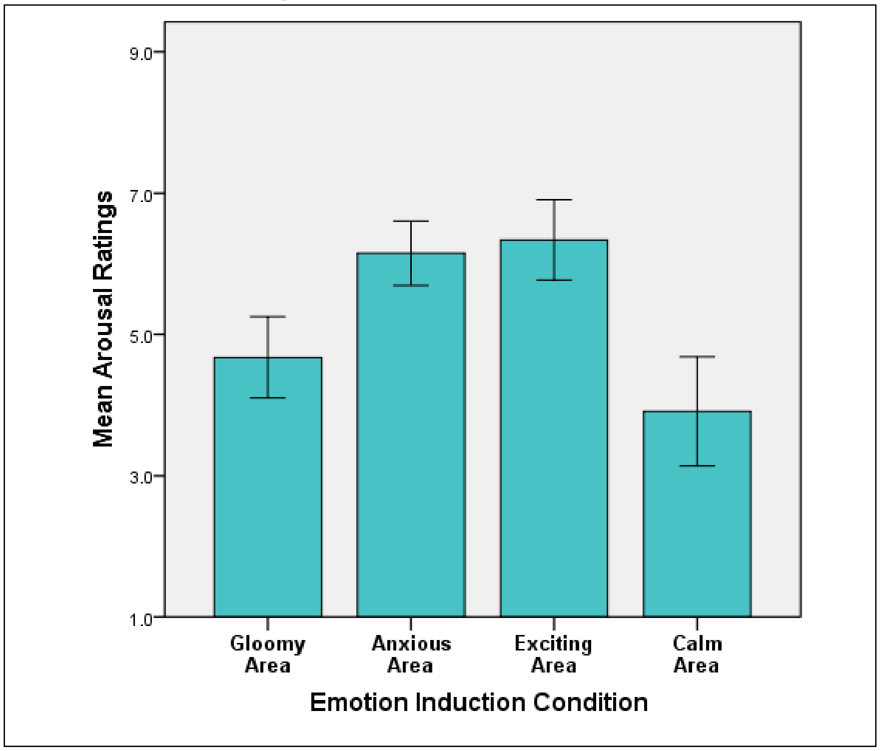

Figure 2: Mean arousal ratings across the virtual reality conditions.

When valence ratings were examined, an *ANOVA* determined that there were significant condition differences in valence ratings, $F(3, 99) = 26.42$, $p < .001$, $\eta^2_p=.45$. Figure 3 shows the mean differences in valence ratings across conditions. Follow up Bonferroni comparisons indicated the Calm condition ($M = 7.32$, $SD = .24$), had significantly higher valence ratings compared to other conditions ($p < .001$), and the Anxious condition ($M = 3.88$, $SD = .36$) had significantly lower valence ratings compared to other conditions ($p < .01$). However; although in the predicted direction, there was not a significant difference in valence ratings between the Gloomy condition ($M = 5.35$, $SD = .30$) and the Exciting condition ($M = 6.15$, $SD = .30$). Only the Calm and Anxious conditions induced the intended valence levels.

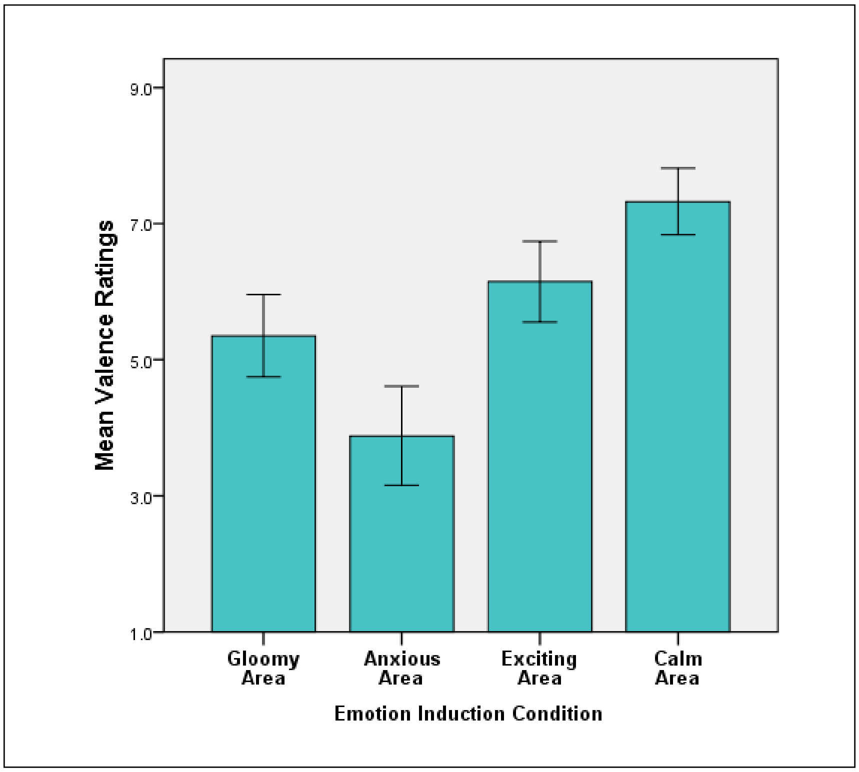

Figure 3*:* Mean valence ratings across the virtual reality conditions.

Additional information about the effectiveness of the emotional induction conditions was collected from the participant's unipolar ratings responses. Participants selected the extent to which each condition made them feel, "Anxious", "Exciting", "Calm", or "Gloomy" on a 1-5 scale. Figures 4-7 display the mean unipolar ratings within each condition. Although bipolar valence ratings did not show significant differences between the Exciting and Gloomy areas, unipolar ratings confirmed that these two conditions did indeed elicit different emotions. Participants rated the "Exciting" area as primarily "Anxious" and "Exciting", while participants rated the "Gloomy" condition as primarily "Gloomy." The unipolar ratings for the other two conditions were as expected. The "Calm" condition was rated as primarily "Calm" and the "Anxious" condition was rated as primarily "Anxious" and "Gloomy."

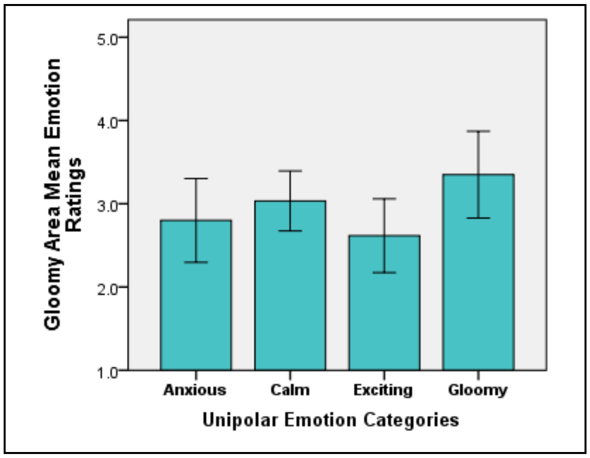

Figure 4: Gloomy area unipolar ratings.

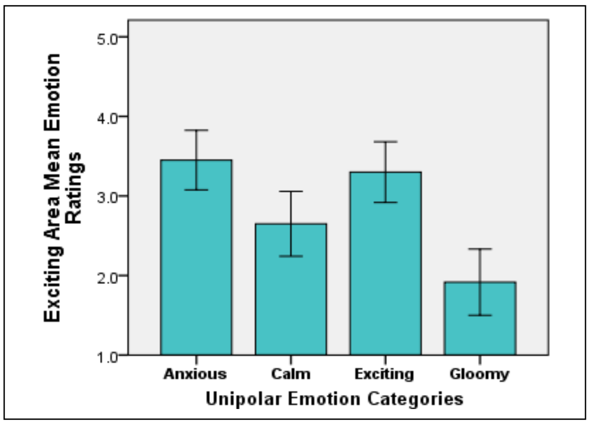

Figure 5: Exciting area unipolar ratings.

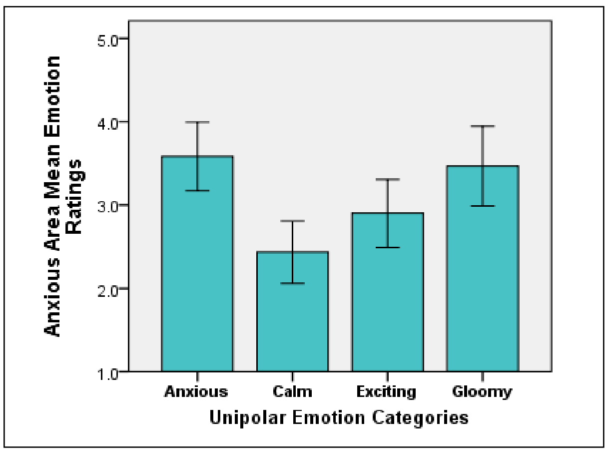

Figure 6: Anxious area unipolar ratings.

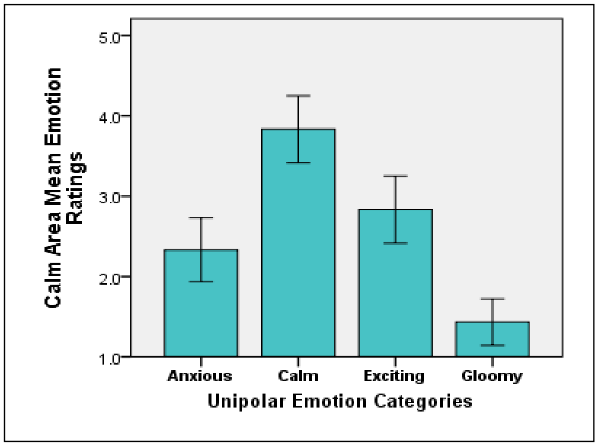

Figure 7: Calm area unipolar ratings.

Table 1 presents the heart rate data for baseline and the emotional induction conditions. Repeated measures *ANOVAs* were used on these variables to test for differences among the 5 conditions. We expected heart rate to be significantly higher in the two high arousal conditions, compared to the other conditions. There was a significant difference among the 5 conditions in beats per minute (bpm), $F(2.75, 68.62) = 8.08$, $p < .001$, $\eta^2_p = .24$. However, Bonferroni comparisons showed that bpm in the baseline condition was significantly higher than bpm in the Anxious, Exciting, and Calm conditions ($p < .05$), but there were no significant differences in heart rate across the four experimental conditions as hypothesized. Analyses on heart rate variability measures did not result in any significant effects. There were no significant differences among the 5 conditions in heart rate variability RMSSD, $F(1.93, 48.33) = 1.33$, $p = .27$, $\eta^2_p = .05$.

Table 1: Descriptives for heart rate (bpm) and heart rate variability measures (RMSSD).

	Mean	95% Confidence Interval	
		Lower Bound	Upper Bound
Baseline bpm	81.13	75.85	86.41
Gloomy Area bpm	78.00	73.96	82.03
Anxious Area bpm	77.76	73.16	82.37
Exciting Area bpm	77.16	72.95	81.37
Calm Area bpm	76.75	72.21	81.29
Baseline RMSSD	44.16	28.45	59.86
Gloomy Area RMSSD	38.65	26.86	50.44
Anxious Area RMSSD	36.96	26.31	47.62
Exciting Area RMSSD	40.63	27.11	54.16
Calm Area RMSSD	41.70	30.56	52.83

bpm = beats per minute. RMSSD = square root of the mean squared difference of successive beat intervals.

Gender, prior video game experience, and current depression level were not found to be correlated with arousal or valence ratings in the experimental conditions. These correlations had small effect sizes ranging from a Pearson's r value of -.26 to .27. Only the Exciting condition valence scores had a marginally significant positive correlation with age, $r(33) = .35$, $p < .05$, indicating that older participants rated the Exciting conditions as more pleasant. Age had no effect on arousal and valence ratings in the other conditions. Among demographic variables, gender was found to have a strong negative correlation with past video game experience, $r(33) = -.67$, $p < .001$. Males had more past video game experience than females.

Discussion

We hypothesized that the four video game conditions would elicit different emotions. Emotion rating scales and physiological heart rate measures were used to test emotion differences among the conditions. As hypothesized, the self-reported arousal ratings were in the predicted directions. The two high arousal conditions were rated significantly higher in arousal than the two low arousal conditions, showing that all conditions elicited the intended arousal differences in participants. The self-reported valence ratings partially supported our hypothesis. Two conditions showed significant rating differences in the predicted directions. The high arousal/low valence (Anxious) was perceived as more unpleasant and low arousal/high valence (Calm) condition was perceived as more pleasant by participants. Unipolar ratings also supported this, since the anxious condition was considered “anxious” and the calm condition was considered “calm.”

The other two conditions, the high arousal/high valence (Exciting) condition and the low arousal/low valence (Gloomy) condition, did not have significantly different valence ratings as hypothesized. However, unipolar ratings showed that these two conditions induced different emotional experiences for participants. Specifically, participants thought that the Exciting condition was both “exciting” and “anxious”, while the Gloomy condition was thought to be more "gloomy". Since "gloomy" is a low arousal/low valence emotion and "exciting" is a high arousal/high valence emotion in core affect theory (Russell, 1980), the unipolar ratings suggest the two conditions did elicit the intended emotions.

Even though unipolar ratings supported our hypothesis, there may be reasons why the difference in bipolar valence ratings was not as large as expected. This may have been due to individual differences in perceptions of the background environment. Some people may consider walking on a high mountaintop to be an unpleasant experience, particularly if they have a fear of heights, which was not assessed. This could explain lower valence ratings in the exciting condition. This same reasoning could be applied to the Gloomy condition. Some participants may not consider a foggy background to be an unpleasant environment.

While self-report measures seemed to validate our four mood induction conditions, the cardiovascular measures did not. There were no differences in heart rate or heart rate variability between the four conditions as expected. Different emotions induced while playing games did not seem to affect heart rate or heart rate variability measures. Interestingly enough, the only significant finding demonstrated that heart rate was higher at baseline than during the VR conditions. This could have occurred because participants had walked into the lab before the baseline was conducted. This prior increase in physical activity relative to the sedentary nature of the game play may have explained the baseline and condition differences in heart rate. A relaxation period at the start of the study may be necessary to interpret baseline and condition differences.

Although the findings on heart rate did not support our hypotheses, these results are consistent with the ambiguous relationship between emotion and heart rate found in the literature (Brouwer et al., 2013; Ritz, Thons, Fahrenkrug, & Dahme, 2005; Cuthbert et al., 2003; Srinivasan et al., 2002). For example, when using virtual reality exposure therapy for specific phobias, some studies show heart rate increases with the introduction of high arousal stimuli in the virtual world (Wilhem & Roth, 1998), but a number of others have not found this effect (Wiederhold, Jang, Kim, & Wiederhold, 2002). For instance, Wilhelm et al. (2005) found no differences in heart rate between those with fear of heights and those without while they experienced a virtual height simulation.

The discrepancies found using cardiovascular measures in emotion research may not be an issue of measurement or method. Studies may not be using the best physiological measure to assess arousal changes. Although participants with fear of heights showed no changes in heart rate in Wilhlem et al. (2005), those with fear of heights did show an increase in skin conductance measures compared to those without acrophobia, demonstrating a higher arousal state. The fact that the electrodermal measures found differences where cardiovascular measures did not could be explained by motivational theory, which distinguishes two separate systems related to arousal states, the behavioral activation system (BAS) and the behavioral inhibition system (BIS; Fowles, 1986).

The BAS is a system that is activated when an individual must physically avoid a negative stimulus. The BIS is a more passive system which activates during anxious states, when physical avoidance is not necessary. The former is thought to be related to cardiovascular changes, while the latter is thought to be related to electrodermal changes. Wilhem et al. (2005) hypothesized that since virtual reality does not require any active avoidance of a negative stimulus, emotional states elicited by virtual reality may only activate the BIS. This would explain why individuals demonstrated differences in skin conductance measures but not cardiovascular measures in their study. Furthermore, Wilhelm et al. (2005) discusses that most exposure therapy studies have only found heart rate differences when using in vivo therapy. In vivo therapy, exposure to a fear stimulus is presented in a real environment, which would require active avoidance and BAS activation. In addition, people may be exerting more physical energy interacting with a real environment during in vivo therapy (e.g. walking, standing) than during virtual reality therapy, which traditionally involves sedentary activity. Therefore, cardiovascular measures may not be the most valid way to assess arousal in virtual reality studies, because VR requires little physical exertion and no active stimulus avoidance. In the future, VR research may want to use electrodermal measures like skin conductance as a better predictor of arousal in emotional states. These conclusions can also apply to any study examining emotion. Emotion researchers should determine which physiological measure of arousal would be the most appropriate based on the experimental setting and physical requirements for the task,

Since the bipolar and unipolar self-report ratings showed the four emotion induction conditions successfully induced the intended emotional states, these same conditions were used in Experiment 2 to examine differences in perceived pain intensity and pain unpleasantness. Pain intensity and unpleasantness ratings were compared across the four conditions and a baseline (no-VR condition). We hypothesized pain ratings would be lower in the four emotion induction conditions than baseline, and pain ratings would be lower in the high valence conditions (Exciting and Calm) than the low valence conditions (Gloomy and Anxious). Lastly, we predicted the Calm condition would have the lowest pain ratings and the Anxious condition would have the highest pain ratings within the four experimental conditions.

EXPERIMENT 2: THE EFFECTS OF MOOD INDUCTION ON PAIN PERCEPTION

Method

Participants

Twenty-eight volunteers were taken from undergraduates at the University of North Carolina at Charlotte. Participants ranged between 18-50 years of age (*M* = 20.96, *SD* = 5.97) and were mostly female (76%). Most had never played *Skyrim* before (86%). The sample had a moderate amount of video game experience (*M* = 2.93, *SD* = 1.24) and low levels of depressive symptoms (*M* = 10.14, *SD* = 8.67). Students were excluded if they have a chronic pain condition and/or have taken pain medications in the last 24 hours. No participants were excluded from participation. Written informed consent was obtained before participation and the students received extra credit points towards their psychology class grade for their participation.

Thermal stimuli

Hot thermal sensations were used to produce the painful stimulations. The administration of thermal stimuli replicated temperatures and durations used in Koyama, Koyama, Kroncke, and Coghill (2004). Using the Medoc TSA-II, thermal stimuli were administered through a $16x16mm^2$, non-invasive thermal pad, placed on the participants' calf. Thermal stimuli's duration and intensity was controlled by a Medoc computer software. Each trial consisted of a thermal event which ramped up from a baseline of 35°C/95°F to 49°C/120°F, and remained at the maximal temperature of 49°C for a three second duration before returning to baseline. Thermal stimuli were administered psuedo-randomly, indicating that each thermal stimulus was programmed to occur 15 to 30 seconds after the preceding stimulus.

Measures

Experiment 2 used the same emotion scales, demographics, and CES-D questionnaire used in Experiment 1.

Pain Rating Scales: This primary outcome measure asked participants to rate on a 0-10 scale the degree of pain unpleasantness (0=not at all unpleasant and 10=most unpleasant imaginable) and pain intensity (0=no pain sensation and 10=most intense pain imaginable) experienced during the thermal sensations. This pain scale has been widely used in pain studies, and produces valid quantifiable measures of subjective pain (Price, Bush, Long, & Harkins, 1994).

Presence Scale (Wender et al., 2009): The presence scale measured the amount of virtual presence participants felt during gameplay within the emotional induction conditions. Participants used a 0-7 scale to respond to the following question, "While playing the game, to what extent did you feel you went inside the virtual world?" (0= I did not feel like I went inside at all; 7 = I went completely inside the virtual world).

Procedure

As part of the informed consent procedure, participants were given a sample trial with the thermal sensation (49 degrees C/120 degrees F for 3 seconds) before deciding to participate. Afterwards, they completed the Survey Share questionnaires before participating in the experimental session. During the baseline condition, which was presented first, participants sat in front of the gaming computer with the monitor and sound turned off. Thermal stimuli was delivered to the back of the participants' calf, via a thermode. Over three minutes, participants experienced four thermal stimulus trials, each lasting three seconds in duration. After baseline pain stimulation, the participant completed ratings of pain unpleasantness and intensity using 10-point numerical scales.

Participants were introduced to the game and were informed they would collect glowing orbs in a scavenger hunt task within the four video game conditions, while receiving thermal stimulations. The presentation order of the the conditions was counterbalanced and each condition ran for four minutes. Participants played the game for one minute before thermal stimulation to facilitate presence in the video game environment. Pain stimulation was identical to baseline procedure. Participants experienced four thermal sensations of three second durations presented randomly across the remaining three minutes of gameplay. After completion of each video game area, participants completed the 10-point pain intensity and unpleasantness scales, and well as the presence scale and the two emotion scales measuring emotional valence and arousal. To avoid habituation effects, the thermode was moved to a different location on the calf after each video game area was complete so the same skin site was not repeatedly stimulated. The experimenter recorded the amount of orbs found during each game condition.

Results

Table 2 shows the main self-report ratings for pain intensity and pain unpleasantness (at 95% confidence intervals). Two repeated measures *ANOVA*s were run in order to determine the main effects of perceived pain intensity and perceived pain unpleasantness ratings across the baseline condition and the four experimental conditions. Where appropriate, a Greenhouse-Geisser correction was used when necessary to protect against possible violations of the sphericity assumption. The first analysis showed no significant differences in pain intensity across the five conditions, *F*(4, 96) = .98, *p* = .42, η^2_p=.04. The second analysis showed that were overall differences in perceived pain unpleasantness among the five conditions, *F*(4, 96) = 2.61, *p* < .05, η^2_p=.10. However, Bonferroni comparisons (at the *p* < .05 level) did not show any significant differences in the unpleasantness ratings among the pairwise comparisons. Although significance was not reached, the Calm condition (*M* = 4.32, *SD* = .34) had the lowest pain ratings, and lower pain unpleasantness ratings than baseline (*M* = 5.32, *SD* = .32), which was in the hypothesized direction.

Table 2: Descriptives for perceived pain intensity and unpleasantness

	Mean	95% Confidence Interval	
		Lower Bound	Upper Bound
Baseline PI	5.67	5.01	6.35
Gloomy Area PI	5.53	4.83	6.23
Anxious Area PI	5.10	4.46	5.74
Exciting Area PI	5.57	4.68	6.46
Calm Area PI	5.28	4.68	5.89
Baseline PU	5.32	4.65	5.99
Gloomy Area PU	5.17	4.39	5.96
Anxious Area PU	4.68	4.04	5.31

Exciting Area PU	4.60	3.76	5.44
Calm Area PU	4.32	3.63	5.01

PI = pain intensity rating. PU = pain unpleasantness rating.

Using two repeated measures *ANOVA*, we demonstrated that condition arousal and valence ratings were replicated from Experiment 1. There were significant condition differences in emotional valence ratings, $F(3, 81) = 15.73$, $p < .001$, $\eta^2_p = .37$, and emotional arousal ratings, $F(2.10, 56.72) = 7.20$, $p < .001$, $\eta^2_p = .21$. Follow-up Bonferroni comparisons (at the $p < .05$ level) were conducted the further analyze condition differences in valence and arousal. The two high arousal conditions, Exciting (*M* = 5.82, *SD* = .32) and Anxious (*M* = 2.78, *SD* = .42), had significantly higher arousal ratings than the two low arousal conditions, Calm (*M* = 4.28, *SD* = .49) and Gloomy (*M* = 4.71, *SD* = .41). Valence comparisons showed that the Calm condition (*M* = 7.00, *SD* = .27) had significantly higher valence ratings and the Anxious condition (*M* = 4.25, *SD* = .45) had significantly lower valence ratings compared to the other conditions. As in Experiment 1, the Gloomy (*M* = 5.46, *SD* = .39) and Exciting condition (*M* = 5.78, *SD* = .41) did not differ in valence ratings. We can conclude the video game conditions continued to induce the intended emotional states.

A final repeated measures *ANOVA* analyzed the effects of presence scores, but found no significant differences in presence scores across the four experimental conditions, $F(3, 81) = 1.06$, $p = .37$, $\eta^2_p = .04$. Presence level within different areas did not seem to influence pain perception. Correlations showed that males had more past video game experience than females, r (26) = -.60, $p < .001$, and younger participants had more past video game experience than older participants, $r(26) = -.39$, $p < .05$.

Significant correlations were found between certain condition pain ratings and demographic variables, shown in Table 3 below. Older participants were found to have higher baseline pain ratings, males had lower pain intensity ratings in the Calm and Exciting conditions, and participants with higher depression scores had higher pain intensity ratings in the Exciting condition.

Table 3: Significant correlations between demographics and pain ratings

	Baseline PI	Baseline PU	Exciting PI	Calm PI
Age	.45*	.55**	-	-
Gender	-	-	-.39*	-.47*
Depress.	-	-	.39*	-

PI = pain intensity rating. PU = pain unpleasantness rating. Depress = depression symptoms score. * indicates $p < .05$; ** indicates $p < .01$.

Discussion

Contrary to our predictions, there were no significant differences in pain intensity ratings across the baseline condition and the four video game areas. On the other hand, we did find an overall effect of condition on pain unpleasantness ratings. However, this seemed to be a subtle and small effect, because pairwise comparisons were not found to differ. The Calm condition was the only condition that seemed to have a small influence. Although not significant, it had the lowest pain unpleasantness ratings compared to baseline, which was predicted in our hypotheses. Therefore, areas with calm music and relaxing scenery seem have the most beneficial effect on pain unpleasantness.

Based on previous research, our findings on pain unpleasantness and pain intensity should have both reached significance. Many previous studies examining virtual reality and pain perception have found differences in self-reported pain intensity ratings between baseline and virtual conditions in experimental settings (Dahlquist et al., 2010; Magora et al., 2006; Gordon et al., 2011). Since this study used the same self-report scales and approximately the same video gameplay time as these previous studies, our findings with pain intensity ratings should have replicated as well. This might have been due to an issue in our pain stimulation methods, with the Thermal Pain Simulation (TSA). Previous studies often used thermal pain over a longer duration. For example, in a study using the TSA, pain stimulation was applied over a 30 second, continuous interval during gameplay rather than in multiple trials with shorter pain durations (Wender et al., 2009). In that study, participants may have been more able to effectively report pain intensity perceptions after a longer pain interval than after a series of short intervals. In the future, a longer pain interval might be required to acquire accurate pain intensity ratings.

However, other studies examining emotion and using the TSA have shown pain intensity rating differences with very short stimulus intervals, similar to our study (Roy et al., 2011). A main determinant of our inability to replicate their findings may have been due to the length of time before reporting. In this other study, participants used a similar self-report scale, but reported pain intensity ratings after 30 seconds of brief, pain stimulations, rather than after 3 minutes of pain stimulations. A future study may need to shorten the reporting interval, and when using pain stimulation with short durations, reporting may need to occur within 30 seconds of the pain stimulus. In virtual reality research, this may require researchers to prompt pain intensity ratings during gameplay, decrease the gameplay time, or perform gameplay in shorter segments when using short pain stimulus durations.

Shortening the reporting interval after pain stimulation may also explain the weak effect found with pain unpleasantness ratings. Unlike previous virtual reality studies assessing pain ratings between one baseline and one VR condition (Dahlquist et al., 2010; Wender et al., 2009), our study compared ratings across four VR conditions and a baseline. Having multiple virtual conditions may make condition effects on global pain ratings more difficult to measure because of the subtle differences among the conditions. If pain perceptions were reported within a short interval of pain stimulus administration rather than reported globally, as previous studies have done, these subtle differences in pain unpleasantness might be made more apparent. Secondly, most experimental research with VR distraction administers pain at one stimulus intensity (Dahlquist et al., 2010; Wender et al., 2009). Following protocol in the pain literature, pain stimuli are usually administered at varying intensities in order to increase the reliability and validity of pain measurement (Zeidan, Gordon, Merchant, & Goolkasian, 2010; Gordon et al, 2011**).**

These problems in pain measurement may be avoided altogether if studies use convergent measures of pain intensity, without relying on self-report measures. People may not be able to report pain intensity experiences as accurately as they can report their emotional response to the experience. Measures like fMRI scans, skin conductance, or the RIII reflex may be able to provide objective, physiological evidence of an individual's perception of pain intensity and better capture changes in pain perception. In addition, many behavioral measures assessing pain tolerance can be used as a convergent measure of pain perception. Future studies should consider using these other measures in accordance with self-reports.

Lastly, no differences in presence were observed across the virtual reality conditions. This is contradictory to previous findings, in which participants reported more presence in a pleasant environment than an unpleasant environment (Riva et al., 2007). For the purpose of this study, having the conditions receive similar presence ratings could be interpreted as beneficial. Since participants rated all the VR conditions to have moderate feelings of presence, this shows that participants had equivalent feelings of immersion and engagement within each virtual world. Even if presence did not seem to have a direct role on pain unpleasantness scores in this data, presence may still be an important element in VR distraction. Studies with VR exposure therapy and presence have drawn similar conclusions. Presence was not sufficient to predict treatment success but was considered necessary for patients to engage in treatment, acting as a mechanism that may influence success indirectly (Price & Anderson, 2007). Future pain research may not want to examine direct effects of presence on treatment outcomes, and instead consider its indirect influence when using VR distraction.

To obtain a better understanding of VR mood induction's effect on pain perception, we will be conducting an additional study addressing a few of our method limitations. Using the same VR conditions, we will be collecting pain intensity and unpleasantness scores after each thermal stimulus administration, not after condition gameplay, and we will be administering pain stimuli at various thermal pain intensities.

These may provide more reliable pain measurements and demonstrate stronger overall effects of condition on pain perception ratings.

Although our findings on pain intensity were inconclusive, we demonstrated that the emotion induced by a video game can affect one's perception of pain unpleasantness. Specifically, video game environments that evoke a calm and relaxing emotional state seem to have the most beneficial effect on pain perception. Clinicians intending to use virtual reality distraction in pain treatment or during painful medical procedures should select a game inducing these emotions in order to optimize treatment success.

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APPENDIX A: SURVEY MATERIALS

CES-D scale.

Instructions: Below is a list of ways you may have felt or behaved. Please tell me how often you have felt this way during the past week.

Responses: Rarely or none of the time (less than 1 day), Some or a little of the time (1-2 days), Occasionally or a moderate amount of time (3-4 days), Most or all of the time (5-7 days)

1. I was bothered by things that usually don't bother me.
2. I did not feel like eating; my appetite was poor.
3. I felt that I could not shake off the blues even with help from my family and friends.
4. I felt I was just as good as other people.
5. I had trouble keeping my mind on what I was doing.
6. I felt depressed.
7. I felt that everything I did was an effort.
8. I felt hopeful about the future.
9. I thought my life had been a failure.
10. I felt fearful.
11. My sleep was restless.
12. I felt happy.
13. I talked less than usual.
14. I felt lonely.
15. People were unfriendly.

16. I enjoyed life.
17. I had crying spells.
18. I felt sad.
19. I felt that people dislike me.
20. I could not get “going.”

Demographics

1. Age:
2. Sex:
    a. Male
    b. Female
3. Ethnicity:
    a. Caucasian
    b. African American
    c. Hispanic
    d. Asian
    e. Other
4. How much experience do you have playing video games? (Including console and PC games)
    a. None or very little experience
    b. A little experience
    c. Some experience
    d. Moderate amount of experience

5. Have you ever played *The Elder Scrolls V: Skyrim* before?

   a. Yes

   b. No

Self-Report Scales

Rate the WORST pain you felt while playing the game:

0 1 2 3 4 5 6 7 8 9 10

No pain at all — Moderate pain — Severe pain

How UNPLEASANT was the pain while playing the game?

0 1 2 3 4 5 6 7 8 9 10

Not unpleasant at all — Moderately unpleasant — Severely unpleasant

While playing the game, to what extent did you feel you WENT INSIDE the virtual world?

0 1 2 3 4 5 6 7 8 9 10

I did not feel I went inside at all — Moderate sense of going inside — I went completely inside the virtual world

How PLEASANT was the game's background music and environment?

1 2 3 4 5 6 7 8 9

Unpleasant — Neutral — Pleasant

How Calm or Excited did you feel while playing the game?

1	2	3	4	5	6	7	8	9
Calm				Neutral				Aroused

Please rate the degree to which the game environment represented each of the following emotions:

Anxious:

1	2	3	4	5
Not at all				A lot

Calm:

1	2	3	4	5
Not at all				A lot

Exciting:

1	2	3	4	5
Not at all				A lot

Gloomy:

1	2	3	4	5
Not at all				A lot