Effects of (inter)active vs passive Virtual Reality environment on the reduction of laboratory-induced chronic pain

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Abstract

Virtual Reality (VR) may be a potential non-invasive and cost-effective alternative solution for the management of chronic pain. Previous studies have shown VR as a tool for reducing pain. The study's aim was to investigate the benefits of VR, both fundamentally and holistically, for pain and body-image. For this study, an experimental protocol was designed using the Advanced Thermal Stimulator (TSA) to induce and resemble chronic pain. The study took place at Maastricht University and included a total of 47 healthy participants ranging in age from 18 to 35 years old. VR equipment and hardware were designed and provided by CUREosity. This study was conducted using a mixed 2 x 2 designs with VR condition (Active vs. Passive) and Time (First and Third Measurement) as the factors. The active condition was an interactive cold-water environment and the passive condition is a non-interactive forest ecosystem. Both of these conditions undergo the same procedure and were measured using the Pain Numeric Scale (PNS) scale. We hypothesized that pain perception will decrease in both conditions; with a significantly greater effect in the active compared to the passive condition. Additionally, we observe the variable body image without any directional assumption. The hypothesis was tested using a two-way repeated measures ANOVA. This was conducted for each dependent variable (pain perception and body image) with Pain Catastrophizing Scores (PCS) as a covariate. Results indicated that there was a significant interaction between PNS scores and condition; while no observed significant interaction was present for body image. These results suggest that VR may be beneficial as a clinical tool for reducing pain. In conclusion, future research may focus on improving current limitations; while observing the long-term benefits and applications of VR on chronic pain.

Keywords: Virtual Reality; Chronic Pain; Body-Image; Advance Thermal Stimulator

Introduction

According to the International Association for the Study of Pain (IASP), pain is defined as any “unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey & Bogduk, 1986). More specifically, chronic pain is identified as any pain lasting more than the expected timeframe of recovery, usually at least six months (Ashburn & Staats, 1999). Pain, especially chronic, has been shown to have detrimental effects on the individual, affecting both economic and social continuity. Some common problems of chronic pain that can cause financial and social stress are sleep deprivation, higher unemployment rate, and an inability to enjoy hobbies (Birse & Lander, 1998).

Regarding the world population, chronic pain appears to impact 20.4% of the adult population (Zelaya et al., 2019). Although chronic pain appears to be widespread worldwide, lack of policy mention and priority has led to financial instability and mental unrest (Leadley et al., 2012). A study conducted by Skinner et al., 2004, illustrated a potential two-way causality effect posed by chronic arthritis pain. For example, financial stress, an economic and social determinant, is significantly linked to an individual's physical health. On the contrary, the same study showed that chronic arthritis pain can lead to a negative effect on an individual's financial stability and mental health (Skinner et al., 2004). This cycle of harm is only one decrementing effect posed on people suffering from chronic pain, with many other causal factors (e.g. social, environmental, emotional, distal, etc.) simultaneously impacting the individual’s livelihood. For example, a person’s mental state can be one factor that can influence the severity of chronic pain. In research, it has been found that an individual’s mental prowess against pain can heavily influence their pain threshold, tolerance, and intensity (Weissman et al, 2008). Pain catastrophizing is defined as an exaggerated negative “mental set” brought by the potential or existing presentation of pain (Sullivan et al., 2001). Pain catastrophizing is often used to analyze thoughts and emotions toward pain (Weissman et al., 2008). Individuals that catastrophize reported increased anxiety, worry, fear, and exaggerated unpleasantness; and they were unable to shift attention from the pain (Chavez and Brown, 1987). A study examining the relationship between pain catastrophizing and pain perception found that higher scores in pain catastrophizing results in lower pain tolerance, lower pain threshold, and higher pain intensity (Edwards et al., 2004). Another study examined pain catastrophizing in the context of chronic pain and found similar results to Edwards et al., 2004 study, with patients, also feeling more disabled and experiencing augmented psychological distress.

Chronic pain sufferers often find it difficult to experience pain relief, and a root cause of this is due to these individuals having undiagnosed conditions or inoperable clinical syndromes (Ashburn & Staats, 1999). Those in severe pain search for relief at several clinics to find recommendations for reducing their discomfort (Ashburn & Staats, 1999). Some potential treatments that may be used for chronic pain can include opioids, analgesics, and alternative approaches such as VR.

Opioids, used for severe short-term pain relief and as an anesthetic, were commonly prescribed to individuals that suffer from severe acute and chronic pain (IASP, 2021). For example, a study analyzed the effects of opioids on chronic back pain found that it was statistically significant in reducing pain intensity in both the short-acting opioid (oxycodone) and longer-acting opioid (morphine) (Jamison et al., 1998). Even though opioids have been found to reduce pain intensity, the improvement of function associated with this medicine can be limited or even harmful (Ballantyne & Shin, 2008). For example, a systematic review observed the effects resulting from opioids and found that 80% of participants experienced at least one side effect between nausea, constipation, and somnolence (Kalso et al., 2004). Similarly, the same can be said for non-opioid-based analgesics. For example, paracetamol has been found to act as a placebo for chronic pain relief and does not offer long-term support (Saragiotto et al., 2016).

Opioids are highly criticized by the general public, with many people fearing that they might result in devastating effects on their mental and physical health (Ballantyne & Shin, 2008). Given that opioid use requires a higher dosage of prescription when the pain becomes more severe, these fears are justified (Sullivan & Howe, 2013). In conjunction with the higher dosage, the rate of opioid prescriptions in the United States and Canada has augmented three times the rate compared to 1999 published data (Guy et al., 2017; Porras et al., 2019). For this reason, many physicians have become increasingly hesitant to prescribe this type of medication to patients (Tse et al., 2005).

Thus, alternative non-pharmacological treatments for chronic pain may provide treatment with fewer associated risks and similar benefits. A study conducted by Tse et al., 2005 found that about 75% of the older population, when in severe pain, preferred alternative approaches such as yoga, massage therapy, relaxation, and distraction techniques. Moreover, it found that many of these non-medicinal-based types of approaches were very effective in managing pain and providing short-term relief. For example, an systematic review of ten studies on yoga, nine of these studies were successful in reducing pain (Posadzki et al., 2011). Additionally, another study observed the preliminary effects of massage therapy on chronic pain. They found that massage therapy was just as significant in reducing pain as standard medical care, and the effects of yoga were sustained longer than standard medical care (Walach et al., 2003).

Likewise, VR may also be another promising non-pharmaceutical cost-effective alternative to providing relief from chronic pain. VR, a technologically simulated realistic environment, allows people to interact and explore user-programmed designs (Rothbaum, 2009; Latta & Oberg, 1994). Originally developed for military training and entertainment, VR has started to become more widely researched by the clinical world in the past decade. This is widely due to the decrease in cost and increases in accessibility (Maples et al., 2017; Slater & Sanchez, 2016; Wiederhold et al., 2014). VR is useful in several clinical contexts such as exposure therapy, anxiety disorders, mental disorders, and pain relief (Bell et al., 2020; Mahrer & Gold, 2009).

Concerning pain relief, VR has been shown in research to act as a distraction analgesic for pain relief and as an ability to help chronic patients cope through skill-building (Ahmadpour, 2019; Hoffman et al., 2007). Research suggests that VR achieves this “analgesic” effect by using visual, auditory, and proprioception stimulation to distract from pain (Ahmadpour, 2019). In a study analyzing audiovisual distraction effects on VR, they found that VR created a successful distraction effect on sufferers of chronic pruritus experiencing an itching sensation. Moreover, they found that the remediating effect gained through the virtual reality experience held as long as an additional ten minutes after exposure to the environment (Leibovici et al., 2009). Another study confirmed Leibovici et al., 2009 results by further analyzing the impact that VR can have on chronic pain patients. They found that patients reported an average pain decrease of 60% compared to pre-intervention pain intensity levels (Jones et al., 2016). Similarly, a VR study compared chronic pain resistance skill-building in an immersive 3-D to a non-immersive 2-D environment over a period of 8-weeks. They found that both environments were substantial in reducing pain, but the more immersive 3-D environment provided more pain reduction and longevity. This research suggests that VR can help modulate pain via an attentional shift and emotional involvement from negative stimuli (i.e. pain) to positive stimuli (Triberti et al., 2014).

Furthermore, these immersive VR environments also provide benefits that many therapeutic and pharmaceutical alternatives do not: engagement and entertainment. Because VR is designed for immersive interaction, many patients look forward to therapy (Garrett et al., 2017). For example, in Jones et al. 2016 study, patients stated that the VR experience was "amazing" and wanted to extend and revisit the virtual experience.

On a different note, VR has also been shown to improve people's perception of body image. Body image, a multi-layered mental construct reflecting physical appearance, can either be a fleeting thought or appear in a more rooted form (Cash, 2002). In the context of VR, the holistic benefits associated with body image are in the infant stages of research. Although new, several studies have produced promising results supporting affective and perceptual body image manipulation using VR technology (Ferrer-Garcia & Gutierrez-Maldonado, 2012; Irvine et al., 2020; Porras et al., 2019). For example, a study observed VR on females concerned with body image using 3-D models that varied in BMI (Body Mass Index). They found that perception changes, using BMI, were significant in shifting an individual's perception of body size and shape (Irvine et al., 2020). In addition, another study conducted research examining the effect of VR on body image affect and perception through manipulated avatar body sizes. As a result, all participants experienced higher levels of body image disturbance and anxiety after being exposed to the larger size virtual body (Porras et al., 2019). This research further helps to identify body image as a state instead of a trait, which means that individuals can be influenced by internal and external factors (Ferrer-Garcia & Gutierrez-Maldonado, 2012). Furthermore, a study examining attitudes and constructs toward body image found that overall body satisfaction, self-efficacy, and motivation to change significantly increased with exposure to a 50-minute virtual environment compared to the control (Riva et al., 2001). This suggests that VR can be beneficial in changing the attitudes and perception of body image in the short term. In conjunction with attitudes and perception, another study analyzed emotional responses to virtual stimuli using a VR avatar. They found that individuals elicited higher emotional responses to environmental stimuli in the experimental condition compared to the control condition (Gall et al., 2021). Overall, these results suggest that VR embodiment techniques have an impact on attitudes, perception, and emotions towards body image.

In conclusion, the present study focuses on measuring the effects of the VR conditions (passive and active) on pain perception and body image. The goal of this study is to mimic the effects of chronic pain in a controlled lab-based environment to see a reduction in pain and see if there is a positive association between VR and body image. We hypothesized that pain perception will decrease in both conditions, experimental (*active VR*) and control *(passive exploration)*, with a significantly greater effect in the experimental compared to the control condition. In addition to pain, we will measure the effect that VR has on body image. To examine any possible avenues of body image, we do not have a directional hypothesis for this variable given the nature of our manipulation. Similarly, we want to measure the effect that pain catastrophizing has on both average temperature threshold and pain difference scores. For this additional analysis, there is no directional hypothesis assigned.

Method

Participants

Participants were recruited from Maastricht University in the Netherlands. The study contained a total of 47 participants, ranging in age from 18 and 35 years old. Based on a power analysis, the necessary sample size for this study was 90 with a medium effect size of .5 and a power of 90% (Faul et al., 2007). The final recorded sample size (*n*= 47) did not reach power, but will still be examined as an exploratory analysis. Table 1 shows the means, standard deviations, and t-test scores for participant data. Table 1 displays no statistically significant differences between data in any of the groups.

Table 1

Analyzing Means, Standard Deviations, and t-test scores of Participants Characteristics and Questionnaires.

Measure	**Active (n=23)**	**Passive (n=24)**	***t*(45)**	***p***	**Cohen's *d***
Age			-.157	.876	-.046
Mean	22.70	22.54			
SD	3.21	3.51			
Sex, *n* (%)					
Male	*10* (21.3%)	*9* (19.1%)			
Female	*13* (27.7%)	*15* (31.9%)			
Avg. Pain Threshold °C			-.706	.484	-.206
Mean	43.16	42.64			
SD	2.53	2.48			
Pain Catastrophizing			-.566	.575	-.165
Mean	18.83	17.46			
SD	7.31	9.13			
Body Image State Pre-			.325	.747	.095
Mean	34.78	35.38			
SD	6.05	6.43			

Note. Significance p<0.05; Effect Size; Small= 0.200, Medium = 0.500, Large= 0.800.

In the study, Participants were excluded if they had chronic or acute pain; psychiatric conditions; neurological conditions; pregnancy; heavy medication that interferes with pain perception; and if they have a history of motion sickness, migraines, or balance problems. Those who meet all inclusion criteria (right-handed, between 18 to 35 years of age, healthy, corrected or normal vision) were invited to participate. The study excluded no candidates based on sex, race, or ethnicity.

Materials

The Body Image States Scale (BISS)

The Body Image States Scale was developed by Cash et al., 2002, and is used to identify an individual's current body image momentary state. The BISS compares satisfaction with an individual's momentary looks, attractiveness, and peer comparison. The BISS is a 6-item instrument and uses a 9-point Likert scale. The items (e.g. question phrasing are stated as “Right now I feel….with my physical appearance” and “Right now I feel….than the average person looks") are modified to fit the study context. The mean of these items is used to calculate a body image score (α=0.69) (Cash et al., 2002).

The Pain Catastrophizing Scale (PCS)

This is a 13-item instrument used to help identify the exaggerated extent that individuals experience pain. The PCS asks participants to reflect on previous thoughts or feelings experienced using the 13 questions. Participants are asked to rate their experience on a 5-point scale with endpoints being (0) not at all and (4) all the time. Scores can be observed using three subscales: helplessness, rumination, and magnification (Sullivan et al., 1995). Items in this scale were randomized and modified to fit the format of our study context. For example, instrument items (e.g. subjects consider questions like “I feel I can’t take it anymore” or “I wonder whether something serious will happen”) were used to compare the scores, within the study, to normal pain. The PCS total scores can range from 0-52 with a higher number indicating increased exaggeration through pain catastrophizing. A sample conducted by Loreto-Quijada et al., 2014, found that reliability was high for the PCS score (α=0.90).

The Pain Numeric Scale (PNS)

This is a 1-item instrument used to help measure current pain intensity. The version of the PNS conducted during this study will ask the participants to rate their pain from 0 (“no pain”) to 10 (“worst possible pain”). For this study, scores were measured using the average and measuring the pain reduction over a period of time. Pain intensity scores were referred by the three separate categories recommended by Krebs et al., 2007: mild (1-3), moderate (4-6), and severe (7-10).

Equipment

Thermal stimulation was administered using the Medoc Pathway Pain & Stimulation System (Medoc Advanced Medical Systems Ltd, Ramat Yishay, Israel). The Medoc Pathway can be programmed for precise heat targeting using the Advanced Thermal Stimulator thermode (TSA). The TSA uses a 30mm x 30mm square contact and can range in temperature between 0°C and 55°C (Thibodeau et al., 2013).

The VR equipment and custom-built VR environments were provided by CUREosity, Dusseldorf (Germany) (https://www.cureosity.de/en) . CUREO, the name given for the equipment, is a VR system composed of hardware such as VR glasses, controllers, and tablets. CUREO was designed as a therapeutic device to support cognitive rehabilitation. The VR environments were built in conjunction with the study design. There were two VR environments: a forest ecosystem and a cold-water environment. The forest ecosystem was a passive 360° visual environment where the participant was placed in a field of grass surrounded by nature.

This environment contained no auditory or interactive elements. The cold-water environment was an active 360° environment where the individual was placed in front of a fountain surrounded by stone arches. This environment contained visual (body-color distortion, VR avatar), auditory (meditative voice lines, water acoustics), and interactive elements (virtual body replicated movements, fountain).

Procedure

The study is approved by the Ethics Review Committee of Psychology and Neuroscience (ERCPN-248_14_02_2022) at Maastricht University (NL). Participants were composed of student attendees from Maastricht university, but participation in this study was not confined to the University and was available to the general public. Participants were recruited using SONA (a school web-based psychology recruitment system), public advertisements in university buildings, and email. Individuals participating in our research study contacted the research team directly, or sign up directly via the SONA portal. Shortly after registration, all eligible participants received a confirmation letter reinstating the appointment time, exclusion criteria, and study location.

A pre-screening questionnaire was conducted through Qualtrics before participants are accepted into the study. SONA candidates can fill out the pre-screening questionnaire through a website link. To access individuals outside of the university, sign-ups are available by reaching out through the provided contact information and getting forwarded to the screening questionnaire manually. This study was voluntary, so participation was not mandatory, but to participate an informed consent form was collected for each participant.

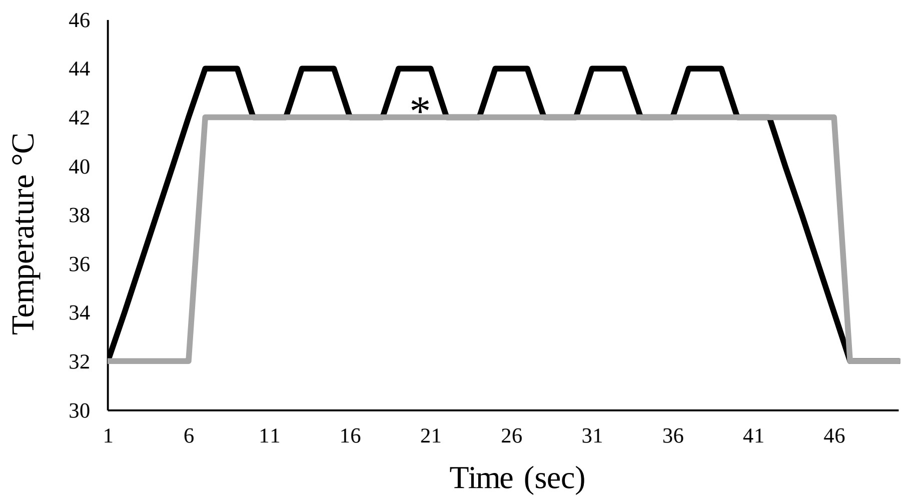
Before the study commences, participants were instructed on the basic procedure and structure associated with the study. They were further reminded of the risks associated with the nature of the study; such as sensitive skin originating from prolonged exposure to pain, short-lived skin irritation, redness, headaches, and possible nausea.

The participants were asked to fill out a pre-and post-questionnaire battery that lasted approximately 10 minutes. To avoid consistency bias and habituation, the questionnaires and items of the battery were randomized. The questionnaire battery is composed of a numeric pain rating scale, pain catastrophizing scale, and body image state scale. The study was performed in two parts: (1) pain calibration, and (2) pain induction.

In the pain calibration, The TSA was applied onto the volar left forearm by the researcher. Before the pain is administered, participants will receive a short instructional debriefing and were notified when pain is administered to the forearm through a countdown. The pain calibration is similar to Agostini et al., 2020 study, and will consist of a total of four trials to help establish the pain intensity and threshold of the thermal stimuli. In each trial, the tonic thermal stimulus will increase from a baseline of 32°C by 0.5°C/sec until it reaches the individual threshold. The participant's threshold was determined by the verbal indication "stop" the moment the induced sensation was experienced as painful. During calibration, participants were able to experience temperatures ranging from the baseline of 32°C to a potential 50°C. After the administration of all four trials, the average of all the thresholds was calculated to determine the threshold that is used for the pain induction. After the conclusion of the pain calibration, the TSA application to the forearm was moved slightly to help avoid habituation of pain.

Figure 1

Illustration of Pain Induction Protocol



Note. (*) Represents the area where PNS scores were recorded.

In the pain induction, the TSA was re-administered after a slight adjustment on their left forearm. The participants were informed not to move their left forearm during the virtual simulation. During this stimulation, participants will undergo a max of eight trials. Each trial will begin with the tonic thermal stimulus increasing at a rate of 2°C per second from the baseline temperature of 32°C until it reaches the individual average pain threshold. Once this threshold is reached, the temperature will oscillate every 3 seconds between +1°C and -1°C for a total of 30 seconds at the threshold. After the threshold is held, the temperature will return to the baseline (32°C) to resemble a break that lasts between 8-10 seconds. The total duration of stimulation is 5-minutes. During these five minutes, participants were asked to verbally indicate their level of pain at three-time points using a pain numeric scale, which ranges from 1 (No Pain) to 10 (Worst

Possible Pain). These pain ratings were logged at +1°C participants' threshold and were recorded during the 1st, 3rd, and 5th trials. Figure 1 illustrates one complete trial of the pain induction and displays the target area for recording PNS scores.

Parallel with the pain induction, participants were introduced to the VR environment. The researcher securely places and adjusts the VR goggles onto the head of the participants, and calibrates the VR system determined by the participants' height and their surrounding environment. During this study, participants were introduced to one of the two possible VR environments: a forest ecosystem (passive) or a cold-water environment (active). In the forest ecosystem, participants were not assigned a task and were allowed to freely view a 360° designed forest ecosystem. Participants in the active condition experienced a fully interactive cold-water environment. Participants were exposed to these environments for a total of 5 minutes.

Following the VR session, the researcher asks the participant to remain still while they remove the VR equipment. After safely removing the VR device, the participant is asked a series of questions by the researcher to provide a qualitative understanding of the participant's experience with pain. For example, the questions were aimed toward participants' experience, satisfaction, and perceived study effects; while the researcher also left open-ended questions for feedback and additional comments. Data were categorized based on their responses. Compensation for participation was provided through a 10-euro Amazon voucher or the choice of obtaining 1 SONA credit. Compensation was sent to participants via email.

Experimental Design

A mixed 2 x 2 design was used. The first factor, VR conditions, is measured using a between-subject design; while the second factor, time, was analyzed using a within-subject design. The first factor had 2 levels: an active and passive condition. Participants were randomly assigned to either of the two conditions. The second factor had two levels: Time 1/Pre-scores and Time 3/Post-scores. The dependent variables analyzed in this study were pain perception (using PNS scores) and state body image (using BIIS scores).

Statistical Analysis

Studentized residuals were used to test for outliers and were observed for ± 3 standard deviations. To test for normality, a Shapiro-Wilk test was conducted on both dependent variables. Two repeated measures ANOVA's were conducted in SPSS, one for each dependent variable. Pain catastrophizing was included as a covariate for the first ANOVA on pain perception, but was not utilized for the following ANOVA on state body image. A paired samples t-test was conducted as a supplemental analysis following a statistically significant result from the repeated measures ANOVA. In the paired samples t-test, each group was analyzed separately to account for each time point.

As an additional analysis, a 2 x 3 repeated measures ANOVA for both study groups and time. In this analysis, the factor time is measured with the additional data point, Time 2, to investigate extra confounding effects and interactions. A paired-samples t-test was used to measure within-subject effects between time and condition. An independent t-test was used to analyze the between-subject effects of group and time points 2 and 3. Furthermore, a Pearson's correlation was analyzed between PCS scores and both PNS difference scores and threshold temperatures °C.

Results

A two-way repeated measures ANOVA was employed to determine the main effect VR environments have on pain perception. There was a total of 46 participants for this analysis; with 1 participant excluded because of incomplete data (2.1%). Since we had a small sample size that did not meet the recommended power to detect statistically significant differences, we performed standard tests for normality and outliers for each dependent variable. The Shapiro-Wilk test ($p>0.05$) was performed on the baseline measure (Time 1) and displayed no statistically significant difference in the data (W= 0.970, p-value= 0.16). A studentized residual was analyzed for ± 3 standard deviations and showed no outliers for this condition. Table 2 displays the means and standard deviations for the factors group and time.

Table 2

Descriptive Statistics for PNS Scores.

Condition	**Time 1**		**Time 2**		**Time 3**	
	M	*SD*	*M*	*SD*	*M*	*SD*
Passive (*N*=23)	4.83	1.95	4.61	2.59	5.17	2.69
Active (*N*=23)	4.91	2.26	4.17	2.21	4.00	2.49

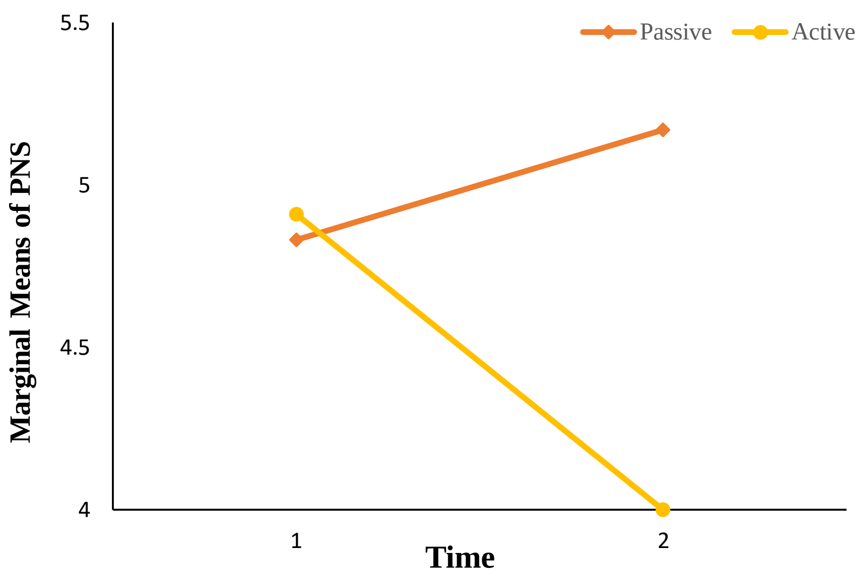
Note. *M*= Mean, *SD*= Standard Deviation, *N*= Number of Participants

VR condition was analyzed as a between-subject effect. There was no statistically significant effect for VR Conditions $F(1, 43) = 0.647$, $p = 0.426$, partial $\eta^2 = 0.015$. Within-Subject effects of Time, Time and Condition, and Time and Covariate (PCS) were measured. There was a statistically significant effect for Time $F(1, 43) = 7.322$, $p = 0.01$, partial $\eta^2 = .145$. There was also a statistically significant interaction comparing time and condition $F(1, 43) = 10.960$, $p =$

0.002, partial η^2 = .203. Figure 2 illustrates the relationship between conditions and PNS scores. Comparing time and the covariate, PCS scores, we found a significant relationship $F(1, 43)$ = 5.423, p = 0.025, partial η^2 = .112. Therefore, a paired samples t-test was run. Table 2 shows the Means and Standard Deviations for each time point. Results showed that pain numeric scores were not significantly different between Time 1 and Time 3 in the passive condition; $t(22)$ = -1.115, p = .277, d= .145. However, pain numeric scores were statistically significantly different between Time 1 and Time 3 in the active condition; $t(22)$ = 3.339, p = .003, d= .383.

Figure 2

Changes in PNS Mean Scores compared to VR Conditions.



Note. PNS scores were measured at Time 1 and Time 3.

On the other hand, a two-way repeated measures ANOVA was conducted to determine the effect VR conditions have on body image. The Shapiro-Wilk test (p>0.05) was performed on the pre-BISS scores and displayed no significant difference in the data (W= 0.981, p-value= 0.64). A studentized residual was analyzed for ± 3 standard deviations and showed no outliers for this condition. Therefore, 47 participants were analyzed for this measurement. Table 2 contains the Means and Standard Deviations for BISS scores for each condition.

Table 3

Descriptive Statistics for BISS Scores.

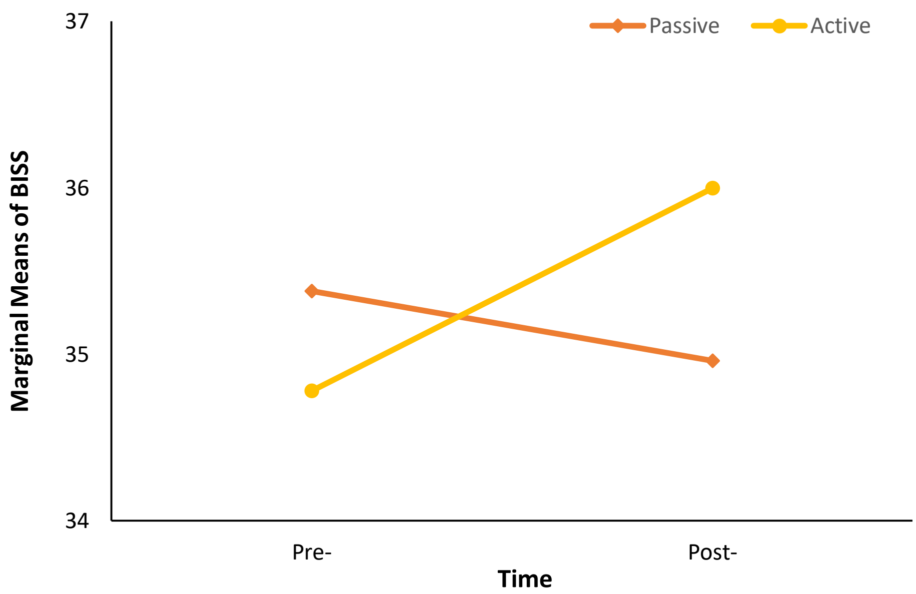
Condition	Pre-Scores		Post-Scores	
	M	*SD*	*M*	*SD*
Passive (*N*=24)	35.38	6.43	34.96	6.82
Active (*N*=23)	34.78	6.05	36.00	5.60

Note. *M*= Mean, *SD*= Standard Deviation, *N*= Number of Participant

For this study, within-subject effects of time and condition were measured. There was no statistically significant effect for Time $F(1, 45) = .597$, $p = 0.444$, partial $\eta^2 = .013$. There was also no statistically significant interaction comparing time and condition $F(1, 45) = 2.486$, $p = .122$, partial $\eta^2 = .052$. Figure 3 illustrates the interaction between the mean scores and the conditions.

Figure 3

Changes in BISS Mean Scores compared to VR conditions



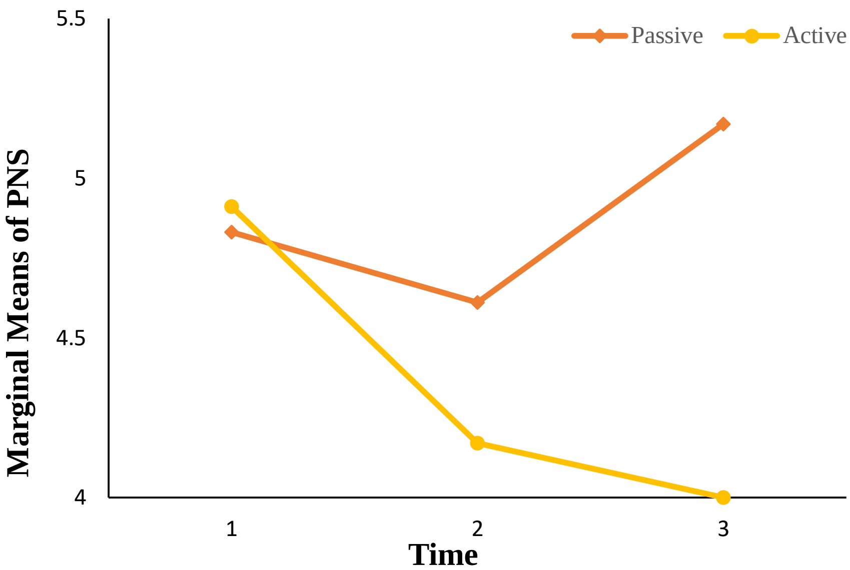
Note. BISS scores were measured Pre-Condition and Post-Condition

As an additional measurement, a two-way repeated measures ANOVA was used to compare VR groups with three different PNS time measurements (T1, T2, T3). As stated above, the Shapiro-Wilk test (p>0.05) of normality was not violated, and no outliers were observed in this data. The Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated, $\chi^2(2)$ = 8.448, p = .015, and therefore data was analyzed using the Greenhouse-Geisser. Table 2, as previously displayed above, shows the means and standard deviations with the additional level, Time 2.

In this analyses, there was a statistically significant effect for Time $F(1.692, 72.745)$ = 4.962, p =0.013, partial η^2 = .103. There was also a statistically significant interaction comparing time and condition $F(1.692, 72.745)$ = 7.322, p = 0.02, partial η^2 = .144; and time and covariate, PCS scores, $F(1.692, 72.745) = 7.231$, $p = 0.04$, partial $\eta^2 = .077$. An independent samples T-test was used to compare between-subject's effects at Time 2 and Time 3. Results showed that groups were not statistically significant at Time 2; $t(45) = -527$, $p = .601$, $d = .154$, and Time 3; $t(45) = 1.371$, $p = .177$, $d = .400$. A paired t-test was performed to observe within-subject interactions with the additional data point, Time 2. Results showed that pain numeric scores were not significantly different between Time 1 and Time 2 in the passive condition; $t(22) = .789$, $p = .439$, $d = .096$. However, pain numeric scores were statistically significantly different between Time 2 and Time 3 in the passive condition; $t(22) = -2.764$, $p = .011$, $d = .212$. There was a statistically significant effect between Time 1 and 2 in the active condition; $t(22) = 3.118$, $p = .005$, $d = .332$. However, pain numeric scores were not statistically significantly different between Time 2 and Time 3 in the passive condition; $t(22) = .940$, $p = .357$, $d = .072$. Figure 3 shows the relationship between the marginal means of PNS scores at different time points. In Figure 4, a quadratic (u-shape) effect is observed for the passive condition, while a linear effect is observed on the active condition.

Figure 4

Changes in PNS Mean Scores compared to VR conditions

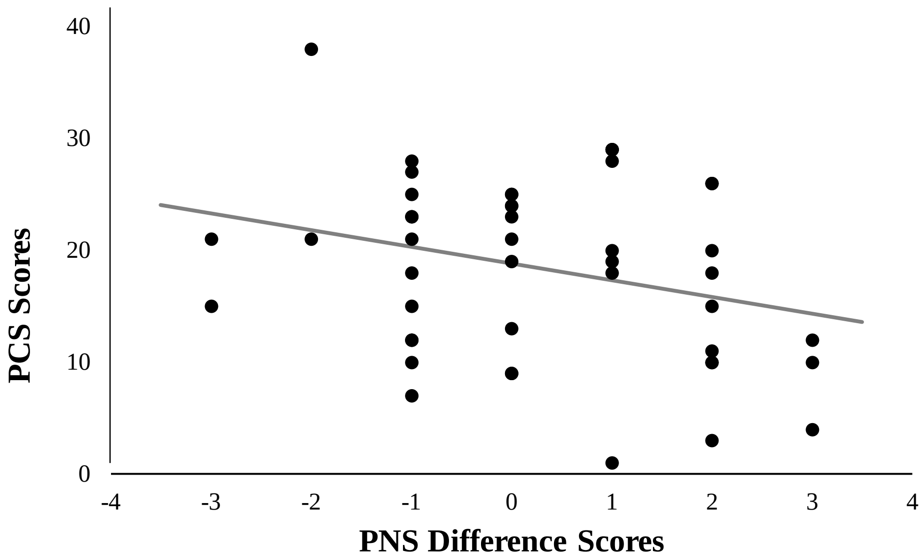


Note. PNS Scores measured at Time 1, Time 2, and Time 3.

Finally, a Pearson's Correlation was conducted to compare PCS scores to PNS difference scores (Time 1- Time 3) and threshold temperatures °C. The Shapiro-Wilk test ($p>0.05$) was performed on the PCS scores and displayed no significant difference in the data (W= 0.975, p-value= 0.436). However, this test was performed on the PNS difference scores and the test showed that the data was not normally distributed (W= 0.885, p-value = .023). A studentized residual was analyzed for ± 3 standard deviations and displayed no outliers for this condition. The data suggests there was no statistically significant correlation between PCS scores and the PNS difference score, $r(46)=-.281$, p= 0.058. In figure 5, you can see the correlation between PCS scores and PNS difference scores.

Figure 5

A scatterplot depicting the comparison of PCS scores to PNS Difference scores

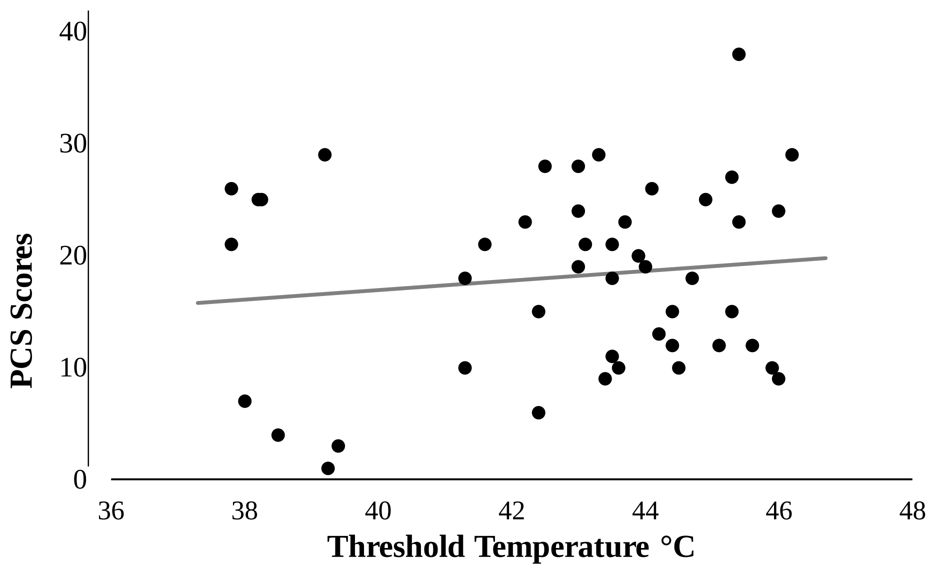


Note. Difference scores are calculated by subtracting Time 1 and Time 3. Positive values indicate an increase in PNS scores, negative values indicate a decrease in PNS scores.

Similarly, there was no statistically significant correlation between PCS scores and Threshold Temperatures °C, $r(46)=-.126$, $p= 0.406$. In figure 6, you can see the correlation between PCS scores and Threshold Temperatures °C difference scores.

Figure 6

A scatterplot depicting the comparison of PCS scores to the threshold temperature °C



Note. (°C) Stands for degrees Celsius.

Discussion

The purpose of the study was to determine how a VR environment would affect an individual's perception of pain. In our study, we separated participants into two conditions: an active condition and a passive condition. We hypothesized that individuals in the active condition would experience a greater reduction in pain perception than those in the passive condition. The main findings in this present study were that: (1) the active condition is associated with a greater reduced level of pain compared to the passive condition, (2) the passive condition displayed a significant increase in pain levels from Time 2 to Time 3, (3) VR was not significantly linked with body image in either condition, (4) PCS scores provided no statistically significant impact on pain threshold and perceived pain.

First of all, our study examined the effects of virtual reality on perceived pain. Although our study did not reach full power, we found that the active condition resulted in a greater reduction and longevity in pain compared to the passive condition. A potential probable cause of this link may be that our active condition contains more sensory input that is designed to reduce pain than our passive condition. For example, a study found that when an additional stimulus is presented it prevents the information from being present at a conscious level (Riva et al., 2001). Therefore, in this study's active condition: auditory, interactive, and visual immersion elements could have prevented an individual's awareness of pain due to distraction stimuli. On the other hand, the passive condition contained only visual immersion elements which may have resulted in a greater focus toward the pain stimuli; therefore, increasing the individuals' perception of pain. These findings are similar to another study that observed the pain-reducing effect that VR distraction would have on labor pain. This study found that pain intensity scores significantly decreased in the VR condition compared to no VR administration (Frey et al., 2018). Figure 2 shows that pain in the active condition sustained a linear decline throughout VR exposure between Time 1 and Time 2. Although the cause of the sustained pain reduction is still unknown, we can assume that additional sensory input sustains the pain reduction during induction. As other studies have reported, the awareness of pain deeply influence an individual's tolerance of pain (Leibovici et al., 2009; Magora et al., 2006; Triberti et al., 2014). Conversely, in our passive condition, pain readings from Time 2 to Time 3 showed a significant increase in self-reported pain. This assumption lines up with results from another study that found more immersive environments, compared to non-immersive environments, led to an increased reduction in perceived pain (Kenny et al., 2016; Leibovici et al., 2009).

Despite not examining individual elements in this study, we can suggest that bodily immersion effects (color change, water immersion) contributed to a reduction in perceived pain. For example, the most frequent post-discussion feedback provided by participants in the active condition stated that the visual cooling effect and the ability to interact with the fountain provided the most pain relief. These statements contradict those of another recent study that concluded that bodily illusions in VR are not effective enough to justify their use in chronic pain patients (Matamala-Gomez et al., 2019a). However, this study further reinstated the idea that some of these effects might be promising only depending on the VR environment. This researcher later performed a different study examining the effect of body illusions for pain relief through a virtual arm. They concluded that manipulating body representation in VR can reduce an individual's perceived pain while embodiment illusions can provide temporary relief (Matamala-Gomez et al., 2019b). These results are in correspondence with our VR results, which displayed significant pain reduction in the active condition. Despite not exploring the origin of this pain reduction, these results suggest that immersive VR can be extremely beneficial to chronic pain patients. Therefore, VR might appear to be a therapeutic alternative for chronic pain relief because of the ease of accessibility and the lack of assistance from a healthcare professional (Kenny et al., 2016).

In our analyses, we also explored the effects of VR conditions (active vs. passive) on state body image. We examined each participant, both pre-and post- pain induction, using the BIIS scale. Although our analysis was not a directional hypothesis, we assumed a significant interaction between the two conditions. We expected a significant effect would occur between conditions because the active condition contained a VR avatar and embodiment audiovisual elements while the passive condition contained neither element. This analysis's findings indicated no appreciable positive or negative link with VR. These results go against other studies that found a relationship (Ferrer-Garcia & Gutierrez-Maldonado, 2012; Gall et al., 2021; Irvine et al., 2020; Porras et al., 2019). However, this is consistent with another study that compared first-person VR with embodiment but produced no conclusive findings (Slater et al., 2010).

As an additional analysis, we observed the impact that pain catastrophizing has on pain temporal summation and thresholds. Our results suggest that pain catastrophizing was not significantly related to pain temporal summation and temperature thresholds. This analysis was not directional, although non-significant results may be enough to take out rumination and hypervigilance to pain as a possible limitation in our study. These results contradict previous findings that illustrate a strong significant relationship between PCS and heat pain ratings (Weissman et al., 2007). Alternatively, figure 5 showed that our virtual environments were approaching a negative correlation between PCS scores and PNS difference scores. Therefore, we can assume that the overall experience of VR could have provided a greater distraction effect to individuals scoring high on the PCS questionnaire.

Limitations

Research examining VR applications on pain reduction has provided promising results. However, this study is characterized by limitations that can be solved in future studies. First of all, one of the main limitations of this study was that our active and passive conditions were not balanced. For example, the passive condition contains different environmental features than the active condition resulting in the output potentially being impacted by other factors. Furthermore, the passive condition contains only visual stimuli while the active condition contains audiovisual and interactive stimuli; which makes the comparison between both VR conditions less controlled and effective. In addition, our study tried to replicate the experience of chronic pain on healthy university students in a lab setting, but this experiment would have produced more conclusive findings if it was represented by the target population.

In our study, the calculated effect size to reach 90% power was not reached. Previous research from Patterson et al., 2006, confirms that approximately 30 participants per group acts as a sufficient sample size. However, in our study, we obtained half of the participants leading to interesting, but preliminary, results. Another limitation of our study is that the participant pool was based on college students compared to the desired target group's mean age. According to a previous study, the prevalence of chronic pain increased with age, peaking between the ages of 50 and 59 (Rustøen et al., 2005).

Conclusion

Overall, this study suggests that the active condition compared to the passive condition provided results that were significant in reducing pain. Alternatively, there was no significant result when comparing body image in both conditions. It must be considered that this study was performed on a small number of healthy participants, within a short period of time, to simulate the experience of chronic pain participants. Future research on VR and chronic pain patients is planned by CUREosity from this exploratory study. Additional research is needed to understand the long-term effects that VR has on pain reduction in body image before conclusions can be drawn. Furthermore, new research could examine the impact of VR on pain tolerance and intensity (Loreto-Quijada et al., 2014), the individual impact of different sensory stimuli on chronic pain in immersive VR environments, and chronic-pain differences between immersive and non-immersive based augmented environments. Moreover, an additional qualitative analysis could have been recorded during piloting to account for cultural differences and environmental preferences. Finally, our study could have utilized another comparison group to test the distinctions between different environmental stimuli, or between other non-medicinal based programs.

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Appendix

The Pain Catastrophizing Scale (PCS)

Instructions: We are interested in the types of thoughts and feelings that you have when you are in pain. Listed below are 13 statements describing different thoughts and feelings that may be associated with pain. Using the following scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

0	1	2	3	4
Not at All	To a slight degree	To a moderate degree	To a great degree	All the time

When I am in Pain.......

1. ______ I worry all the time about whether the pain will end
2. ______ I feel I can't go on
3. ______ It's terrible and I think it's never going to get any better
4. ______ It's awful and I feel that it overwhelms me
5. ______ I feel I can't stand it anymore
6. ______ I become afraid that the pain will get worse
7. ______ I keep thinking of other painful events
8. ______ I anxiously want the pain to go away
9. ______ I can't seem to keep it out of my mind
10. ______ I keep thinking about how much it hurts
11. ______ I keep thinking about how badly I want the pain to stop
12. ______ There's nothing I can do to reduce the intensity of the pain
13. ______ I wonder whether something serious may happen

BODY IMAGE STATES SCALE

For each of the items below, check the box beside the one statement that best describes how you **FEEL RIGHT NOW AT THIS VERY MOMENT.** Read the items carefully to be sure the statement you choose accurately and honestly describes how you feel right now.

1. Right now, I feel...
   - ***Extremely dissatisfied*** with my physical appearance
   - ***Mostly dissatisfied*** with my physical appearance
   - ***Moderately dissatisfied*** with my physical appearance
   - ***Slightly dissatisfied*** with my physical appearance
   - ***Neither dissatisfied nor satisfied*** with my physical appearance
   - ***Slightly satisfied*** with my physical appearance
   - ***Moderately satisfied*** with my physical appearance
   - ***Mostly satisfied*** with my physical appearance
   - ***Extremely satisfied*** with my physical appearance

2. Right now, I feel...
   - ***Extremely satisfied*** with my body size and shape
   - ***Mostly satisfied*** with my body size and shape
   - ***Moderately satisfied*** with my body size and shape
   - ***Slightly satisfied*** with my body size and shape
   - ***Neither dissatisfied nor satisfied*** with my body size and shape
   - ***Slightly dissatisfied*** with my body size and shape
   - ***Moderately dissatisfied*** with my body size and shape
   - ***Mostly dissatisfied*** with my body size and shape
   - ***Extremely dissatisfied*** with my body size and shape

3. Right now, I feel...
   - ***Extremely dissatisfied*** with my weight
   - ***Mostly dissatisfied*** with my weight
   - ***Moderately dissatisfied*** with my weight
   - ***Slightly dissatisfied*** with my weight
   - ***Neither dissatisfied nor satisfied*** with my weight
   - ***Slightly satisfied*** with my weight
   - ***Moderately satisfied*** with my weight
   - ***Mostly satisfied*** with my weight
   - ***Extremely satisfied*** with my weight

4. Right now, I feel...
   - ***Extremely*** physically ***attractive***
   - ***Very*** physically ***attractive***
   - ***Moderately*** physically ***attractive***

- ***Slightly*** physically ***attractive***
- ***Neither attractive nor unattractive***
- ***Slightly*** physically ***unattractive***
- ***Moderately*** physically ***unattractive***
- ***Very*** physically ***unattractive***
- ***Extremely*** physically ***unattractive***

5. Right now, I feel...
    - ***A great deal worse*** about my looks than I usually feel
    - ***Much worse*** about my looks than I usually feel
    - ***Somewhat worse*** about my looks than I usually feel
    - ***Just slightly worse*** about my looks than I usually feel
    - ***About the same*** about my looks as usual
    - ***Just slightly better*** about my looks than I usually feel
    - ***Somewhat better*** about my looks than I usually feel
    - ***Much better*** about my looks than I usually feel
    - ***A great deal better*** about my looks than I usually feel
6. Right now, I feel that I look...
    - ***A great deal better*** than the average person looks
    - ***Much better*** than the average person looks
    - ***Somewhat better*** than the average person looks
    - ***Just slightly better*** than the average person looks
    - ***About the same*** as the average person looks
    - ***Just slightly worse*** than the average person looks
    - ***Somewhat worse*** than the average person looks
    - ***Much worse*** than the average person looks
    - ***A great deal worse*** than the average person looks

Score: __________

Profile of Mood States (POMS Modified)

Below is a list of words that describe feelings people have. Please CIRCLE THE NUMBER that best describes how you are feeling right now

	Not at All	**A Little**	**Moderately**	**Quite a lot**	**Extremely**
Tense	0	1	2	3	4
Angry	0	1	2	3	4
Worn Out	0	1	2	3	4
Unhappy	0	1	2	3	4
Lively	0	1	2	3	4
Confused	0	1	2	3	4
Sorry for things done	0	1	2	3	4
Sad	0	1	2	3	4
On-edge	0	1	2	3	4
Grouchy	0	1	2	3	4
Unable to Concentrate	0	1	2	3	4
Energetic	0	1	2	3	4
Uneasy	0	1	2	3	4
Restless	0	1	2	3	4
Alert	0	1	2	3	4
Fatigued	0	1	2	3	4
Feeling Blue	0	1	2	3	4
Relaxed	0	1	2	3	4
Annoyed	0	1	2	3	4
Discouraged	0	1	2	3	4

Nervous	0	1	2	3	4
Miserable	0	1	2	3	4
Confident	0	1	2	3	4
Bitter	0	1	2	3	4
Exhausted	0	1	2	3	4
Anxious	0	1	2	3	4
Helpless	0	1	2	3	4
Weary	0	1	2	3	4
Lonely	0	1	2	3	4
Bad Tempered	0	1	2	3	4
Furious	0	1	2	3	4
Worthless	0	1	2	3	4
Forgetful	0	1	2	3	4
Carefree	0	1	2	3	4
Uncertain about things	0	1	2	3	4
Embarrassed	0	1	2	3	4