Spring 2017

OBJECTIVE AND SUBJECTIVE TEMPERATURE EFFECTS OF VIRTUAL REALITY

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OBJECTIVE AND SUBJECTIVE TEMPERATURE EFFECTS OF VIRTUAL REALITY

A Thesis

Presented To

Eastern Washington University

Cheney, Washington

In Partial Fulfillment of the Requirements

for the Degree

Master of Science in Experimental Psychology

By

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Spring 2017

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ABSTRACT

The purpose of this study was to examine whether we could manipulate an individual's body temperature by immersing them in a virtual environment. Virtual reality (VR) involves digital environment immersion of individuals and their movements into a digital space designed to simulate a real environment. The goal of VR is to give the perception that people are actively interacting with the virtual environment. The present study examined the effects of VR on participants in two conditions: the experimental condition of a snowy blizzard environment and the control condition of a temperate forest environment. It was hypothesized that participants would experience an objective surface temperature decrease as well as a subjective body temperature decrease in the experimental condition. Results revealed no significant objective change in surface temperature. For the subjective measure, a main effect was observed for time, which was modified by an interaction between time and condition. Participants showed a significant perceived temperature change through the subjective measure. Overall, these results suggest VR can have an effect on peoples' perception of temperature, indicating usefulness in clinical settings where it is desired to create a mental effect.

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CHAPTER I

INTRODUCTION

Virtual reality is a rapidly growing field that has been advancing with increasing speed ever since the announcement of the Oculus Rift in 2012. Commercially, virtual reality software revenue is projected to net approximately $2.57 billion in 2017 (Statista, 2015) and the user base for virtual reality is projected to reach 171 million users by 2018 (Statista, 2015). One year before Oculus even announced their final product (Dredge, 2014), the Oculus Rift caught the eye of Facebook, who acquired it for $2 billion dollars in March of 2014. There were relatively few studies done with virtual reality prior to this study, but the number is increasing dramatically with the commercial release of virtual reality.

Previous studies have suggested the benefits of using virtual reality for clinical applications, ranging from treating chronic pain (Wiederhold, Gao, Sulea, & Wiederhold, 2014) to phobias (Baños , Osma, Garcia-Palacios & Quero 2004). While studies could be found manipulating various physiological responses from participants, none could be found that specifically dealt with using virtual reality as a future avenue for research that could not normally be done in a lab.. Specifically, this study will examine the psychological and physiological effects a virtual blizzard has on the objective skin temperature of participants, as well as their subjective perception of temperature.

Virtual reality, or VR, involves a digital environment immersing an individual and his or her movements into a digital space designed to simulate the real environment. The goal is to give the perception that an individual is actively interacting with the virtual environment, in accordance with their bodily movements (Fox, Arena, & Bailenson, 2009). This is achieved by seamlessly mimicking cues from the real world with digital cues. The term virtual reality was coined in 1987 by Jaron Lanier (Firth, 2013). His company, Visual Programming Lab, created the first virtual reality equipment, such as the Dataglove, EyePhone, and Virtual reality goggles. Modern virtual reality equipment such as the Oculus Rift and HTC Vive have much more accuracy with motion capture and detail in their head-mounted displays. Combined with human factors such as immersiveness and absorption, this modern approach to virtual reality can recreate environments not typically available in a lab for testing.

Immersiveness and absorption are two key concepts that affect how effective the simulation will be at creating a sense of realism (Insko, 2003; Wiederhold, Davis, & Wiederhold, 1998). Immersiveness is the perception of being physically present in a virtual world. It determines how in-depth the virtual experience is, and to what extent subjects feel a desire or obligation to interact with the experience (Macedonio, Parsons, Digiuseppe, Weiderhold, & Rizzo, 2007). That desire to interact with the experience is known as absorption, which determines how invested in mental imagery people can become (Crawford, 1982). In other words, absorption is a person's desire to interact with the virtual environment, whether it be ducking when a ball is thrown or wanting to reach out and touch virtual snow. People with a high absorption disposition tend to daydream and are easily hypnotizable – (Tellegen & Atkinson, 1974). These people will be most likely to experience physiological feedback from a virtual environment, as virtual environments can be thought of as an altered state of consciousness similar to daydreaming (Glicksohn 1997). In short, immersion is the feeling of being present in the environment, absorption is the desire to interact with said environment.

Virtual Reality and Physiological Effects

The present study examined the physiological and subjective effects virtual environments can have on participants within virtual reality. The purpose of this study was to determine the effectiveness of using virtual reality to manipulate subjective and objective ambient temperatures. The clinical applications of VR have been well studied in psychology, especially in the areas of specific phobias and pain (e.g., Baños et al., 2004; Wiederhold, Gao, & Wiederhold, 2014).

Baños and colleagues (2004) investigated people with flying phobias and were able to use the virtual simulations of flight sequences as an intermediate step in treatment of their flight phobia. The most effective therapy for treating phobias is in vivo exposure. Many clients do not readily accept this type of therapy, however. Twenty to 25 percent of participants refuse to participate in in vivo treatments due to them being too intense. Additionally, in vivo exposure lacks confidentiality and control over the situation, and can sometimes be expensive (as in the case of flight phobia).   An alternative treatment method is imaginative therapy, in which a scenario involving the specific phobia is created. This type of therapy is less effective in treating the phobia, but is considerably more tolerable for participants. The study performed by Baños and colleagues aimed to bridge the gap. Baños believes that virtual reality could be invaluable to therapy due to its confidentiality, control over the situation, and relatively low cost-to-treatment. The simulation allowed participants to focus on the specific portion of a flight that causes panic for the individual. For example, if participants are only afraid of the landing involved with flying, participants were able to experience just the landing, rather than having to experience an entire plane ride each session. Nine participants, all meeting the DSM-IV criteria for specific phobia, took part in the study. VR produced an activation of fear and avoidance behaviors that were reported by participants in self-report measures about flight phobias. These behaviors decreased in intensity over the study as participants were exposed to their phobia through a simulated environment. In the 5 months following the treatment, all of the participants were able to fly unaided by medication or alcohol. None of the participants required any follow-up treatment, nor did any receive any additional treatment(Baños, 2004).

As a treatment for pain management, virtual reality has been found to change the *perception* of our biology (Wiederhold et al., 2014). Weiderhold and colleagues attempted to demonstrate dental operation pain can be mitigated through distraction from the perception of pain. Pain has a strong psychological aspect that requires constant attention to the stimuli. Wiederhold and colleagues worked to create a virtual environment that distracts people and prevents them from paying attention to the stimuli. This virtual environment, projected from a head-mounted display, consisted of a forest, beach, river, or a mountain. Five Participants were given a self-report measure of perceived pain twice: once when they had no VR distraction, and again whilst navigating a virtual environment. Participant heart rate and respiration rate were also monitored. Participants were exposed to 5 minutes of dental procedure without virtual reality, and 5 minutes within the virtual environment. The study met limited success, finding only marginally significant results that indicated slightly decreased heart rates, anxiety and fear levels, and respiration rates. This study, however, was important in establishing their follow-up study.

During their follow-up study, Weiderhold and colleagues used a modified version of their VR distraction condition from the previous study. This study also included relaxing music, and additional environmental effects such as branches swaying. The swaying was slow and rhythmic, approximately 6 to 8 times a minute, in order to help regulate breathing. Participants were exposed to the environment for 15 minutes, after which they were asked to complete a brief questionnaire scoring their pain levels on a 7-point Likert Scale. Thirty-four patients completed the study, and all patients reported a decrease in perceived pain while within the virtual environment, with significances ranging from $p<.05$ to $p<.01$.

One of the most compelling arguments for the use of virtual reality as a research tool is that if the environments prove to be highly immersive, a virtual environment could simulate a potentially dangerous or (typically) unethical situation that could not happen in a lab. Due to the high immersion levels from the virtual environment, people's perception of the environment could be indistinguishable from the actual environment, thus allowing for study of unconventional scenarios. For example, participants could experience their own death in a very graphic and realistic manner, allowing for studies on feelings of mortality, gratitude, etc. Researchers could also study decision-making during dangerous situations, such as having a gunman in a crowd or having the participant stuck in a forest fire.

There are several other factors that make virtual reality a valuable asset to research and clinical treatment. With virtual reality, it is possible to manipulate temperature and other environmental factors without leaving the confidential space of the lab. Having the therapy take place within a clinical setting allows for greater control over the situation, and virtual reality offers consistency between each session (e.g. having the same amount of people walking around a mall for treatment/research of agoraphobia). The clinician can also pinpoint trigger stimuli by monitoring where the patient is looking, given that the clinician will be able to see exactly what the patient is seeing (Baños, 2004). With commercial virtual reality available now, therapy could be administered remotely, greatly increasing ease of access, which in turn could increase treatment retention.

Biofeedback

One area of clinical treatment that I believe would benefit most from virtual reality therapies is biofeedback. Biofeedback is a method by which people monitor involuntary processes such as heart rate and blood pressure, with the eventual goal of influencing their bodily processes. One of the most commonly used biofeedback machines is the polygraph, which measures physiological responses (and not lie detection, as is often portrayed in the media).

The goal of biofeedback is to make ourselves more aware of the physiological functions of our body so that a person can freely manipulate their physiology to a desired state, such as increasing circulation to extremities, or calming down their heart in a panicked situation. This is often achieved through use of instruments that monitor the activity of those systems. Common biofeedback techniques include measuring body temperature, muscle tension, and skin conductance (i.e., galvanic skin response). Combined with other techniques such as relaxation training, it has been used to treat numerous clinical conditions, ranging from Irritable Bowel Syndrome (Leahy & Epstein, 2001) to Raynaud's disease (Karavidas, Tsai, Yucha, McGrady, & Lehrer, 2006).

People with Raynaud's disease experience numb and cold extremities of the body, most commonly fingers and toes, as a response to cold temperature as well as stress. When stressed, arteries and blood vessels in the body spasm, resulting in decreased blood flow to the extremities,which leads to a decrease in temperature. Temperature biofeedback provides patients information regarding the blood flow to those extremities. People with Raynaud's often experience distal vasoconstriction, which causes their blood vessels to constrict and limit blood flow. By conditioning themselves to elicit a vasodilation response, participants in biofeedback therapy are able to reverse the constriction of their blood vessels. Combined with relaxation training, Karavidas et. al found that temperature biofeedback allows individuals to gain more control over the blood flow to their extremities, combating the effects of Raynaud's (Karavidas et al., 2006).

With this in mind, virtual reality could help to make biofeedback therapies more interactive, and thereby, more effective. In the case of Raynaud's, there are several potential applications. First, virtual reality could provide real-time information regarding their extremity temperatures in order to facilitate biofeedback. Secondly, virtual reality could be used to simulate situations that a patient finds stressful, in order to allow relaxation training for real life circumstances. The more realistic the simulation appears, the more likely the patient will be able to effectively apply the therapy in real life.

The Present Study

As stated above, virtual reality can be an effective tool in therapy for treatment of things such as phobias, and alteration in physiological processes. The purpose of this study was to examine whether I could manipulate their objective and subjective body temperature by immersing them in a virtual environment. I hypothesized that participants would demonstrate decrease in objective surface temperature after being exposed to the experimental virtual environment. Secondly, I hypothesized that individuals would report a subjective decrease in body temperature after the experimental condition.

CHAPTER II

METHOD

Participants

Participants were recruited using Eastern Washington University's Sona System, a cloud-based participants pool management system. Initially, 124 students completed the prescreen tests. Forty participants were male, 82 were female, and 2 declined to specify gender. 16 participants were excluded from the study due to health concerns based on self report of epilepsy or severe motion sickness. 47 of the students of the remaining students did not meet the inclusion criteria. In total, 61 participants were invited to the lab for the experimental condition. Of these, 28 participants participated in the experimental trials. Of the 28 participants, 6 of the participants had incomplete data and were excluded from the final analysis. The 22 participants who were analyzed consisted of 12 female participants, 9 male participants, and 1 participant who declined to answer. Majority of the participants were between the ages of 18 and 21 (65%) and the average total score on the TAS was 163.73 (SD = 19.46). Participants reported having no difficulties with visual acuity.

Prescreen

Two prescreens were used for both inclusion and exclusion of participants.

Tellegen Absorption Scale(Tellegen & Atkinson, 1974): This is a 34-item self-report inventory that identifies individuals' susceptibility to absorption. The TAS assesses a person's ability to become deeply absorbed into what he or she is doing in an environment (for more, please see Roche & McConkey, 1990). The TAS is commonly used in VR research (Kober & Neuper, 2013; Macedonio et al., 2007; Wiederhold et al., 1998). For this study, thirty-four items on this inventory were scored on a 7-point Likert scale, where 1 represents 'highly disagreed' and 7 represents 'highly agreed'. Sample items include "I can be greatly moved by eloquent or poetic language" and, "At times I somehow feel the presence of someone who is not physically there." Higher scores represent higher hypnotizeability or more suggestibility (Glisky et al., 1991) and more open to self-altering experiences (Tellegen & Atkinson, 1974). Participants' average score of 139.76 (SD = 39.05), which is consistent with the average total score of 140 found in the general population (Glisky et al., 1991). Wanting at least average level of absorption, only participants (n = 69) scoring above the general population total average were included in the current evaluation.

Demographic Survey: 2 items in the demographic survey addressed potential health concerns. Virtual reality can result in individuals experiencing motion sickness, or potentially exacerbate conditions such as epilepsy. Participants who self reported motion sickness above a 4 on the 7-point Likert scale were excluded. Additionally, any participant reporting epilepsy were excluded. Inclusion and exclusion criteria with participants numbers can been seen in Appendix E. Participants completing the pretest were compensated for their time with extra credit in eligible classes.

Experimental Design

This experiment investigated the impact of temperature cues in a virtual environment and the effect on subjective and objective body temperature. Virtual environment temperature (cold versus neutral) was used as an independent variable, while subjective and objective physiological responses to the virtual experience, as measured by extremity temperature and questionnaires, were used as the dependent variables. The experiment utilized a 2 x 2 within-subjects design, with participants experiencing both the experimental condition and the neutral condition. Conditions were counterbalanced to control for the accumulation of order effects.

Materials

Virtual Reality Hardware/Software. An Oculus Rift Development Kit 2 was used to create the virtual environment participants experienced. The computer running the Oculus Rift was capable of running Skyrim on max settings, while also running multiple in-game modifications (mods).

The Oculus Rift rendered the 2011 fantasy-role playing game Skyrim on the Steam gaming platform using a third party program known as vorpX. Several modifications were added to the game using Steam’s Workshop function, including a snow detail enhancement, as well as overall graphic texture improvement.

A non-contact infrared temperature gauge was used to measure people’s temperature during each condition, and each biometric reading was taken approximately one foot from the participant’s hand.

Participants were tested within a soundproof testing booth and room temperature was kept constant. Each participant sat in a stationary chair that allowed for the participant to turn approximately 140 degrees to either side of their vision without lifting their back from the chair. To prevent tangling with the equipment as well as offering a consistent view, participants were asked to avoid turning more than 180 degrees.

Measures

Demographics. A basic demographics questionnaire was administered during the pretest on-line through the participants' pool management software, SONA. This questionnaire included questions regarding age, gender, race, and known health issues that could be affected by video games (e.g., epilepsy, flashing lights). Another question asked participants about their visual acuity.

Subjective Temperature. To assess participants' subjective perception of temperature, participants were asked to rate their subjective perception of temperature on a 7-point Likert scale (i.e., 1 = very uncomfortably cold to 7 = very uncomfortably hot).

Objective Temperature. To assess participants' objective temperature a non-contact infrared temperature gauge was used.

Virtual Realism Scale. To assess immersiveness, I created a 6-item virtual reality scale. Items were scored on a 7-point Likert scale, where 1 represents 'far from realistic' to 7 'completely realistic'. The alpha coefficient was .75 suggesting relatively high internal consistency.

Procedure

Participants were instructed in each condition via a pre-determined script (Appendix D). Participants were immersed in 2 different virtual environments. Each condition lasted 10 minutes, followed by a 5-minute washout period between conditions to eliminate any residual effects of the previous condition. In the experimental condition, participants were exposed to a simulated blizzard upon the Nordic mountainside at approximately 10 p.m. This created an extreme temperature condition with many temperature cues, such as swirling winds, dense snowfall, and thick cloud coverage. In the control condition, participants were exposed to a temperate forest with minimal temperature cues (e.g. lack of wind and cloud cover) at 10 p.m. Objective surface temperature was assessed using a non-contact infrared temperature gauge, taking the temperature from approximately 1-foot above each participant's hand. The measure was taken every 2 minutes, beginning just prior to the beginning of the condition, and ending just after the condition completed. Subjective temperature was assessed using the temperature perception questionnaire.

Analysis

The dependent measures (i.e., subjective and objective pre-/post-temperatures) were analyzed using a two (i.e., pre-temperature and post-temperature) by two (i.e., experimental and control conditions) 2 x 2 analysis covariance (ANCOVA). Immersiveness, as measured by the Virtual Realism Scale, was included as a covariate in the models. In both instances, the covariate was not found to be significant. Thus, the analysis was repeated without including the covariate of immersiveness (Tabachnick & Fidell, 2012). Pairwise comparisons were computed using Tukey's HSD post-hoc tests when appropriate. Significance level was set at .05 for the ANCOVA or ANOVA and post-hoc tests. Eta-squared was used as a measure of effect size.

CHAPTER III

RESULTS

Objective Measure of Temperature

Main Analysis. A 2 x 2 Repeated Measures ANCOVA was used to compare surface skin temperature at the beginning and end of each condition's sessions for both the snow and forest conditions controlling for level of immersiveness. The covariate was not significant, $F(1, 20) = 0.10$, $p = .76$, so analyses were analyzed again without the covariate. Results revealed no main effects of the experimental condition, $F(1, 21) = 0.45$, $p = .51$, $\eta^2 = .02$, or time, $F(1, 21) = 3.57$, $p = 0.07$, $\eta^2 = 0.15$, nor an interaction effect between condition and time, $F(1, 21) = 0.94$, $p = .34$, $\eta^2 = .04$

Exploratory Analysis. Given the small sample size, exploratory-paired samples *t* tests were also calculated on the dependent measures for each condition. Results showed a significant increase in temperature in the control condition, $t(21) = -2.55$, $p = .02$. This indicates that participants' body temperature increased from the start of the trial (M = 87.82, SD = 3.66) to the end (M = 89.02, SD = 3.67). There was no difference between pre-condition and post-condition temperatures during the experimental condition, $t(21) = 0.33$, $p = .75$. This suggests that temperature in the experimental (cold) condition was statistically similar at the start of the trial (M = 87.85, SD = 3.48) as it was at the end (M = 88.26, SD = 3.65).

Subjective Measure of Temperature

A 2 x 2 Repeated Measures ANCOVA was also used to test subjective measures of temperature before and after each condition, controlling for immersiveness.

Specifically, participants provided ratings of their perceived temperature on a Likert scale *before* and *after* completing each of the VR conditions. Again, the covariate was not significant, $F(1, 20) = 0.10$, $p = .76$, so analyses were analyzed again without the covariate. Contrary to the hypothesis, there was no main effect of condition, $F(1, 21) = 2.78$, $p = 0.11$, $\eta^2 = 0.18$. A main effect of time was observed, $F(1, 21) = 5.91$, $p = 0.02$, $\eta^2 = 0.22$, that was qualified by a significant interaction between time and condition, $F(1, 21) = 4.53$, $p = 0.05$, $\eta^2 = 0.18$.

As seen in Figure 1, simple effects tests revealed participants *perceiving* a significant drop in body temperature after completing the experimental condition (M_{pre} = 4.23, SE = 0.19; M_{post} = 3.68, SE = 0.14), $F(1, 21) = 7.88$, $p = .01$, $\eta^2 = .27$. In comparison, there was no different in perceived body temperature within the control condition (M_{pre} = 4.23,SE = 0.15; M_{post} = 4.18, SE = 0.13), $F(1, 21) = 0.11$, $p = .75$, $\eta^2 = .01$. This suggests that individuals perceived a decrease in body temperature in the experimental condition but not the control condition.

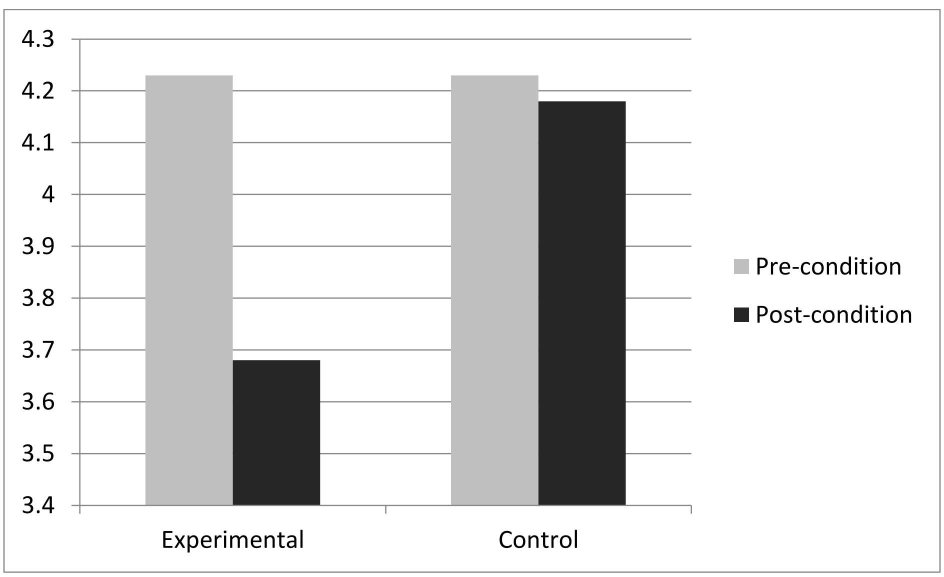

Figure 1: Means of pre/post perceived temperature

CHAPTER IV

DISCUSSION

The purpose of this study was to determine the efficacy of virtual reality in manipulating subjective and objective surface temperature of participants. It was hypothesized that participants would experience an objective as well as subjective decrease in body temperature within the experimental condition. Specifically, I expected to find a decrease in participants' body temperatures and that participants would perceive a drop in temperature in an experimental cold environment than in a control temperate environment with minimal temperature cues.

Prior research with virtual reality has not focused on the physiological effects of virtual reality. What it has focused on is the clinical effects of exposure and distraction therapies in virtual reality, which are based in manipulating perception (Baños et al., 2004; Weiderhold et al., 2014; Weiderhold et al., 2014). We already know through research on the placebo effect that manipulating a person's perception can have physiological effects (Price, Finniss, & Benedetti, 2008). Around the same time I was running my study and asking this question, Hashiguchi and colleagues (2016) ran a study examining this concept. They found that temperature perception is strongly influenced by visual perception. During the study, Mixed Reality (MR) equipment combined superimposed images with haptic tools to create desired perceptions, such as bees stinging and temperature manipulation. This ability to influence perception could result in beneficial gains for biofeedback therapies. The ability to manipulate biological perception of temperature could be critical to treatment of people with Raynaud's phenomenon.

The results of my objective measure (surface temperature) were both nonsignificant and inconclusive, I believe, at least in part because of an unanticipated temperature issue discovered during the experiment. While in the control condition we expected participants to take their temperature cues from the ambient temperature of the room. We had tested this previously on limited single pilot runs of the condition. However, prolonged use of the room and equipment, as seen in the actual study, resulted in a noticeable increase in temperature that was reflected in the surface temperature of participants. Due to this, I was not surprised to find nonsignificant results and it is impossible to support the objective hypothesis. There may be an observable effect, but due to this problem I am not able to make a reasonable assertion.

Although objective temperature did not decrease, individuals *perceived* a decrease in temperature during the experimental condition. Specifically, participants reported significantly lower perceived temperatures within the experimental condition than in the control condition. There is evidence to suggest that virtual reality has the ability to change a person's perception of his or her biology. In a 2014 study, Weiderhold et al. found that virtual reality treatments caused alterations to perceptions of personal biology. In that study, participants were exposed to a relaxing scene, such as forests, beaches, and mountains. Soothing music was also combined with the experience to increase the effect. Similar to this study, participants were using a Head Mounted Display (like the Oculus Rift), and posttest self-report questionnaires consisting of 7-point Likert Scales were administered (Wiederhold et al., 2014). The current study reinforces this existing evidence that virtual reality can alter perceptions of personal biology.

While the objective effects of VR were not observable in this study, the findings on changes in perception could still be highly useful in the worlds of therapy and research. As previously studied by Weiderhold et al. (2014), pain is highly subjective and can be altered through disrupting perceptions of pain. With the increase in the overall capabilities of virtual reality with the commercial release of several virtual reality headsets, the opportunity for treatment of pain is more abundant than ever. After initial training with the virtual environment, patients could even bring the therapy home. Biofeedback could also see excellent new therapies emerge with the help of virtual reality. Specifically, temperature biofeedback therapies can be made much more personalized and realistic. Rather than simply observing a 2-D video, participants could interact with a virtual environment. And now that virtual reality headsets are available to the public, individuals would not need to exclusively receive therapy on site, they could continue some of their therapy at home.

Before concluding, I discuss limitations to the current study. As noted in the results, temperature increased in both conditions; however, only the control condition had a significant change in temperature. Temperature increase in both conditions could be partially attributed to the insulated room and poor air dispersion. The room used for testing was designed to be soundproof, which was purposeful to prevent noise outside the lab from interfering with the immersiveness of the experience. Consequently, the soundproofing resulted in the room retaining heat very well. The hand that was used to analyze temperature had to remain on a metal table in a stationary position, which could have further added to the temperature increase due to heat dispersion. Additionally, the virtual reality headset had foam padding surrounding the eyepiece that also contributed to an increase in perspiration and body temperature.

The primary limitation for the present study was the small sample size (twenty-two). Analyses indicated the current study was grossly underpowered (0.05) to find expected results. A priori power analysis indicated a preferable sample size of 48. Unfortunately, the present study was unable to obtain this size due to several factors. First, the strict inclusion and exclusion criteria eliminated 63 participants from the potential sample. Participant mortality at 54% severely reduced the sample size from 61 to 28. While participant mortality is always to be expected, I did not anticipate such a high mortality rate. Six participants not completing all phases of the protocol further compounded these problems. It is likely the study was not adequately powered to accept or reject our null hypothesis accurately, which raises concerns about drawing conclusions. However, the sample obtained was not that far from participant numbers found in other studies utilizing virtual reality (Baños et al., 2004; Weiderhold et al., 2014; Weiderhold et al., 2014). In addition, scatterplots revealed no temperature readings fell outside three standard deviations from the average.

As I previously stated, biofeedback could benefit immensely from virtual reality. As my study has demonstrated, virtual reality can have a powerful effect on perception. Biofeedback therapies rely heavily on altering perception; therefore future studies could incorporate the efficacy of virtual reality in providing that state of altered perception. More extensive research into the strength this perception has on impacting physiology should be further investigated. While my study did not impact physiology in the way I intended, there could be a physiological effect that was unobservable due to confounds as stated above.

With the high levels of absorption and immersion that are present in the newest models of virtual reality, there is a pressing need for research into the possible side-effects of playing high-stress/violent virtual reality games. Games with high graphical fidelity and realistic violent scenarios could potentially result in traumatic stress responses. As post-traumatic stress disorder by proxy is already a well-established condition, virtual reality could be capable of a similar effect. I have already observed how effective virtual reality can be on perception, if that effect extends to VR gaming, the potential consequences need to be researched.

Future studies should also examine exactly how efficacious virtual reality is versus real life counterparts. A study trying to examine the efficacy of virtual reality would benefit from using some of the most advanced virtual reality haptic controls to date. The current study was only capable of head motion capture with the Oculus Rift Development Kit 2. For full haptic control I would suggest using the HTC Vive, which uses hand and head motion tracking, as well as a 20-foot interaction space.

The purpose of this study was to determine the efficacy of virtual reality in manipulating subjective and objective temperature of a person. We were unsuccessful in finding a significant effect on objective temperature based on condition. However, individuals reported perceiving a decrease in temperature in the experimental condition compared to the control condition. Given significant limitations within the current study, additional research is needed to investigate the usefulness of virtual reality to influence physiology.

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VITA

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Lab Technician, Washington State University, Spokane, Washington, 2014

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APPENDICES

Appendix A: Thesis Questionnaires

A1 Perceived Temperature Questionnaire

Please rate how realistic you perceived each of the items below from the virtual environment with 1 being far from realistic to 7 being completely realistic.

1=Very uncomfortably cold

4=Comfortable

7=Very uncomfortably warm

1. How would you rate your current perceived temperature?

A2 Tellegen Absorption Scale (AB, 34 items)

The Tellegen Absorption Scale (TAS) was not included due to it being a copyrighted test.

This is a 34-item self-report inventory that identifies individuals' susceptibility to absorption. The TAS assesses a person's ability to become deeply absorbed into what he or she is doing in an environment (for more, please see Roche & McConkey, 1990). The TAS is commonly used in VR research (Kober & Neuper, 2013; Macedonio et al., 2007; Wiederhold et al., 1998). For this study, thirty-four items on this inventory were scored on a 7-point Likert scale, where 1 represents 'highly disagreed' and 7 represents 'highly agreed'. Sample items include "I can be greatly moved by eloquent or poetic language" and, "At times I somehow feel the presence of someone who is not physically there." Higher scores represent higher hypnotizeability or more suggestibility (Glisky et al., 1991) and more open to self-altering experiences (Tellegen & Atkinson, 1974).

A6 Online Demographic questionnaire

1. How old are you? (Age)

2. What is your gender? (What gender)

3. What is your highest level of education achieved? (What is your hi)

4. What is your primary language? (What is your pr)

5. Are you prone to motion sickness? (Are you prone t)

6. Do you have any visual impairments? (Do you have any)

7. Are you prone to seizures caused by flashing lights? (Are you prone t)

Appendix B: Consent Form

EASTERN
WASHINGTON UNIVERSITY
start something big

Consent Form
Physiological Effects of Virtual Reality

Nick Lauderdale, principal investigator, Department of Psychology, 509-714-3067
Jonathan Anderson, responsible principal investigator, Department of College of Social and Behavioral Sciences and Social Work, 509-359-2856

Purpose and Benefits

The purpose of this study is to examine temperature biofeedback functioning in people via a virtual environment, and is being done in fulfillment of a graduate studies thesis. As a benefit of participating, you will receive research credit for use in a psychology course. The credit you earn will be equated with time spent participating in the study.

Procedures

The in-lab testing will take approximately 60 minutes. During in-lab testing, you will be equipped with biometric equipment (such as a temperature monitor) and will experience a virtual forest environment, as well as a virtual blizzard. The second portion of the study will potentially involve flashing light, fast motion pictures, and situations that may induce motion sickness. After each trial you will be asked to complete questionnaires regarding the experience (i.e. "how realistic would you rate the snow?").

Risk,Stress, or Discomfort

People who are prone to severe motion sickness as well as seizures induced by flashing lights will be excluded from this study as a safety precaution. In order to avoid motion sickness for participants in general, participants will be standing in the virtual environment, rather than walking or running around the environment.

Other Information

All information collected will kept strictly confidential. You are free to withdraw from participation at any time without penalty of any kind, and will be compensated with credit for the time completed for the study. Credit will be awarded within a month of participating in the study.

date: __________
Nicholas Lauderdale, Principle Investigator

The study described above has been explained to me, and I voluntarily consent to participate in this study. I have had the opportunity to ask questions. I understand that by signing this form I am not waiving my legal rights. I understand that I will receive a signed copy of this form.

Participant Signature

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protection Administrator, at (509) 359-6567 or rgalm@ewu.edu."

Department of Psychology
Martin Hall • Cheney, WA 99004-2445
509-714-3067, nlauderdale@eagles.ewu.edu

Appendix C: Sona Study Description

Descriptor of Study on SONA

Dept. Of Psychology Graduate Student: Nick Lauderdale/Dept. of Psyc/ (509)714-3067/nlauderdale@eagles.ewu.edu

Supervising Faculty: Dr. Jonathan W. Anderson - 121 Senior Hall (email: janderson@ewu.edu) (509) 359-6707

The purpose of this study is to examine temperature biofeedback functioning in people via a virtual environment. As a benefit of participating, you will receive research credit for use in a psychology course. If you choose to participate in this study, you will first be asked demographics about your age, sex, and questions pertaining to virtual reality, such as visual acuity and tendency to motion sickness. A second questionnaire will evaluate your presence (how immersed in an activity or environment you become).

This is an in-lab study, with initial questionnaires being filled out here for pre-screening. If eligible, you will be qualified to participate in the main study, which will be completed on-campus in a testing lab. The in-lab testing will take approximately 60 minutes. During in-lab testing, you will be equipped with biometric equipment (such as a temperature monitor) and will experience a virtual forest environment, as well as a virtual blizzard. This portion of the study will potentially involve flashing light, fast motion pictures, and situations that may induce motion sickness. After each trial you will be asked to complete questionnaires regarding the experience (i.e. “how realistic would you rate the snow?”).

This research is for participants who are 18 years or older. Your participation in this study is completely voluntary and your responses are anonymous. This survey software does not identify and/or download any Internet Server Provider (ISP) information. You have the right to withdraw from the study without penalty. If you complete any part of any question, you are imply your consent to participate. This survey should take about 10-15 minutes. If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator (509-359-6567).

Appendix D: Lab Assistant Testing Script

Participant Testing Script (Abridged) 2.0

PRIOR TO STUDY:

1. Have stopwatch prepared

2. Make sure first trial is prepared and loaded, camera is centered

When the participant arrives

1. Greet the participant
2. Write down participant info on the Log sheet (Need their SONA ID)
3. Consent Form (Keep one, give one to participant)
4. Make sure fans are on, keep door paritally open

Outfitting

1. Demonstrate proper hand positioning for biometrics.
2. Outfit with Oculus Rift
    a. If image is blurry, have participant first adjust headset on head. If still blurry, try cleaning lens.

Snow Trial

3. Read first,
    a. "We will now begin the Snow trial which will involve immersion in a virtual blizzard. You will be immersed inside the virtual environment for approximately 10 minutes. During this time, please feel free to look around the virtual world. You may look left, right, and behind you, but please refrain from standing up or leaning more than a foot. Once 10 minutes has passed I will tap you on the shoulder and inform you the trial is over. You will be asked to complete 2 short questionnaires before moving onto the next trial."
4. Administer questionnaire S1
5. Put participant in snow trial
    a. unpause game
    b. start stopwatch
    c. take baseline temperature
6. As trial is going, record temperature measures every 2 minutes, including at the beginning of the trial.

Snow Trial (ended)

1. Administer questionnaires S2 and S3
2. Once participant has completed surveys, proceed to Forest Trial or End of Study (depending on which was done First).
3. [Wait 5 minutes for next trial, begin setup]

Forest Trial

1. Read first
2. "We will now begin the Forest trial which will involve immersion in a virtual forest. You will be immersed inside the virtual environment for approximately 10 minutes. During this time, please feel free to look around the virtual world. You may look left, right, and behind you, but please refrain from standing up or leaning more than a foot. Once 10 minutes has passed I will tap you on the shoulder and inform you the trial is over. You will be asked to complete a short questionnaire."

3. Administer Questionnaire F1
4. Check to make sure camera is centered
5. Put participant in Forest Trial

---

a. unpause game

b. start stopwatch

c. take baseline temperature

<u>Outfitting</u>

6. Demonstrate proper hand positioning for biometrics.

7. Outfit with Oculus Rift

   a. If image is blurry, have participant first adjust headset on head. If still blurry, try cleaning lens.

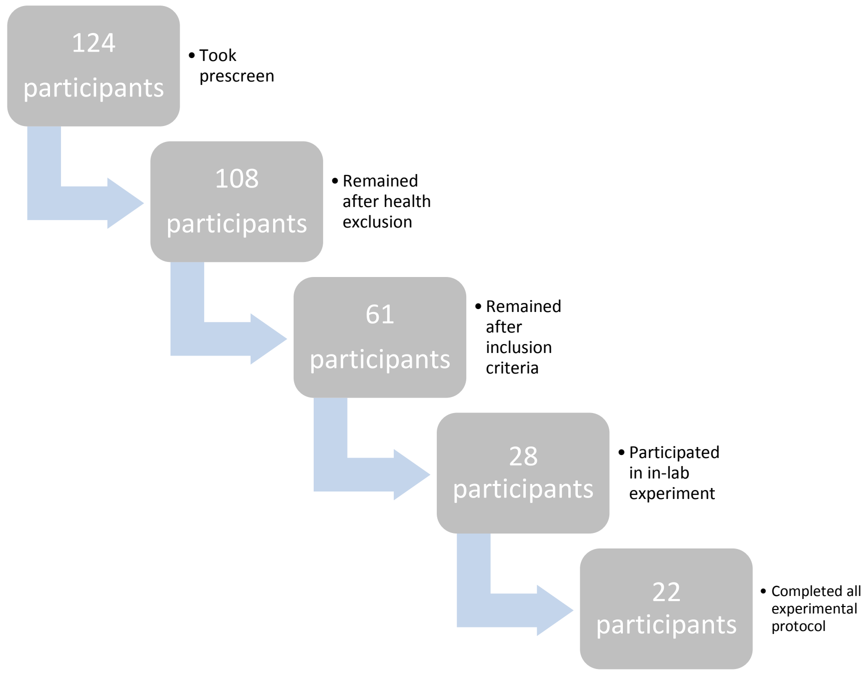
<u>Forest Trial Ended</u>

8. Administer Relationship to Virtual World Questionnaire (F2)
9. [Wait at <u>least</u> 5 minutes before next trial.]
10. Once participant has completed surveys, proceed to Snow Trial or End of Study (depending on which was done first).

<u>End of Study</u>

11. This has concluded our testing period. Thank you for participating in this study. You should receive your credit within the week.

Appendix E: Flowchart mapping sample formation



Appendix F: Thesis figures

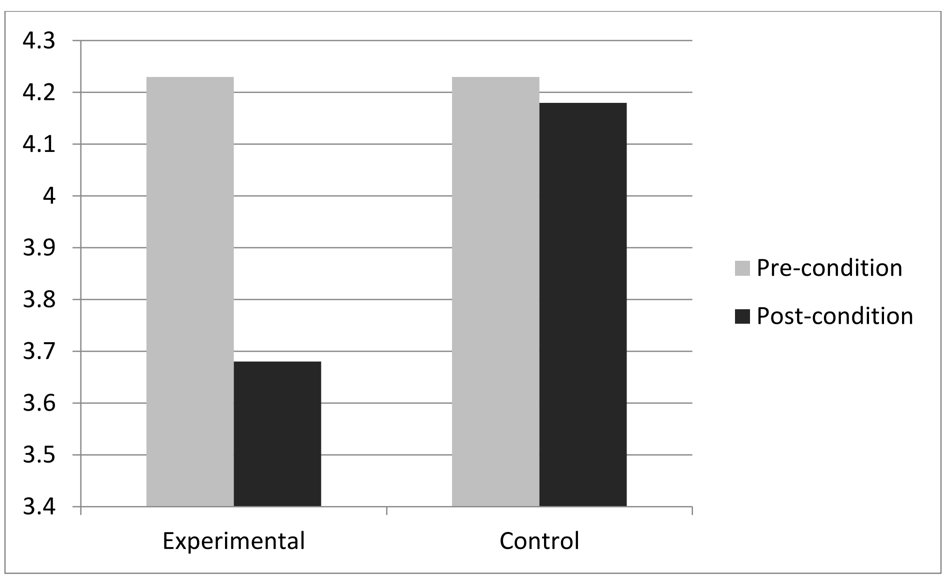


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Figure 1: Means of pre/post perceived temperature