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Virtual Reality as a Pain Distraction Modality for Experimentally Induced Pain in a Chronic Pain Population: An Exploratory Study

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Abstract

Virtual reality (VR) has shown promising results as an adjunct therapy for pain management. Recent literature exploring the use of VR for pain management among a chronic pain (CP) population has produced encouraging results, although little has been done to explore what about a VR intervention is the provider of the analgesic response. Furthermore, as has been suggested in the literature previously, little has been said of the association between pain tolerance and presence. This study primarily aimed to investigate pain tolerance differentiation between VR-head-mounted display (HMD) active and control interventions. Secondarily, this study looked to report on whether presence correlates to pain tolerance, among a CP population. A repeated-measures study design was used. Twelve participants received two 5-minute interventions while being subjected to experimentally induced pain. The interventions were as follows: (a) “active intervention,” an immersive and interactive experience (b) “control intervention,” and a nonimmersive controlled experience with no interaction. Tolerance to pain was assessed via the total time the participant continued the intervention. Presence was assessed via the Witmer and Singer’s presence questionnaire. Participants also completed the Simulator Sickness Questionnaire, the Presence Questionnaire, and the Brief Pain Inventory. Pain tolerance was significantly higher in the active intervention compared with the control intervention ($p = 0.005$). There was a positive correlation between pain tolerance and presence during the active VR intervention. The media as opposed to the medium was determined to be responsible for greater tolerance to pain, as well as greater sense of presence, which was positively correlated to an increase in pain tolerance.

Keywords: virtual reality, chronic pain, distraction, presence, pain tolerance

Introduction

Chronic pain (CP) is defined as pain lasting longer than 3 months.1 Back pain alone accounts for 40 percent of sickness absence in the U.K. National Health Service2 and costs £10 billion for the U.K. economy annually,3 with females being disproportionately affected.4,5

Methods for alleviating CP often include treatment using opioid-based medication, which, while providing short-term alleviation from pain,6,7 can also lead to addiction and increased tolerance.8,9 The need for a variety of alternative treatments has been discussed and attributed to personal circumstance, preference, cost, feasibility, and availability.10,11 Complementary and Alternative Medicine therapies and interventions, which are not considered conventional treatments for CP,12 can include meditation,13,14 massage,12,15 and distraction techniques12,16,17 (which are traditionally cognitively intense).

Of particular relevance to this research are approaches that intend to elicit distraction, a theory grounded in research based upon the idea of humans’ limited capacity for attention.18–20 primarily Melzack and Wall’s Gate Control Theory.18 Previous work has explored the use of distraction and coping techniques,21,22 and more recently, studies have
investigated the use of virtual reality (VR) as a distraction-based technique, where cognitive load and attention are focused away from the painful stimuli and toward a more rewarding and engaging interaction.

VR is considered to be a good choice for pain alleviation because of its ability to elicit a high degree of presence, "the sense of being in a Virtual Environment rather than the place in which the participant’s body is actually located,"27 which has been associated with reported pain reduction.25,28–30

VR has been reported to reduce acute pain via distraction, demonstrating that it can be an effective method for providing analgesia.31–34 More recent work concerned with VR efficacy as a distractor for CP has demonstrated significant reductions in 5–20-minute sessions,25,29,35,36 indicating that VR may have at least short-term efficacy in managing CP.33 However, it has been highlighted that CP studies frequently neglect to differentiate the effects of the media and the medium itself.37

To date, few studies concerned with CP distraction using a VR-head-mounted display (HMD)-based intervention are looking to understand whether it is the technical immersion of the medium, or the media itself, that is providing analgesia to participants, and the few that are seem to be using non-VR comparison conditions.25,38,39 Furthermore, there is a deficiency in the literature comparing active VR-HMD interventions with a VR-HMD-based control intervention counterpart.

By comparing a within VR-HMD active intervention with a within VR-HMD control intervention, we can better understand whether the technical immersion of the HMD is responsible for distracting the user, or whether an immersive experience is also required to elicit pain alleviation via distraction. Furthermore, it has previously been suggested that presence could be a meaningful factor in VR analgesia, but with presence measures often comparing a VR versus non-VR experience, it is not known whether the presence is an important factor in itself, or is simply a correlate of the immersive system. To gain insight into this, it would be necessary to control for technical immersion during different levels of presence.

Definitions of immersion and presence are a matter of some debate in the literature, with the terms often being used synonymously,35 in terms of how they are measured in the context of VR. Frequently, studies have either used subjective measures (such as single question visual analogue scale assessment),46 or no assessment altogether. The most widely used measure is arguably the Witmer and Singer presence questionnaire. However, this does not clearly differentiate between technical immersion and subjective immersion or presence, although this limitation would be less important if immersion is controlled for in the study design. Measuring how users report presence between two interventions conducted within VR may give better insights as to whether we should be focusing on the applications used to elicit a distraction from a painful stimuli or whether using a VR-HMD is enough to distract participants, regardless of the interventions used.

This article is primarily concerned with whether CP pain tolerance is differentially affected by different levels of immersive VR distraction. We look to understand this further by investigating whether presence correlates with pain tolerance, or whether the immersive properties of a VR-HMD alone are sufficient to provide an analgesic response.

Therefore, we hypothesize the following:

(a) Pain tolerance will differ significantly between VR-HMD active and VR-HMD control interventions.
(b) Presence will be positively correlated to pain tolerance.

Materials and Methods

Participants

Twelve participants were recruited from the U.K. pain support groups and networks (Table 1). No monetary incentive was offered. Eligible participants were ages 18–70, and had been experiencing CP (defined as a period lasting 3 months or longer). Individuals completed a screening pre-study questionnaire. Criteria for exclusion were as follows: health issues that could prevent someone from using a visual display for an extended period of time, severe motion sickness, and being fitted with a pacemaker. All 12 participants completed the study.

Hardware and software

An Oculus Rift CV1 HMD was used to deliver both software interventions.

The active intervention consisted of a game called Bananaland (Fig. 1; Cognifisense, Inc., Sunnyvale, California), in which the user is set upon an on-rails movement track through a jungle populated by bright plants and animals, with ambient music to accompany the visuals. Bananas can be thrown at objects in the environment (e.g., fruit on a tree, hidden gems). The control intervention consisted of a gray screen with vertical lines (Fig. 1). In this condition, the users could look around, however, their visuals would stay the same. This was designed to be neutral and nonengaging for the users.

Design

A repeated-measures study design was used. Participants were randomized to each condition using block randomization. This was evenly distributed and counterbalanced between condition orders.

Table 1. Participant Demographic and Brief Pain Inventory Data

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>5 (41.7%)</td>
</tr>
<tr>
<td>Female</td>
<td>7 (58.3%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause of pain</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nociceptive</td>
<td>8</td>
</tr>
<tr>
<td>Neuropathic</td>
<td>3</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Least pain BPI in last 24 hours</td>
</tr>
<tr>
<td>Worst pain BPI in last 24 hours</td>
</tr>
<tr>
<td>Average pain daily BPI</td>
</tr>
<tr>
<td>Pain right now BPI</td>
</tr>
<tr>
<td>Years spend living w/CP</td>
</tr>
</tbody>
</table>

BPI, Brief Pain Inventory; CP, chronic pain; SD, standard deviation.
Procedure

Participants signed a consent form before completing a baseline Brief Pain Inventory (BPI) and Simulator Sickness Questionnaire (SSQ).

To induce a standardized level of experimental pain, participants were fitted with a blood pressure cuff, applied to their nondominant arm, with pressure gradually increased and sustained at 200 mmHg. The participant was periodically asked to grip a ball to stimulate blood flow. This procedure was a modified approach due to the users’ vision being occluded via the VR headset, although submaximal grip strength was measured before exposure, as well as grip duration limited and measured from the start of induction, in accordance with the Submaximal Tourniquet Effort Test (SMET) and sustained throughout the experimental conditions. Each intervention lasted for a maximum of 5 minutes or until the participant reached pain tolerance and asked the experimenter to stop, at which point the pressure cuff would immediately be deflated and the intervention ended. Total duration (in seconds) before termination was used to indicate the participant’s pain tolerance.

After completion of each VR session, participants were given follow-up questionnaires, consisting of the SSQ and The Witmer and Singer Presence Questionnaire. After each session, the participant was given time to rest until there was no residual pain or other effects from the VR or SMET, before experiencing the second condition.

Further elaboration of this study’s SSQ procedure and implications has been previously discussed.

The study was approved by the University of Portsmouth Institutional Ethics Review Board.

Results

Pain tolerance will differ significantly between within VR-HMD active and control interventions

A Shapiro–Wilk test of normality was conducted and indicated that data for the active VR intervention were not normally distributed. A Wilcoxon signed-rank test showed that pain tolerance in the active intervention (M = 258.58, SD = 65.063) and control intervention (M = 212.08, SD = 76.943) was significantly different (z = -2.805, p = 0.005) (Fig. 2).

Pearson’s correlations were performed to determine whether a relationship existed between BPI average daily pain, BPI pain now (baseline pain), and tolerance to pain during either intervention. There were no significant correlations between any of the tested relationships (Table 2).

Presence will positively correlate to an increase in pain tolerance

A Pearson’s correlation was conducted to determine the relationship between pain tolerance and reported presence. No significant correlation existed between total pain tolerance and reported presence when measuring across both interventions (r = 0.391, n = 24, p = 0.059).


FIG. 2. Graph of the mean pain tolerance between the active and control VR interventions.
Table 2. Brief Pain Inventory Preintervention: Pain Tolerance Correlations

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPI average daily pain—pain tolerance (control)</td>
<td>0.268</td>
<td>0.400</td>
</tr>
<tr>
<td>BPI average daily pain—pain tolerance (active)</td>
<td>0.325</td>
<td>0.302</td>
</tr>
<tr>
<td>BPI pain now—pain tolerance (control)</td>
<td>0.002</td>
<td>0.996</td>
</tr>
<tr>
<td>BPI pain now—pain tolerance (active)</td>
<td>0.097</td>
<td>0.765</td>
</tr>
</tbody>
</table>

A Pearson’s correlation was conducted to determine the relationship between pain tolerance and reported presence of individual interventions. There was a positive correlation between pain tolerance and reported presence during the active VR intervention, which was statistically significant ($r=0.584$, $n=12$, $p=<0.05$). There was no significant correlation between pain tolerance and reported presence during the control VR intervention ($r=0.033$, $n=12$, $p=0.918$).

A post hoc statistical power analysis was performed for sample size estimation. The effect size in this study was 0.40. With an alpha $=0.05$ and power $=0.70$, the projected sample size needed with this effect size is approximately $N=12$. An $N$ of $\sim16$ would be needed to obtain statistical power at the recommended 0.80 level.

Discussion

First, this study investigated whether pain tolerance will differ significantly between active and control VR-HMD interventions. Second, this study investigated whether pain tolerance increased with higher reported presence.

The results indicated that there was a significant difference in pain tolerance between the VR interventions, and that no participants lasted longer in the control intervention than they did in the active intervention. Participants tolerated the painful stimuli on average 15 percent longer in the active intervention versus control intervention. None of the participants rated pain higher during the control intervention than the active. Seven of the 12 participants lasted the full 5 minutes in the active intervention, while only 2 lasted the full amount in the control intervention (Fig. 3).

Performing the control intervention within a VR-HMD allows us to better determine that it was likely not an effect of the medium (VR headset) that made the participants feel distracted from the painful stimuli, but rather the active intervention that was successful in causing the distraction. This is important as it helps establish that the intervention itself was beneficial for the purpose intended, and implies that the VR-HMD alone was not responsible for this effect. Future studies could use this approach to using a control comparison.

There were no significant relationships between reported daily pain or preintervention pain and pain tolerance in either intervention (Table 2). This suggests that the benefits of VR distraction analgesia may not necessarily be limited to particular levels of preexisting pain. However, this study was investigating experimental pain, although induced in a CP population; thus, no direct inference can be drawn in relation to the effect on the preexisting pain.

There was a significant positive correlation between presence and pain tolerance in the active intervention, supporting the findings in previous work. In contrast, no correlation was found to exist between presence and pain tolerance in the control intervention. However, presence scores in the control intervention were minimal, and therefore, it may be that the level of presence was insufficient to detect any correlation with reported pain.

Age and ethnicity have been reported to affect pain reports, and although not explored, could be considered a limitation of this work.

Jones et al. postulated that the effectiveness of VR could be relative to the attentional factors through the gate theory mechanisms. Our control intervention was intended to be nonengaging, and thus, a significant difference between our active and control interventions was predictable because of the disparity in interactivity. However, our observation of relatively high presence scoring in the active intervention, and the positive correlation between presence and pain tolerance, gives credence to the possibility that the effectiveness of the active intervention is due, in part, to the distraction elicited. This supports Jones’ theory that the effectiveness of VR could be based solely on the attentional factors through the Melzack and Wall’s gate theory mechanisms. Wiederhold has similarly found that presence positively correlated to pain tolerance during VR pain distraction, however, the induction of painful stimuli differed, therefore it could be argued that the quality of pain differed also.

In summary, technological immersion alone is not enough to induce VR-analgesia, and it is the content and presence of the VR distraction that made the participants feel distracted from the painful stimuli, but rather the active intervention that was successful in causing the distraction. This is important as it helps establish that the intervention itself was beneficial for the purpose intended, and implies that the VR-HMD alone was not responsible for this effect. Future studies could use this approach to using a control comparison.

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generated by this content that seem to facilitate the analgesic response. Although this was a small study with 12 participants, only 4 more would have been required to fully power it, and confirm these findings. Further work with slightly larger sample sizes is suggested to explore the differential roles of presence and distraction in a range of VR applications.

Acknowledgments

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Authors’ Contributions


Author Disclosure Statement

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References


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