ASRA PAIN MEDICINE
22nd Annual Pain Medicine Meeting
November 10-11, 2023 | New Orleans, Louisiana
#ASRAFall23

Abstract: 4725

Scientific Abstracts > Emerging Technology

MEASURING THE IMPACT OF VR PAIN TREATMENT ON THE BRAIN – A TIME-DOMAIN FUNCTIONAL NEAR-INFRARED SPECTROSCOPY PILOT STUDY

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Kernel

Introduction

One in five US adults reports chronic pain, which leads to a reduced quality of life and less functionality [1]. Chronic pain not only disrupts daily life but also affects the brain and its activation patterns [2,3]. One emerging technology for pain management is the use of virtual reality (VR), however there is very little work on the neural mechanisms of action for VR pain treatments. This pilot study aims to fill in this gap by exploring the effect of a VR 8-week training program on Chronic Lower Back Pain (CLBP) patients by measuring physiology and brain activity patterns using a Time-Domain functional Near-Infrared Spectroscopy (TD-fNIRS) system.

Materials and Methods

The study was a single-blind, sham-controlled design with the primary objective of comparing brain activation patterns and physiological metrics before, during, and after VR experiences in CLBP patients. Nineteen participants (11 females and 8 males, age (mean ± SD): 50.3 ± 12.34 years, range 22–66 years) completed two study visits, one study visit prior to starting treatment and the other study visit after completing 8 weeks of at-home VR treatment. Participants gave written informed consent before beginning the study in accordance with the ethical review of the Advarra IRB (#Pro00063837), which approved this study, and the Declaration of Helsinki.

The baseline visit consisted of (1) filling out surveys (demographics, the Brief Pain Inventory (BPI), and medication logs); (2) performing a resting state session during which they watched a ~7 minute abstract movie while their neural data was recorded using a whole-head TD-fNIRS system (Kernel Flow1); and (3) performing the following three tasks in a randomized order: (a) a pain distraction game named “BearBlast”, (b) a breathing exercise named “Monument”, and (c) watching a soothing nature video named “Theater”. These tasks were presented through VR goggles while neural data was collected using combined TD-fNIRS and VR system (FlowVR). During all VR tasks, the respiratory signal was also recorded using a respiratory belt. Participants were randomized into either the Treatment (RelieVRx, FDA approved for treatment of CLBP) or Sham (Control) group (matched for age, gender, and pain interference), and were given the corresponding VR device for their at-home use.

Beginning the day after the baseline study visit, participants were asked to start using their study provided VR device daily. The treatment VR consisted of activities similar to BearBlast and Monument study tasks and included pain education and skills training, while the Sham VR (control) consisted of two-dimensional non-interactive nature videos similar to the Theater task with no pain education or skills training.

During the closeout visit, participants underwent the exact same protocol as the baseline visit with surveys (except the demographics survey), resting state with whole-head TD-fNIRS, as well ass the three VR tasks with integrated TD-fNIRS and the respiratory belt. At the end of the visit, participants returned the VR device.

Results/Case Report

We analyzed participants' survey data to ensure there were no significant differences between the treatment and sham group in terms of critical metrics. Participants' pain levels in the two groups, as measured by the BPI survey at the baseline visit, were similar (t-test p=0.51). In terms of at-home VR use, there was no significant difference in adherence levels between the two groups (t-test p=0.43). Both treatment and sham groups showed a significant reduction in pain interference between the two visits (Wilcoxon Test: Treatment p=0.02, Sham p=0.04).

We explored participants' breathing rate during the VR tasks to ensure they were indeed breathing at a slower rate in the Monument task (breathing exercise) as compared to the Theater task (nature video). Using a repeated measures ANOVA, we found that the task was a significant factor in determining breathing rate (p=1.00x10-4) on both the baseline and closeout visits. As expected there was a significant difference in breathing rate between Monument and Theater tasks during the baseline visit (slower breathing on Monument, post-hoc t-test p=0.02). This difference was still present at the closeout session but only in the sham group (p=0.02) and not the treatment group (p>0.1). At closeout, the lack of difference in breathing rate between tasks (in the treatment group) can be attributed to participants lowering their breathing rate even in the Theater task after undergoing VR treatment.

To investigate whether there were global differences in brain activity across tasks and treatment groups, we quantified whole-brain fractional amplitude of low-frequency fluctuations (fALFF). Similar to the physiology results above, we found a significant main effect of task type (repeated measures ANOVA p=0.01) such that whole-brain fALFF was higher during the Theater task compared to the Monument task. It is notable that this effect was present at the baseline session suggesting a short-term effect of the Monument task on brain activity

We also tested if we could retrieve pain-related information from brain measurements recorded during the resting state session using the whole-head TD-fNIRS system. Across participants and visits, various edges of the connectivity matrix demonstrated significant negative correlations with pain levels, a finding that is consistent with prior literature [4,5] (Fig. 1a). Furthermore, when considering whole-brain connectivity, both static and dynamic connectivity metrics showed a significant difference between the two treatment groups, such that the change in the treatment group was higher than the sham group (t-test p=0.03 and p=3.29x10-03, for static and dynamic connectivity respectively)(Fig. 1 b).

Discussion

This pilot study showed that TD-fNIRS can successfully measure changes in brain activity after a VR pain treatment that are related to changes in subjective reports of pain. This is an interesting finding because both the treatment and sham group showed a reduction in pain between the two visits, but only the treatment group exhibited the expected changes in functional connectivity in the direction of pain alleviation [5]. This finding also supports the hypothesis that a difference in brain activity between the two groups may be due to different biological mechanisms of action for the pain reduction reported by each group. Future directions could include developing precision VR pain treatments using brain

measurements of pain.

References

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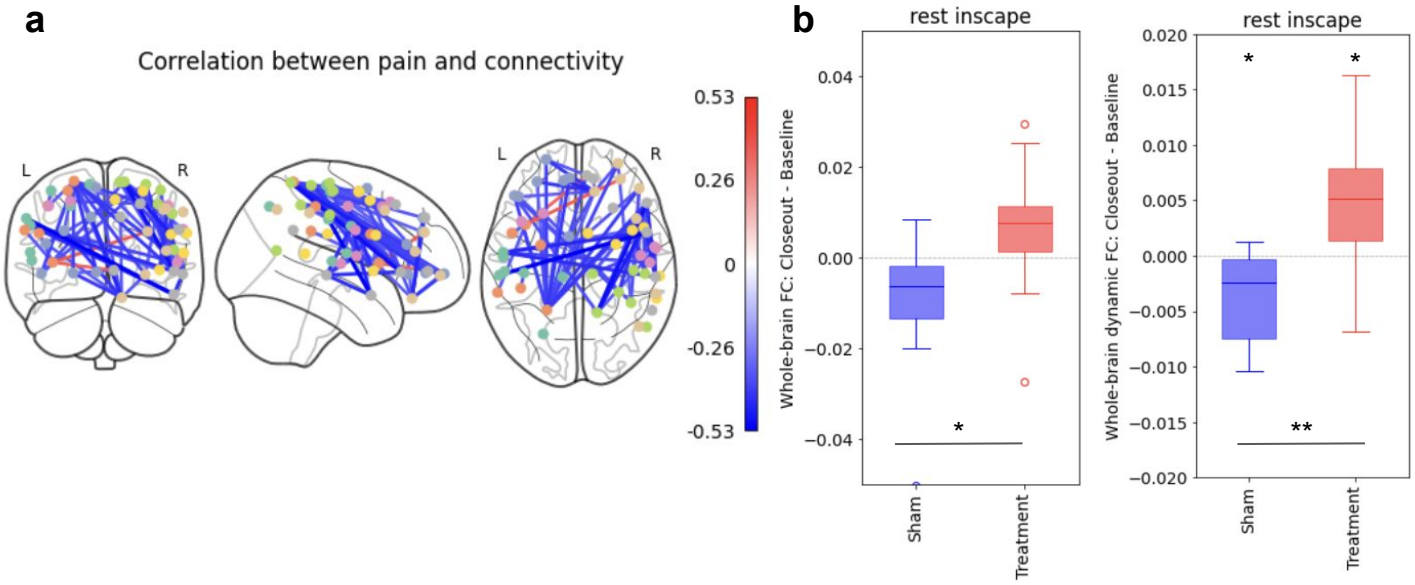
Disclosures

Yes

Tables / Images

Figure 1. Resting state functional connectivity as a reliable proxy for pain.



a. Various edges in the connectivity matrix (lines: edges of FC matrix, circles: brain regions) showed a significant negative correlation with pain. Shown are the correlation maps between the strength of each edge in the connectivity matrix and pain measure from the BPI survey at the baseline visit. **b.** Change in whole-brain static (left) and dynamic (right) connectivity from baseline to closeout visits. There was a significant difference between the two groups (t-test p=0.03 and $p=3.29x10^{-03}$), with the treatment group showing an increase in connectivity, often associated with pain relief.