FLASHLIGHT

Play the pain away -

Pain regulation and attention in virtual reality

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HIGHLIGHTS: Virtual reality (VR) has been shown to be a powerful method to divert attention away from pain (Malloy & Milling, 2010). In an ongoing study[1] healthy participants play the VR game *Subnautica* in two conditions (high vs. low cognitive load). Pain thresholds and psychophysiological measures are assessed during play to measure the distraction effect. Additionally, pain management will be compared to individual executive functions and attention investigated before playing.

Keywords: virtual reality, pain regulation, executive functions, distraction effect

[1] data collection will be finished in late December 2019.

Pain regulation and attention in virtual reality

Even though video games are one of the most popular virtual worlds that people engage in for entertainment reasons (Entertainment Software Association, 2018), VR and games are not restricted to entertainment purposes only, but are more and more commonly used in various other fields, such as the health sector (e.g., mental health: Freeman et al., 2017; rehabilitation: Laver, George, Thomas, Deutsch, & Crotty, 2015). Similarly, various studies have pointed out that VR technology can very effectively help pain patients by engaging them in an immersive game and thereby diverting their attention away from severe pain (Malloy & Milling, 2010). Therefore, this interdisciplinary project combines the research fields of pain distraction and management, attentional (dys)functions and immersive virtual reality and gaming. In contrast to previous publications on this topic, this study uses a sample of healthy adults and integrates a wide range of additional variables of interest to further investigate the relationship between pain, attention and VR.

Theoretical background and hypotheses

Pain, the probably most common medical condition, has a rather high prevalence around the globe and can affect people regardless of sex, age or socioeconomic status (Goldberg & McGee, 2011). Pain perception is not only driven by the noxious input, but can be modulated by various psychological factors, such as the focus of attention (Wiech, Ploner, & Tracey, 2008). Engaging in a cognitively demanding task, for instance, has been found to be an effective pain modulation strategy, presumably by competing with pain-related processes for limited attentional resources (Johnson, 2005). Virtual environments provide high-demanding, multi-sensory settings and have been proven to be an effective distractor, both in clinical setting with pain afflicted patients and in cases of experimentally administered pain. Effect sizes of VR interventions for pain ranged so far from medium to large (Malloy & Milling, 2010). Given these findings, VR might serve as a promising alternative or addition to standard pain therapy (e.g., pharmacological treatment). As VR has no severe side-effects and costs for VR setups are declining, it might become more and more suitable for clinics, but also more popular in private households.

H1: When playing a demanding VR game, participants will experience less pain (i.e., they will reach higher pain thresholds by tolerating greater heat temperatures) when compared to a less demanding game or a control setting (VR without playing).

Variations in the effectiveness of distraction from pain suggest that individual differences, may play an important role in the ability to modulate pain. Especially individuals with impairments in executive functions (e.g., attention deficit hyperactivity disorder [ADHD]) might respond differently to distraction via VR. ADHD-related deficits in executive functions have been linked to the hypo-activation of the prefrontal cortex (Castellanos & Proal, 2012), which plays an important role in the cognitive control of pain (Wiech et al., 2008). Only a few studies have looked at the association between ADHD and pain, reporting higher odds of experiencing pain in adults with ADHD symptoms (Stickley, Koyanagi, Takahashi, & Kamio, 2016) and a higher sensitivity to pain in ADHD (Treister, Eisenberg, Demeter, & Pud, 2015). Therefore, it is promising to test, whether an overall increased experience of pain in individuals with ADHD symptoms might result from difficulties in pain modulation due to executive functions impairments. Furthermore, research on ADHD and media usage has been somewhat two-fold. On the one hand ADHD has been related to excessive media use (Weiss, Baer, Allan, Saran, & Schibuk, 2011) and on the other hand ADHD symptoms have been shown to improve by using VR with children (Rohani, Sorensen, & Puthusserypady, 2014). It is therefore also interesting to analyze the relation between executive function impairments associated with ADHD and the use of VR as a pain distraction tool.

H2: Pain perception is additionally dependent on executive functions and the severity of ADHD symptoms, proposing the same distraction effect, but to a weaker extent: individuals with impaired executive functions and/or high ADHD symptoms will be less affected by the change in cognitive demands and will experience more pain compared to participants with good executive functions and/or less ADHD symptoms.

Implications of our two hypotheses might not only be useful for future research, but also for the practical application of all three fields (ADHD, pain, VR).

Participants

As the study is still ongoing, no final sample is collected. A priori analysis with G*Power indicated that a total sample of 84 participants is sufficient, which will serve as the minimum N. Inclusion criteria allow adults 18 to 35 years old either fluent in German or English to participate. Exclusion criteria include a diagnosis of photosensitive epilepsy and neurodermitis or other skin-related diseases on the non-dominant lower calf. Participants with a history or a current diagnosis of psychiatric or neurological conditions, with acute or chronic pain, neuropathy or using analgesics, anticonvulsants, narcotics, antidepressants or anxiolytics, will not be a priori excluded from the study, but their data will not be analyzed. As this is not a clinical study, we did not aim for participants with an ADHD diagnosis, but are instead interested in sub-clinical variability of ADHD symptoms as well as executive impairments within a student sample. Participants are recruited via email and posters on campus. Additionally, the study was advertised on national, public radio.

Procedure

The study takes place in the Media and Experimental Lab at the University of Luxembourg. After signing an informed consent, each participant answers questions on basic demographics, their gaming habits and skills. Then the attitude towards pain and the degree of subclinical ADHD symptoms is assessed, followed by a short battery of computerized neuropsychological tests (programmed in PEBL2) measuring a range of executive functions including visuo-spatial short-term memory and working memory (Corsi block tapping task; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000), inhibitory control (Go/No go task; Bezdjian, Baker, Lozano, & Raine, 2009) as well as attentional control (Eriksen flanker task; Eriksen & Eriksen, 1974). Before entering the VR setting, participants are cabled with electrodes (chest for electrocardiography and foot for electrodermal activity) and the thermode (*Medoc Ltd.*) is installed on the lower, non-dominant calf. Then the VR headset (*htc Vive*) is put on and adjusted to participants' pupil distance. Before playing, participants are placed statically in the VR setting to get used to the environment and their individual pain thresholds at rest (baseline) are measured. Then the game material (*Subnautica*, see figure 1) is presented. When participants feel comfortable with the controls, they play two sessions with different levels of cognitive demand each lasting 10 minutes. In the easy condition, participants need to swim along a pipeline in the virtual world. In the more demanding condition, participants swim along the same pipe but need to memorize a series of eight numbers in the correct order that are distributed along the pipe. The sequence of the conditions (high vs. low cognitive load) is counterbalanced across participants. Pain thresholds are logged during baseline measurement and both playing sessions and are investigated as follows. During these three units the temperature of the thermode rises with a slope of 1°C/sec in irregular intervals. Participants are instructed to press a switch with their dominant foot as soon as they perceive the heat as painful. Upon pressing the pedal, the temperature is logged and returns to baseline (38°C) with a slope of 5°C/sec. The great benefits of this assessment method consist in measuring pain continuously rather than post-hoc and in not having to rely on subjective pain rating scales that are prone to errors. Furthermore, asking participants to press a pedal is less intrusive and should lead to less severe breaks in presence than administering a questionnaire after each pain stimulus. Between both sessions a short break is taken, during which participants answer a short questionnaire evaluating the first session in terms of spatial presence and motion sickness. After both sessions, participants answer the same follow-up questionnaires evaluating the second playing session. Participants are then debriefed and receive remuneration (25€ gift vouchers each). All data gathered will be stored anonymously.

Results

As the testing is still ongoing, we are unfortunately unable to present any results, yet. However, by this date already $n = 51$ participants have taken part in the study. However, 4 participants had to be excluded from further analysis (did not finish due to sickness symptoms or had chronic pain), leaving a sample of $n = 47$ ($n_{\text{female}} = 27$). Average age of generally valid participants is 23.89 ($SD = 3.22$). Although an ANOVA on mean pain thresholds (see figure 2) during baseline, low and high cognitive load condition revealed a non-significant result ($p = .08$, n.s.), direct comparison of the baseline and both gaming condition showed significant results (baseline vs. low load: $t = -2.02$, $p = .049$; baseline vs. high load: $t = -3.52$, $p = .001$). Data collection will continue until late December 2019 and we are confident that we are able to present the results on the International Communication Association Conference in 2020.

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Figures

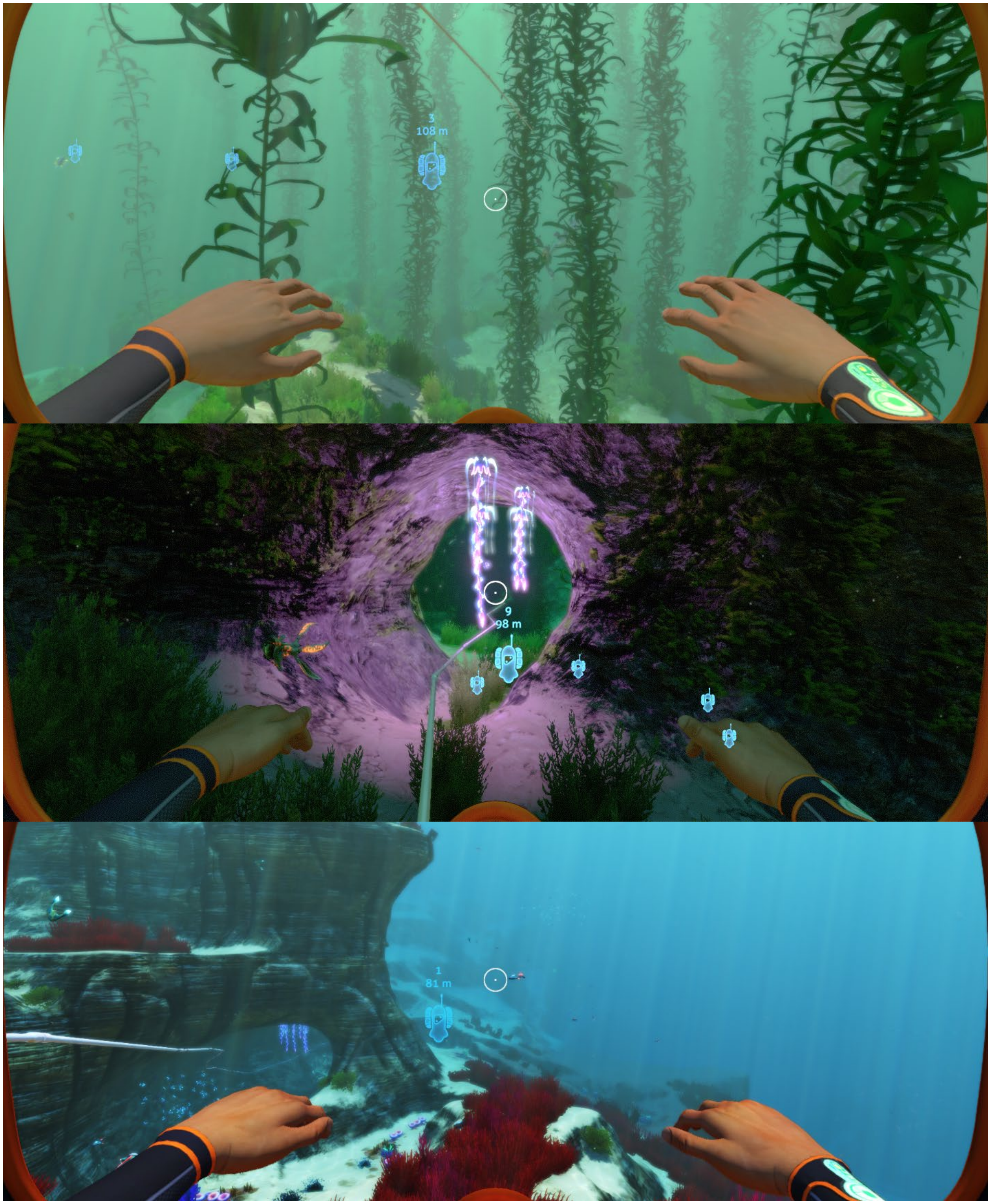

Figure 1. Screenshots from the *Subnautica* route (high cognitive load condition), displaying pipeline (top, down, left), beacons with numbers to memorize and distance to them (© 2017 Unknown Worlds Entertainment, Inc.).

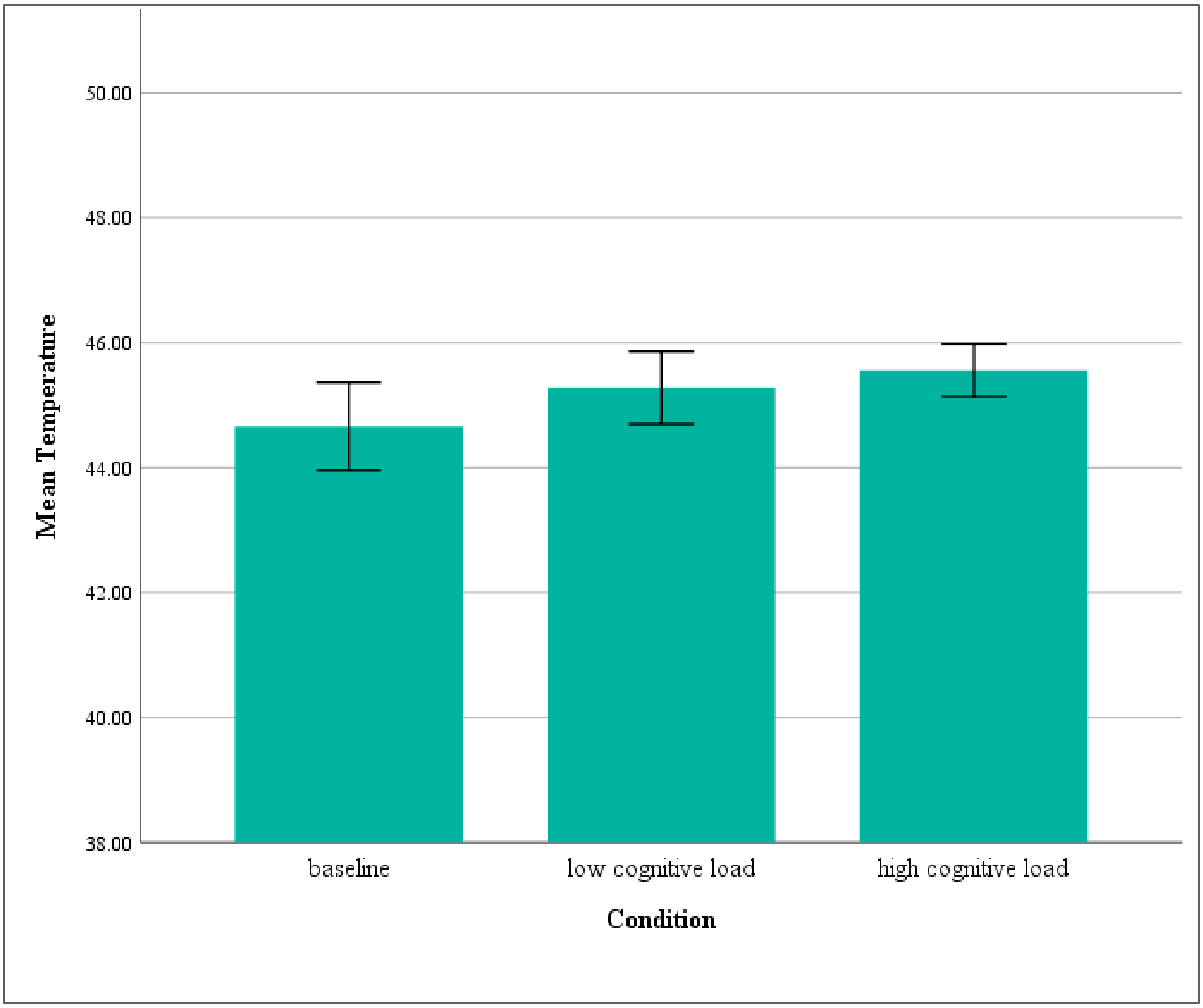

Figure 2. Descriptive bar chart of mean temperature (pain thresholds) across conditions. *Note*: baseline: $M = 44.66$ ($SD = 2.37$); low cognitive load: $M = 45.28$ ($SD = 1.96$); high cognitive load $M = 45.56$ ($SD = 1.42$), $n = 47$.