Designing a VR Experience to Reduce the Experience of Pain: Scare, Excite or Relax?

Erik D. van der Spek(✉) and Luuk P. M. Roelofs

Industrial Design, Eindhoven University of Technology, Den Dolech 2, 5612AZ Eindhoven, The Netherlands
e.d.vanderspek@tue.nl, l.p.m.roelofs@student.tue.nl

Abstract. Ever since Snow World, there has been a proliferation of Virtual Reality (VR) for pain alleviation in clinical settings. VR provides a relatively low-cost and side-effects free way to distract patients from acute pain. Numerous studies have shown the feasibility of using VR to reduce pain compared with control conditions, however very little research has been done on how the VR experience itself should be designed to optimally distract a user's attention away from the pain. Here, we used the circumplex model of affect as an input to design three affective, wireless, passive VR experiences, viz. a tense experience (horror), an exciting experience (parachuting) and a relaxing experience (nature-walk). In a counterbalanced within-subjects experiment, 14 participants underwent a cold pressor test through three experimental and one control conditions. There was a significant effect of condition, with participants in the tense (horror) condition being able to withstand pain for longer. This may also be due to the anticipation inherent in horror experiences however.

Keywords: Virtual Reality · Pain reduction · Affective VR · Game design

1 Introduction

1.1 VR Based Pain Alleviation

The experience of (acute) pain is a partly physiological but also partly psychological process that serves to direct our attention to a painful stimulus [23]. As it is contingent on attention, directing attention away from the pain experience itself has been found to be a useful strategy to mitigate pain [1], because pharmaceutical analgesics can be costly or have unwanted side-effects. Over the past two decades, the advent of Virtual Reality (VR) technologies as a means to distract patients from pain with entertaining virtual worlds has been shown to be highly effective, both in lab experiments and in clinical settings. VR-based distraction methods typically show statistically significant superior pain reduction compared with control groups or non-VR distraction methods, by large effect sizes [15]. In the US alone, reportedly more than 250 hospitals already employ VR for this purpose [2].

Several theories have been proposed why VR distracts a patient from the pain they are experiencing [14]. One of these theories is based on the Multiple resource theory by Wickens [26]. The Multiple resource theory states that people have a limited amount of

Published by Springer Nature Switzerland AG 2019
E. van der Spek et al. (Eds.): ICEC-JCSG 2019, LNCS 11863, pp. 97–110, 2019.
https://doi.org/10.1007/978-3-030-34644-7_8

mental resources that can be spent on sensing, perceiving or thinking. If someone is fully focused on one thing, they do not have the mental resources to focus on anything else. In the case of using VR to distract people from experiencing pain, this means that they would use all their mental resources in perceiving and thinking about the virtual environment, and subsequently have no resources left for the pain. Related to this, the degree of presence, or the mediated illusion one is present inside the virtual world, and everything that entails for perception and believability of the virtual world, has been found to be correlated to the effectiveness of pain reduction [11, 23].

1.2 Related Work

One of the first well researched and widely publicized VR experiences for pain distraction in hospitals was the VR game Snow World [11]. Here, patients who have to undergo painful burn wound treatments, get to play a game set in a snowy world, where they fly through an icy gorge and throw snowballs at among others penguins and snowmen. The efficacy of Snow World to reduce the experience of pain has been well documented [e.g. 15]. Since then, immersion in VR for analgesic purposes and arguments to its efficacy has been researched for dental pain [10], multiple types of cancer treatment [3], long term fibromyalgia relief [8], and more.

1.3 The Design of VR Experiences for Pain Reduction

The research around VR experiences for pain reduction seems to have so far centered on its efficacy compared with other types of pain reduction, the psychological factors surrounding it and explanations for the measured effect. To the best of our knowledge however, very little research has been done on how to design the VR world or VR experience itself in order to engender a reduction in pain. Is the simple act of immersing and distracting enough, as the multiple resource theory for pain reduction would imply [26]? In another paper, Johnson suggests that additionally altering mood, anxiety and arousal next to engaging attention would more effectively reduce pain [12]. In this light Snow World, next to being distracting and arousing in the game mechanics, also appears to have design qualities of being immersive and entertaining, lowering anxiety, while stimulating opposite affective connotations to what originated the pain, i.e. snow instead of fire, and thereby altering mood. While on the surface it seems like a good idea to give patients an environment that is both moderately relaxing and stimulating an opposite affective response, it's less clear what the right affective environment would be for a host of other, less evocative or easy to pinpoint causes of pain. Nor do we get closer to understanding the type of affective experience that best mitigates pain, and why.

Therefore, we propose an experiment with different types of affective experiences, and to measure the amount of time which the experiences can engender people to sustain a simple cold pressor test. In order to delineate different types of affective experiences, the Circumplex Model of Affect by Russell was used [18]. This plots a range of possible affective states in a 2D plane according to the amount of Arousal (vs Boredom), and Valence (Pleasant-Unpleasant) a person experiences; see Fig. 1. With the two axes giving the possibility for both negative and positive scores, four quadrants are formed, with at the extremities Excited, Relaxed, Tense and Depressed. However, given the usual application domain of these kinds of pain alleviation experiences, i.e. hospitals, we considered "Depressed" to be wholly unsuitable, as it could strengthen depressive associations with the procedure, and pessimism generally predicts worse physical health outcomes [17]. A similar argument could indeed also be made for the "Tense" affective setting; however we contend that the popularity of thriller or horror movies and games show that enough people consider these forms of entertainment to be engaging enough to actively seek out immersion in them. Conversely, we think that, given the context, a depressing VR world would not be considered entertaining and therefore the player would be less likely to engage with it.

Most VR for pain reduction research has so far focused on elaborate VR technologies that tether bulky headsets with wires to large gaming PCs. With the advent of low-cost mobile VR, we envision a future where these will be more often used because physicians and surgeons will be able to more easily navigate around them. As general treatments require patients to remain still, we also focused on passive entertaining VR experiences for the purpose of this experiment. The experiences are consequently developed with passive mobile VR in mind.

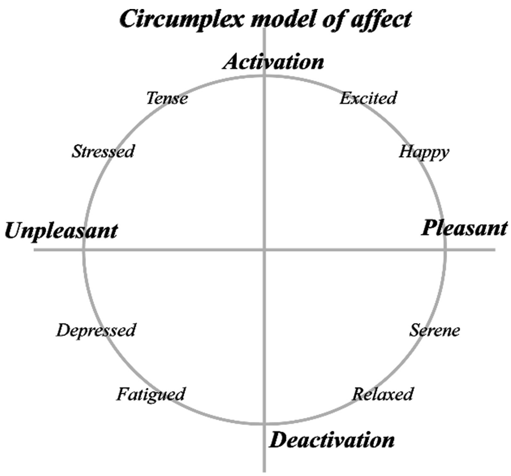

Fig. 1. Circumplex model of affect, adapted from [17] and used in the experiment to measure affective states.

1.4 Tense, Exciting and Relaxing Experiences

All of the 3 emotions chosen from the Circumplex model of Affect have different reasons for why they could work in distracting the patients of their pain while being immersed in VR entertainment.

For the first one, Unpleasant & Activation ("Tense"), the patient could be distracted from their pain by creating fear for something outside of the real world. Fear can be an overwhelming emotion [24], thus if someone is placed in an immersive world, where a fear is created for something, someone could lose awareness of what happens in the real world. The mental resources would be drawn away from the real world and the pain they are experiencing, to the fear of the experience in the virtual world. This could lead to being distracted from the pain in such a way that they are not experiencing it actively anymore.

For the second one, Pleasant & Activation ("Excited"), the patient could be perceiving so much audiovisual stimuli, that it would be overwhelming for the senses of the patient, and in this way make them focus less on the other senses (cf. Multiple resource theory). In this case enough complexity in audible and visual stimuli could hypothetically overload cognitive processing capacity, making people less aware of haptic stimuli.

For the final one, Pleasant & Deactivation ("Relaxed"), the experience is designed to stimulate an affective response opposite to the stress and anxiety induced by the real world pain, similar to Snow World for burn victims. This could furthermore create a mindfulness experience and give the patient a place which allows them to retreat to their thoughts and ignore the real world. There is some evidence that mindfulness meditation can reduce pain [20], and mindfulness has been stimulated in VR by nature walks in e.g. [5, 7].

As explained above, the three different experiences have very different reasons why they could work in reducing the experienced pain. In addition, by contrasting them directly we may be able to tease out the relative contributions of the factors that were purported to make Snow World a good pain reduction game, viz. distraction, immersion and a game world that stimulates opposite affective responses. Therefore, Russell's circumplex model of affect was used as a guideline in designing the different Virtual Reality Experiences. The experiences are operationalized as described below. The three different experiences are contrasted with a control group, where participants undergo the cold pressor test without a designed affective experience, in order to have a baseline of pain tolerance for each participant.

2 Designed VR Experiences to Engender Tense, Exciting and Relaxing Affective Responses

For the *Tense* experience (Unpleasant & Activation) a virtual walk through a moodily-lit creepy hospital was created (see Fig. 2). The player can hear unintelligible whispering voices and two jumpscares (a frightening event where something loud and "in your face" happens to make people "jump" out of their seat), were implemented to cause some distress in the player; first a non-humanlike humanoid creature jumps at the player and at the end the player is surrounded by ghosts with a stroboscope effect. Both non-humanlike humanoids and sounds without an identifiable source are well-known tricks in the survival horror genre to induce fear [22]. Due to the limited graphical output of mobile VR and to make the experience palatable to people who do not like horror movies, the experience was probably more akin to a haunted house theme park than something truly unnerving.

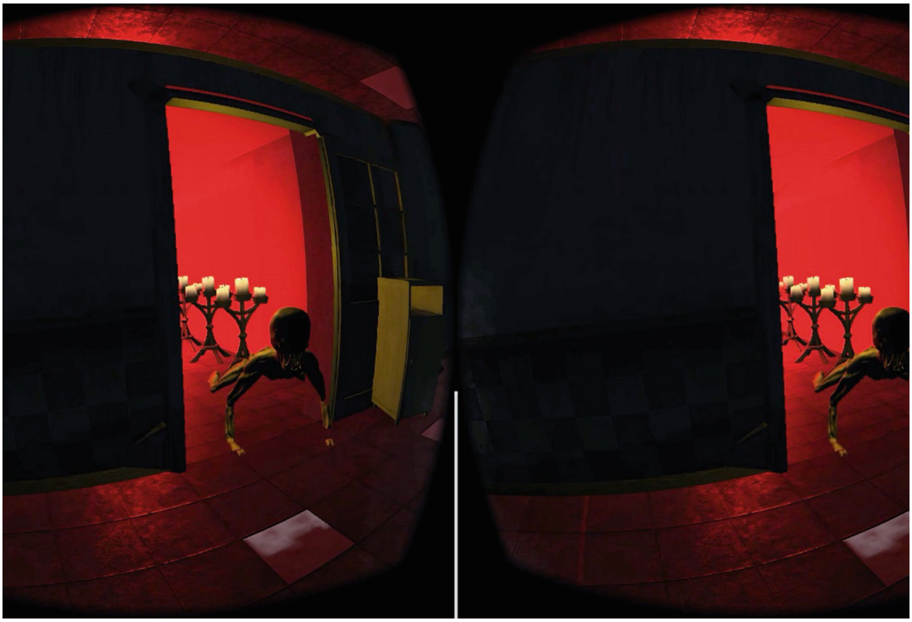

Fig. 2. A screenshot of the Horror Virtual Reality experience with the non-humanlike humanoid used in this research.

For the *Exciting* experience (Pleasant & Activation) we had to design something that was thrilling and fun. The initial idea was a rollercoaster or high-speed race, but due to technical limitations with the amount of scenery that could be drawn at the same time at high speeds, these were scrapped for something easier to render. As such, we settled on a skydiving experience, where the player falls downwards towards the ground and cloud particles shoot past the player, as wind sounds fill their ears (see Fig. 3). The cloud particles provided a high amount of visual complexity, while the visual and sound design were intended to create a sense of speed through visual and auditory vection cues [13]. Since vection (the mediated illusion of self-motion) may lead to motion sickness, no rotation or translation was added, and motion sickness was included as a measurement. If the player can hold out long enough to reach the lake on the ground, they would shoot through it and reemerge high above the world. This would be repeated, with a new world rising underneath you every time.

In the third and final *Relaxing* experience (Pleasant & Deactivation), the player had to experience a calm, relaxing and serene environment. For this, a relaxing forest was created (see Fig. 4) (similar to relaxing VR games like [5, 7]). In this forest, the player would walk along a path next to the river with a waterfall, with the sounds of birds chirping, a calming pan flute song and the rushing of the waterfall. There was not much activity in the experience, outside of the waterfall, which was designed to calm the players down and make them as relaxed as possible. Both the Tense and Relaxing experiences were designed to last about three minutes; the Exciting experience could potentially loop forever.

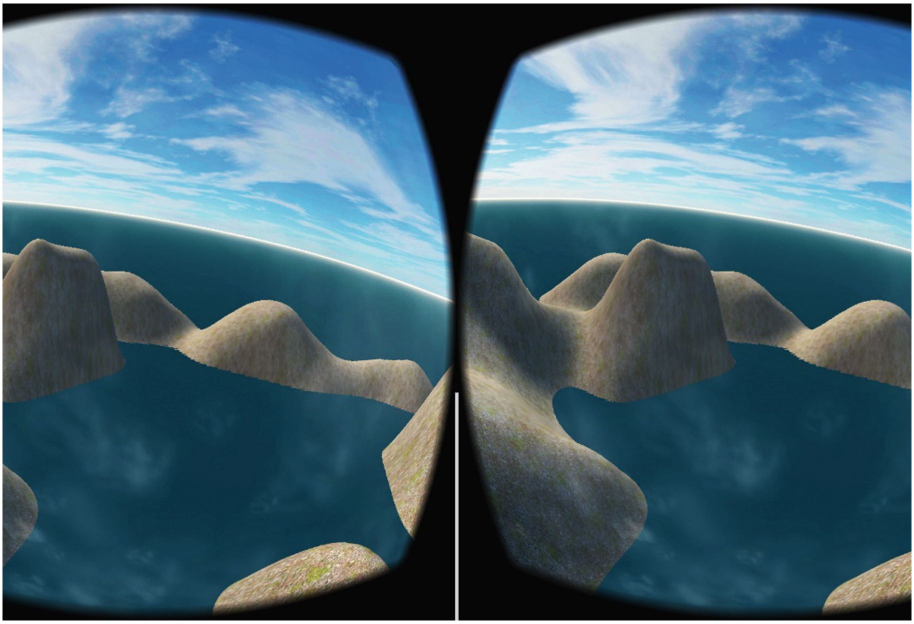

Fig. 3. A screenshot of the Exciting Virtual Reality experience used in this research.

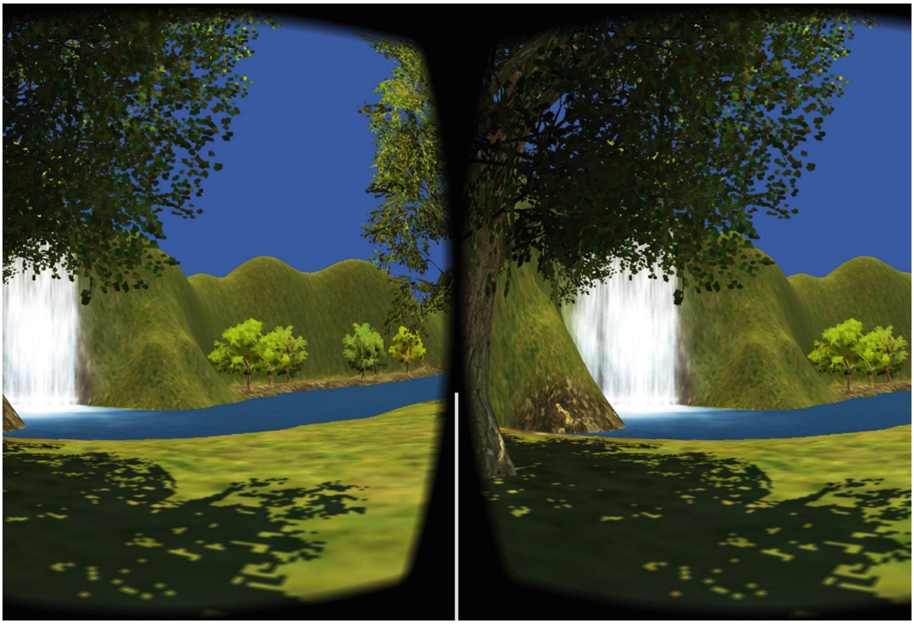

Fig. 4. A screenshot of the Relaxing Virtual Reality experience used in this research.

3 Method

3.1 Participants

In total 14 participants (6 Female, 8 Male, Age between 21 and 57, mean age 24.64) participated in a within-subjects design. Because there were four conditions (three experiment groups and one control group), the participants were counterbalanced in a Latin Square design. One person (male, 21 years old) was not able to complete the full experiment due to the equipment malfunctioning, leading to Valid N = 13 for most tests.

3.2 Cold Pressor Test and Apparatus

An often used and ethically acceptable way of simulating pain and testing the pain tolerance is the Cold Pressor Test (CPT) [1, 27]. This test asks people to put their hand in cold water at a regulated temperature and times how long someone can hold their hand submerged in the cold water before taking it out. This test is already used in some cases with Virtual Reality [4, 16], and is therefore also used to test the conditions with here.

From other research done with the CPT [16] and testing with water temperatures from 0 °C to 10 °C, a temperature between 6.5 °C and 7 °C was chosen as most useful for this experiment, as anything below 6 °C would lead to the hand being submerged in the water too briefly to experience much of the VR, whereas anything above 8 °C would lead to high variability in the users, compounded by possible disengagement from the designed VR experiences. An important thing to keep into account while doing a CPT is the dangers that are involved in submerging a body part into cold water. The safety prescriptions include prevention of cold-induced tissue damage by setting a maximum time and prevention of an accidental electrical shock [16]. To avoid targeting of the maximum time by the participants, this time was blinded from the participants. The maximum time in this research was set to 2:30 min (150 s) [25]. Prevention of an accidental electrical shock was provided by clearing the area of the water of electrical devices. The water temperature was measured by a safe thermometer with a cord of 1.5 m, the phone used in the Virtual Reality goggles was waterproof and the headphones were fitted with a well manufactured sealed cord and were too big to fit in the water bucket while the hand was submerged (Fig. 5). Besides this, the participants were watched carefully by a researcher at all times.

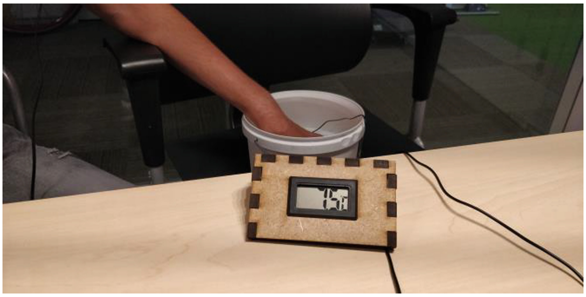

Fig. 5. An illustration to show how the Cold Pressor Test was conducted in this research

In between tests, the water was kept between 2 °C and 5 °C in a fridge. It was subsequently taken out and mixed with normal water right before the test to get to 6.5 °C. The water was put in a bucket deep enough to fully submerge the hand in a comfortable way, while not requiring too much cold water. A waterproof thermometer was used in this test, which measured the temperature with a precision of 0.1 °C and a low adoption time, as the longer it takes to measure the temperature, the more the temperature of the water rises.

The Virtual Reality was played on a mobile phone (Samsung S5) which was put in a VR Box Virtual Reality headset. The phone was connected to high quality Sennheiser headphones to make sure the sound was of good quality and canceled out any other sounds.

3.3 Materials and Procedure

Upon entry of the lab, the participants were informed about the experiment and told that they were allowed to quit at any time. They were additionally questioned about prior experience with VR and in particular whether they were prone to simulator sickness. After filling out a consent form, they were then administered the conditions in a counterbalanced Latin square order. The water temperature was recorded and the stopwatch started each time they put their hand into the water. At the moment they took their hand out of the water, the time was stopped and the water temperature was recorded again. After every CPT, the participants had time to dry and warm up their hands, and then they were asked to fill in an adapted version of the Visual Analogue Scale (VAS) [6] about the level of experienced pain, the level of nausea experienced and the emotion which was evoked in the Circumplex Model of Affect [18]. For the purpose of filling in, a program was created that presented visual scales on a tablet with a granularity of −400 to +400 where participants could easily visually select how much they agreed/disagreed with the statement. After this, in the three experiment conditions the participants were asked to fill in the Igroup Presence Questionnaire (IPQ) [19], to determine how present they had felt in the virtual environment. After participating in all four conditions in a latin square counterbalanced order, the person was thanked for his or her participation. No reward was provided.

4 Results

4.1 Validity of VR Experiences

As a general indication, the participants were asked to position their affective response from the VR experience onto the x (valence) and y (arousal) coordinates of the circumplex model of affect. It should be noted that we did not use the official questionnaire to measure their affective response, out of fear we would overload the participants with too many questions for all of the conditions combined. Therefore these results (in Fig. 6) should be taken as a very general indication without much construct validity. From this we may surmise that the Control, Relaxing and Tense conditions are all roughly in the position we expect them to be, and since the participants weren't told where they should be, that the designed experiences portray the mood that we intended. However the same cannot be said for the Exciting condition, which appears not Pleasant enough.

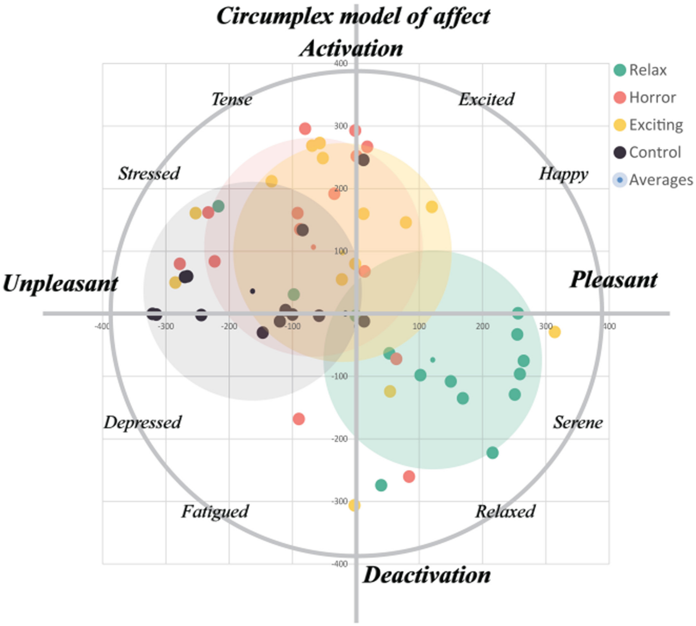

Fig. 6. Visual indication of affective responses to the VR experiences

4.2 Pain Reduction Expressed in Time

Mauchly's test showed the assumption of sphericity had not been violated $\chi2(5) = 2.14$, $p = 0.83$. A repeated measures ANOVA with the four conditions as within-subjects independent variable and the time the hand was submerged as dependent variable, shows a significant effect of condition on the time the participant was able to submerge their hand $F(3,33) = 5.413$, $p = 0.004$, partial $\eta^2 = 0.33$. A Sidak-corrected post-hoc test attributes this mainly to a significant difference between the Tense condition and the Control condition ($p = 0.014$), with the participants in the Tense condition ($M = 48.15$, $SD = 26.04$) being able to keep their hands submerged significantly longer than in the Control condition ($M = 34.15$, $SD = 18.10$). A trend was found between the Tense and the Exciting condition ($p = 0.052$), with the participants in the Tense condition being able to keep their hands submerged longer. The other within-subjects differences were not significant. The results of the analysis are shown in Fig. 7. Note that 95% confidence interval whiskers are quite large, meaning there was quite some variability in pain tolerance.

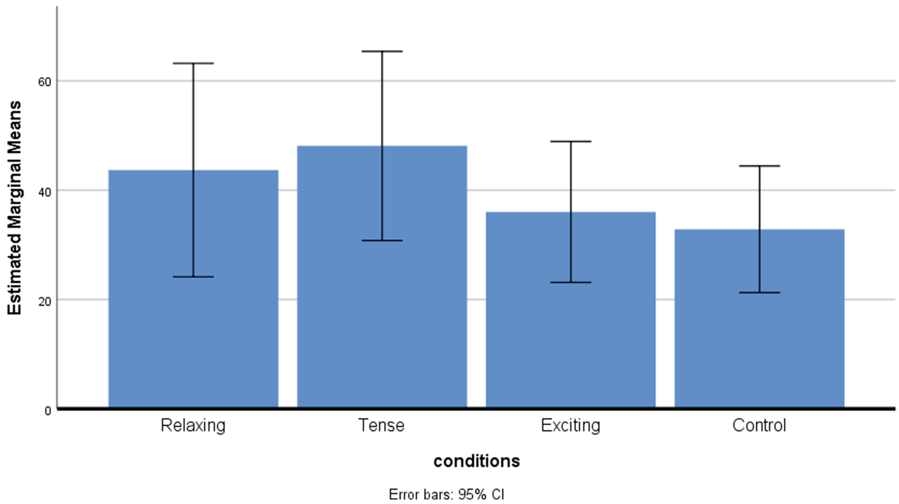

Fig. 7. Results of the four conditions on time hand is submerged in water

4.3 Presence

The reported presence scores violated the assumption of sphericity (Mauchly's test $\chi 2$ (2) = 6.844, $p = 0.033$), subsequently a Greenhouse-Geisser corrected Repeated-Measures ANOVA with conditions as independent variable and reported presence as dependent variable showed a significant effect of condition, $F(1.394, 26) = 8.951$, $p = 0.004$, partial $\eta^2 = 0.408$. A Sidak-corrected post-hoc test showed that the Tense condition induced significantly more presence (M = 0.79, SD = 0.75) than the Exciting condition (M = 0.32, SD = 0.67). No other differences were significant. The experience of presence was significantly correlated with the time a person could submerge their hand for the Relaxing VR condition ($r(13) = 0.581$, $p = 0.037$), but not for the other two conditions. Average presence for all three conditions was also not significantly correlated with average time the hand was submerged for all three conditions ($p = 0.79$).

4.4 Experienced Pain and Nausea

A visual analog scale to express the degree of experienced pain from the CPT and nausea from the VR experience was administered, but no significant effects of the conditions were found. This means among others that Passive Mobile VR did not significantly introduce nausea over the control condition and the overall level of experienced pain was about equal (though there were still significant differences in the amount of time the pain could be withstood). There was no correlation between the degree of presence in the Exciting condition and the reported nausea.

5 Conclusion and Limitations

In this early exploratory research into the affective design of VR experiences for pain alleviation, we contrasted three conditions, a Tense, Relaxing and Exciting VR experience on their analgesic effect compared with a baseline. It appears that while the use of our VR setup had some analgesic effect in terms of the ability of participants to withstand pain in a CPT (time submerged was higher for all conditions compared with the control condition), only the Tense VR experience was able to cause a significant positive effect on the ability to withstand pain ($p = 0.014$), although the Relaxing setting showed promise ($p = 0.052$). Beforehand we hypothesized that the Tense condition could induce fear, which would overwhelm the attention for the real-world stressor; this could be supported by our findings.

For the Relaxing condition, we hypothesized that the affective response would be the polar opposite to a cold stressor, and the resulting mood change may lead to pain reduction. In addition, we hypothesized that our experience may induce mindfulness, which makes it easier to ignore the pain. Neither can be supported by our findings. However interestingly, here the degree of presence was strongly, positively correlated with the time the hand could be submerged in cold water. Either a natural susceptibility to experiencing presence, a preference for nature walks or the ability to enter a mindful state rapidly may lead to greater success for this type of experience. The latter because brief mindfulness interventions may be ineffective for pain reduction [21]. In any case this should be tested.

For the Exciting condition, we hypothesized that overloading the audiovisual system could draw attention away from the cold stressor, thus lowering the experience of pain. This could not be supported by our findings. On a surface level, this would reject the hypothesis that VR experiences reduce pain solely through stimulus overload from a multiple resource theory standpoint, because the VR condition that would hypothetically have the most audiovisual stimuli, fared the worst.

Before generalizing these conclusions, we should note a number of constraints to the scope. First, the experiment and corresponding results were intended to get an indication of how to design VR experiences, and cannot be easily generalized to affective experiences mediated through other means without additional testing. Second, we focused on distraction through entertainment experiences, since this is one of the main affordances of VR. Other means of distraction, for instance by performing serious tasks, visual noise or through cognitive training could have different effects or influence our results. Lastly, both to serve as a baseline and because it could be more widely applied in real contexts, we focused here on passive VR experiences. However, Snow World is an interactive game, and interaction in an affective game world may lead to differentiated results.

There are some other limitations to consider. Next to the low number of participants and the operationalization of the VR experiences, the Exciting condition did not, on rough visual examination, fall in the expected Excited dimension of the Circumplex model of affect. In addition, even thought the Tense condition created the most presence, there was no ostensible correlation between presence and pain reduction. It could very well be that the low quality of VR experience from mobile VR might not induce enough presence to significantly affect pain experience. This should be quantified in a future experiment, but the notion is supported by Hoffman et al., who found that high quality VR was better at pain reduction than low quality VR [11]. This research is comparatively old however, and current mobile VR may be better than high quality VR in 2004.

6 Discussion

Looking at the results, it is rather striking that the VR experience that should be affectively closest to the control condition also creates the largest and only significant difference (NB construct validity of our circumplex model should be low, but we contend that the placement of the two conditions, viz. unpleasant for the control condition and unpleasant and activated for the horror VR experience, make sense). This may indicate that a person can most easily supplant an unpleasant real-world experience with an “unpleasant” VR entertainment experience, which is also supported by the Tense VR condition showing the highest amount of presence. The haptic stressor from the cold pressor test could be more congruent with the audiovisual stressors induced by the tense VR experience, than for the other two conditions.

However, a lack of effect in the other two conditions that are further away from the control condition, could also indicate something else entirely. Namely that designing for specific affective responses in VR has in fact little bearing on pain reduction. A hidden variable may have come to light in the design of the VR experiences that we did not think about beforehand. For the Relaxing condition, we did not want to activate the player and so the experience was sedate and somewhat monotonous throughout. For the Exciting condition, we wanted to create a high-octane experience throughout, making it activating but however also somewhat monotonous. By virtue of creating a Tense experience however, one needs to build up anticipation for an unknown future event (see the design of suspense in a text by Hoeken and Van Vliet [9]), this could have made it so that people were willing to hold their hand in the cold water for longer, just to see ‘what was around the corner’. Snow World may be successful not (solely) because of the distraction and the opposite affective setting, but (partly) because of the user wanting to see what comes next. The role that anticipation in immersive VR entertainment may play in mitigating the experience of pain could therefore be a worthwhile avenue for further research.

References

1. Birnie, K.A., et al.: Systematic review and meta-analysis of distraction and hypnosis for needle-related pain and distress in children and adolescents. J. Pediatr. Psychol. **39**(8), 783–808 (2014)
2. Castanada, R.: How virtual reality can help treat chronic pain. USNews.com. https://health.usnews.com/health-care/patient-advice/articles/2019-01-14/how-virtual-reality-can-help-treat-chronic-pain. Accessed 23 June 2019

3. Chirico, A., Lucidi, F., De Laurentiis, M., Milanese, C., Napoli, A., Giordano, A.: Virtual reality in health system: beyond entertainment. A mini-review on the efficacy of VR during cancer treatment. J. Cell. Physiol. **231**(2), 275–287 (2016)
4. Dahlquist, L.M, McKenna, K.D, Jones, K.K, Dilliger, L., Weiss, K.E., Ackerman, C.S.: Active and passive distraction using a head-mounted display helmet: effects on cold pressor pain in children. Health Psychol. Off. J. Div. Health Psychol. Am. Psychol. Assoc. **26**(6), 794–801 (2007)
5. Damen, K.H.B., van der Spek, E.D.: Virtual reality as e-mental health to support starting with mindfulness-based cognitive therapy. In: Clua, E., Roque, L., Lugmayr, A., Tuomi, P. (eds.) ICEC 2018. LNCS, vol. 11112, pp. 241–247. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-99426-0_24
6. Gould, D., et al.: Visual Analogue scale (VAS). J. Clin. Nurs. **10**, 697–706 (2001)
7. Gromala, D., Tong, X., Choo, A., Karamnejad, M., Shaw, C.D.: The virtual meditative walk: virtual reality therapy for chronic pain management. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pp. 521–524 (2015)
8. Herrero, R., Garcia-Palacios, A., Castilla, D., Molinari, G., Botella, C.: Virtual reality for the induction of positive emotions in the treatment of fibromyalgia: a pilot study over acceptability, satisfaction, and the effect of virtual reality on mood. Cyberpsychol. Behav. Soc. Netw. **17**(6), 379–384 (2014)
9. Hoeken, H., van Vliet, M.: Suspense, curiosity, and surprise: how discourse structure influences the affective and cognitive processing of a story. Poetics **27**(4), 277–286 (2000)
10. Hoffman, H.G., Garcia-Palacios, A., Patterson, D.R., Jensen, M., Furness III, T., Ammons Jr., W.F.: The effectiveness of virtual reality for dental pain control: a case study. Cyber Psychol. Behav. **4**(4), 527–535 (2001)
11. Hoffman, H.G., et al.: Manipulating presence influences the magnitude of virtual reality analgesia. Pain **111**(1–2), 162–168 (2004)
12. Johnson, M.H.: How does distraction work in the management of pain? Curr. Pain Headache Rep. **9**(2), 90–95 (2005)
13. Keshavarz, B., Hettinger, L.J., Vena, D., Campos, J.L.: Combined effects of auditory and visual cues on the perception of vection. Exp. Brain Res. **232**(3), 827–836 (2014)
14. Li, A., Montaño, Z., Chen, V.J., Gold, J.I.: Virtual reality and pain management: current trends and future directions. Pain Manag. **1**(2), 147–157 (2011)
15. Malloy, K.M., Milling, L.S.: The effectiveness of virtual reality distraction for pain reduction: a systematic review. Clin. Psychol. Rev. **30**(8), 1011–1018 (2010)
16. Piskorz, J., Czub, M.: Distraction of attention with the use of virtual reality. Influence Level Game Complex. Level Exp. Pain **45**(4), 480–487 (2014)
17. Rasmussen, H.N., Scheier, M.F., Greenhouse, J.B.: Optimism and physical health: a meta-analytic review. Ann. Behav. Med. **37**(3), 239–256 (2009)
18. Russell, J.A.: A circumplex model of affect. J. Pers. Soc. Psychol. **39**(6), 1161 (1980)
19. Schubert, T.: The sense of presence in virtual environments: a three-component scale measuring spatial presence, involvement, and realness. Zeitschrift fuer Medienpsychologie **15**, 69–71 (2003)
20. Sharon, H., et al.: Mindfulness meditation modulates pain through endogenous opioids. Am. J. Med. **129**(7), 755–758 (2016)
21. Smith, K.E., Norman, G.J.: Brief relaxation training is not sufficient to alter tolerance to experimental pain in novices. PLoS ONE **12**(5), e0177228 (2017)
22. Tinwell, A., Grimshaw, M., Williams, A.: Uncanny behaviour in survival horror games. J. Gaming Virtual Worlds **2**(1), 3–25 (2010)

23. Triberti, S., Repetto, C., Riva, G.: Psychological factors influencing the effectiveness of virtual reality–based analgesia: a systematic review. Cyberpsychol. Behav. Soc. Netw. **17**(6), 335–345 (2014)
24. Van den Berg, A.E., Ter Heijne, M.: Fear versus fascination: An exploration of emotional responses to natural threats. J. Environ. Psychol. **25**(3), 261–272 (2005)
25. Vigil, J.M., Rowell, L.N., Alcock, J., Maestes, R.: Laboratory personnel gender and cold pressor apparatus affect subjective pain reports. Pain Resist. Manag. **19**(1), 13–18 (2014)
26. Wickens, C.D.: Multiple resources and mental workload. Hum. Factors **50**(3), 449–455 (2008)
27. Williams, E.: Cold pressor: acceptance, control and expectations. Plymouth Stud. Sci. **6**(2), 98–123 (2013)