Cardboard Mobile Virtual Reality as an Approach for Pain Distraction in Clinical Settings: Comparison, Exploration and Evaluation with Oculus Rift

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Abstract
Immersive Virtual Reality (VR) has been shown to work as a non-pharmacological analgesic by distracting patients from their acute pain for short periods of time. However, few researchers have investigated the effectiveness of mobile “Cardboard VR” for chronic pain patients. In this research, the viability of the Cardboard VR was examined by comparing it to another Head-Mounted Display (HMD), the Oculus Rift (OR), a desktop HMD. A randomized crossover study was conducted in a pain clinic with 30 chronic pain patients. OR was found to be significantly more effective than both the Cardboard VR and the control condition. Nevertheless, the results of this study demonstrate that Mobile VR has potential to become an effective tool for managing chronic pain because it is comparatively more affordable than VR that is restricted to desktop computers, because it can be deployed in numerous contexts, and because of its ease of use.

Author Keywords
Immersive Virtual Reality (VR); cardboard VR; pain distraction; Oculus Rift desktop VR; chronic pain; clinical settings; effectiveness comparison.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Virtual Reality has been demonstrated to be effective in therapeutic applications for a range of health applications such as psychiatric disorders, rehabilitation and pain management. . Over the last two decades, significant successes have been claimed for the use of immersive VR as an adjunct method for managing acute pain [6] [7]. Its mechanism is so far unknown, but has been attributed to pain distraction [9]. Subsequent virtual environments have built upon pain distraction to mitigate acute pain [3], but only a handful of researchers have focused on the longer-term challenge of using VR to mitigate or help manage long-term chronic pain (CP).

Chronic pain is unlike the pain we are most familiar with. Chronic pain is defined as pain that persists longer than 6 months and persists beyond the healing of its putative cause [4] [11]. It is long-term pain that may not necessarily be associated with a physically traumatic event. CP is influenced by psychosocial factors, which interact with brain processes and a patient's perception of pain [4]. As a serious health problem that affects a fifth of people in industrialized countries, chronic pain is under-recognized by policymakers [2] and is inadequately managed by the healthcare system. Any form of help virtual reality treatment may provide to this demographic would be beneficial to those affected.

Evidence for the use of VR to mitigate forms of pain other than acute pain is sparse. Moreover, this handful of small research studies used the high-end, expensive Head-Mounted Displays (HMD). In a study using a relaxing virtual environment with 76 participants, the researchers found that patients' reported post-operative pain levels were significantly reduced, and that their heart rates had slowed and their body temperatures increased [10]. Unfortunately, there is not sufficient evidence to show that CP patients can benefit from immersive VR applications in the same way as their acute pain counterparts.

In another recent study, VR has been known to encourage meditative practices in CP patients to reduce pain intensity with a desktop 3D display and biofeedback interactive system named *Virtual Meditative Walk* [5]. CP patients, although requiring long-term pain reduction strategies, also suffer from shorter-term spikes in pain intensity [1], during which they may also benefit from non-pharmacological treatment practices like *distraction* using VR environments. Pain *distraction* strategies that work for acute pain patients can be beneficial for the CP patients during these spikes. *Cryoslide* is another immersive VR game that uses the pain distraction strategy and designed for both acute and CP patients; the researchers proved its effectiveness in short-term pain distraction in a clinical setting [8].

The Cardboard is a mobile VR platform developed by *Google* [12] in 2015, and it became more and more popular among users because of its low cost and high accessibility. Named for its foldout cardboard viewer, the platform is intended as a low-cost system to encourage interest and development in VR applications. However, to the authors' knowledge, there is very little or no evidence of using a more affordable Mobile VR yet

Figure 1: *InMind VR* Game

Figure 2: The instruments used in Study 2 (top), the slightly modified Cardboard with a foam nosepiece (bottom).

since it is a very new form of technology that started gaining popularity in recent years. Therefore, this paper aims at contributing to this research gap regarding the use and effectiveness of mobile VR in CP distraction by comparing it with a kind of desktop VR, *Oculus Rift* (OR) DK2. The research question for this study was – Can perceived pain be significantly reduced in CP patients who engage with a VR Game on a Mobile VR platform compared to a traditional HMD?

Method & Study

This study used a repeated-measure design where each patient played *InMind* on both Cardboard and OR in a random order. A random uniform distribution was ensured so that half of the participants used Cardboard first, and the other half used OR first. The primary independent variable was the HMD type, and the primary dependent variable was the retroactive pain intensity (PI). We have two kinds of PIs– Present Pain Intensity and Retroactive Pain Intensity (pain felt in the last 10 minutes). The retroactive PI was measured to understand the patients' perceived pain intensities while they were inside the virtual environment. PI levels were measured thrice repeatedly–once, before playing the VR game; next, after playing the game on one of the HMDs; and finally, after playing the game again on the other HMD. Patients reported the PI by filling out the questionnaires.

Participants

Thirty adult participants (17 Males, 13 Females) of varying ages (23-68) were recruited at a pain clinic in Vancouver, all of whom have CP. The research is conducted in a private room inside the clinic. The patients who considered themselves to be easily susceptible to nausea or motion sickness, patients who had severe pain in the regions where the HMDs needed to be fitted on the person, and patients who did not have any physical pain at the time of the study were not eligible to participate. Participants were all chronic pain patients with various chronic conditions.

Instruments

The participants wore an *Oculus Rift* DK2 and a Cardboard VR v2.0 to play *InMind,* a VR game (Figure 1). We hooked the OR to a Macbook Pro 2011. For the mobile VR, we used the 2nd generation Cardboard VR with a *Samsung Galaxy Note 4*, which has a 5.7 inches Super AMOLED display with a resolution of 1440x2560 pixels (518 ppi density) as shown in Figure 2. The Cardboard had a Velcro adjustable elastic head-strap. For the sound, we used full-sized noise-canceling *BOSE* headphones. The participants sat on a swivel chair so that they could move easily in case they had pain in their neck. For patients with neck pain, it was easy to move their entire body on a chair rather than only moving their head and neck.

Although patients in this study experience vection (Visually perceived movement that one does not feel) in *InMind* because it is an on-rails First-person Shooter game, vection didn't seem to adversely affect Hunter Hoffman's work with patients in his VR projects [7]. Moreover, instead of having a marker (like an arm or a foot) that is intended to associate the user's body with an avatar, the game is adapted to the virtual circumstance, like on a ride at an amusement park, riding in a car or a boat. Further, from our prior experiments with CP patients over the last 15 years, many are unable to stand for more than 20-30 minutes, or cannot sit still during a VR session, regardless of the type of motion in VR.

InMind VR Game
The VR game used for this study is called *InMind VR,* a rail-based first-person shooter (FPS). In this game, the player experiences a journey into a human brain in search of enemy neurons. The enemy neurons are indicated in red. As the player aims and shoots at the enemy neuron, it becomes "cured" and hence turns green.

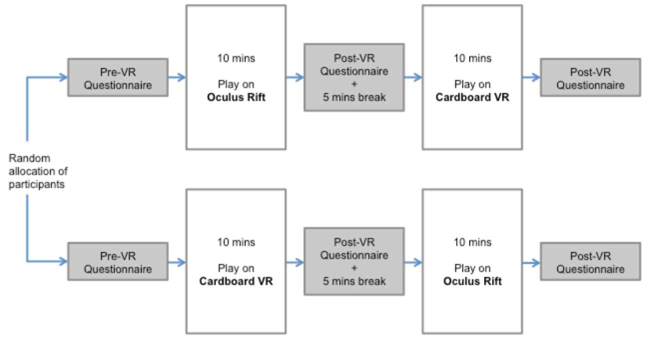

Figure 3: The study procedure chart.

Procedure
In total, each participant spent approximately 30 minutes in the study. At the beginning of the study, they first signed the consent form. Next, they were asked to fill out a short Pre-VR questionnaire; it asked them to rate their present pain intensity and their retroactive pain intensity, or the pain intensity felt in the last 10 minutes, on a scale of 1-100. These two questions were on both Pre-VR and Post-VR questionnaires to account for a potential drop in analgesic effect when patients removed the HMDs later in the study. After completing the Pre-VR questionnaire, the participants took part either in the Cardboard or the OR condition. *InMind* has about 10 minutes of gameplay. Each participant played the game in both conditions in a random uniform order. After playing it on the first HMD, participants had a 5-minute break. During this time, which immediately followed the play session, they filled out one Post-VR questionnaire. After the break, the participants took part in the second condition and filled out another Post-VR questionnaire as before. The study procedure is illustrated in Figure 3.

Results

Retroactive Pain Intensity
Retroactive Pain Intensity was used to measure the pain intensity felt by the participants during the last 10 minutes they were inside the VR world. A repeated-measure ANOVA revealed that the retroactive pain intensity in the three conditions was statistically significant, $F(2,56)=11.007$, $p<0.05$. Mauchly's test indicated that the assumption of sphericity was not violated, $\chi^2(2) = 3.842$, $p = 0.146$. The mean squares for the experimental effect, $MS_M = 892.544$ and, the mean squares of the error term, $MS_R = 81.092$. The effect size for thirty participants (N=30) is $w_{HMD} = 0.5$, which means the effect of VR on the pain intensity is medium. Bonferroni post hoc tests revealed a significant difference between the Pre-VR and OR conditions, $CI_{.95}$ = -17.773 (lower) -4.027 (upper), p=0.001. Also, there was a significant difference between Pre-VR and Cardboard VR conditions, $CI_{.95}$ = -11.516 (lower) -0.151 (upper), p=0.043. However, although only marginally, the difference in pain intensity for OR and Cardboard VR was also significant, $CI_{.95}$ = -10.131 (lower) -4.027 (upper), p=0.050. There was no significant interaction effect for the order of use of the HMDs, $F(2,56) = 0.348$, $p = 0.708$.

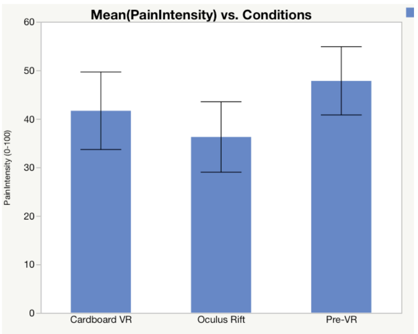

Figure 4: Pain intensity reported retroactively in the VR conditions, and in the Pre-VR (control) condition.

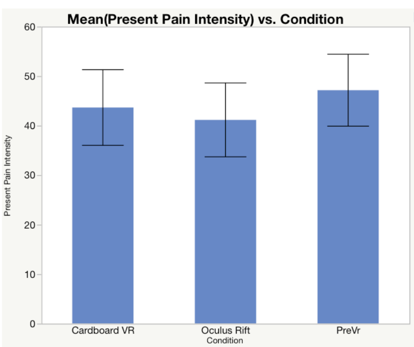

Figure 5: Present pain intensity in the three groups. The Study Procedure Chart

Present Pain Intensity

The analysis of the Present Pain Intensity was quite an interesting outcome. Our analysis revealed that exposure to VR had a significant effect on the present pain intensity too, $F(2,58) = 5.090$, $p<0.05$. The assumption of sphericity was satisfied, $\chi^2(2) = 0.606$, $p = 0.739$. The effect size, in this case, was rather small, $w_{HMD} = 0.3$. The pairwise comparison using Bonferroni post hoc analysis showed that the difference between Pre-VR and OR was significant, CI.95 = -11.11 (lower) -.889 (upper), p=0.017. However, the difference between Pre-VR and Cardboard was not significant, CI.95 = -8.263 (lower) 1.263 (upper), p=0.216.

Discussion and Conclusion

Cardboard VR is combined with a smartphone; as such, it works as a more accessible and affordable kind of VR that a larger number of people could potentially use. This is a great advantage over the traditional VR systems. Therefore, mobile VR has the potential to grow a larger consumer base than the traditional VR. We have seen how smartphones have become the main platform for web browsing and online shopping, replacing the desktop computers. It is possible that the Mobile VR may similarly become the mainstream VR platform in the future. More importantly, it can potentially be used for the large numbers of patients who might use it to alleviate their pain in many contexts, such as in their homes.

The simplicity of Cardboard VR, if coupled with a carefully designed pain management VR game, may ensure the ease of use for CP patients. This easy-to-use and affordable form of technology may have a massive impact as an alternative form of CP therapy. The study in this paper with Cardboard and CP patients is the beginning of Mobile cardboard VR for health. More research needs to be conducted to address more research questions such as what type of applications work best for pain distraction. Games, because of their highly interactive nature, are likely to work best. However, anecdotal observations with CP patients consistently reveal their concern that "games" may reduce the perceived seriousness of their condition, especially given the stigma that already surrounds them [4]. However, 3D movies and social spaces can also be useful in this regard.

It is important to assess whether mobile VR may be more useful if it is used alongside a traditional HMD. *The study results demonstrate that the cardboard VR is not as effective as the traditional HMD in pain distraction for chronic pain patients. Nevertheless, it is capable; VR to a certain extent, of providing an analgesic effect that is significantly higher than the no-VR or Pre-VR condition.* Therefore, it may be useful to use traditional HMDs in the clinics or hospitals, while patients could use the Cardboard or other forms of Mobile VR at home.

Furthermore, in future work, we would also like to examine a number of different applications to better understand which sort of interactions may yield better results. Coupling the Cardboard with biofeedback sensors may also bring forward important findings regarding chronic pain patients. Moreover, the importance of creating intelligent systems is potentially high. Rather than creating all sorts of different VR games to adapt to each patient's need, it may be more helpful to incorporate intelligent agents in the VR system which could determine the needs of individual patients and affect the VR as is specifically needed.

Overall, the study results showed that Cardboard VR, coupled with a smartphone, is capable of reducing CP patients' perceived pain intensity significantly, compared to the control (pre-VR) condition. However, despite early findings from our previous studies, OR was found to be significantly more effective for chronic pain patients than both the Cardboard and the control condition. The results of this study encourage future research inquiries of Mobile VR in the management of CP. Mobile VR, because of its affordability and ease of use, shows the potential to become an effective tool for patients' CP management.

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References

1. Marwan N. Baliki, Dante R. Chialvo, Paul Y. Geha, et al. 2006. Chronic pain and the emotional brain: specific brain activity associated with spontaneous fluctuations of intensity of chronic back pain. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience* 26, 47: 12165–12173.

2. Harald Breivik, Elon Eisenberg, and Tony O'Brien. 2013. The individual and societal burden of chronic pain in Europe: the case for strategic prioritisation and action to improve knowledge and availability of appropriate care. *BMC Public Health* 13, 1: 1229.

3. Bernie Garrett, Tarnia Taverner, Wendy Masinde, Diane Gromala, Chris Shaw, and Michael Negraeff. 2014. A rapid evidence assessment of immersive virtual reality as an adjunct therapy in acute pain management in clinical practice. *The Clinical Journal of Pain* 30, 12: 1089–1098.

4. Robert J. Gatchel, Yuan Bo Peng, Madelon L. Peters, Perry N. Fuchs, and Dennis C. Turk. 2007. The biopsychosocial approach to chronic pain: scientific advances and future directions. *Psychological Bulletin* 133, 4: 581–624.

5. Diane Gromala, Xin Tong, Amber Choo, Mehdi Karamnejad, and Chris D. Shaw. 2015. The Virtual Meditative Walk: Virtual Reality Therapy for Chronic Pain Management. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, ACM, 521–524.

6. David R. Patterson Hunter G. Hoffman, Maryam Soltani Eric Seibel, and Sam R. Sharar Laura Jewette-Leahy. 2008. Virtual Reality Pain Control During Burn Wound Debridement in the Hydrotank [analgesia, burn pain, wound care, distraction, virtual reality]. *Lippincott Williams & Wilkins, Inc.* 24, 4.

7. Jason N. Doctor Hunter G. Hoffman, Gretchen J. Carrougher David R. Patterson, and Thomas A. Furness. 2000. Virtual Reality as an adjunctive pain control during burn wound care in adolescent patients [burn pain, virtual reality, presence, analgesia, distraction, attention]. *IASP* 1, 2: 305–309.

8. Weina Jin, Amber Choo, Diane Gromala, Chris Shaw, and Pamela Squire. 2016. A Virtual Reality Game for Chronic Pain Management: A Randomized, Controlled Clinical Study. *Studies in Health Technology and Informatics* 220: 154–160.

9. Nicole E. Mahrer and Jeffrey I. Gold. 2009. The use of virtual reality for pain control: A review. *Current Pain and Headache Reports* 13, 2: 100–109.

10. José Luis Mosso-Vázquez, Kenneth Gao, Brenda K. Wiederhold, and Mark D. Wiederhold. 2014. Virtual reality for pain management in cardiac surgery. *Cyberpsychology, Behavior and Social Networking* 17, 6: 371–378.

11. Irene Tracey and M. Catherine Bushnell. 2009. How neuroimaging studies have challenged us to rethink: is chronic pain a disease? *The Journal of Pain: Official Journal of the American Pain Society* 10, 11: 1113–1120.

12. Google Cardboard – Google VR. Retrieved January 11, 2017 from https://vr.google.com/cardboard/.