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ANALYSIS OF INFLUENCE OF VISUAL STIMULI ON PERCEPTION OF PAIN THROUGH USE OF VIRTUAL REALITY

Romanek J.[*], Gruszka G.[**], Chmura M.[***], Ples M.[†], Kieś W.[‡], Wodarski P.[§], Jurkojć J.[¶]

Abstract: *According to GlaxoSmithKline survey, 93% of people surveyed experienced pain and 34% of them feel pain on a daily basis. Pharmacologically, pain treatment is classified based on its strength into no opioid; weak but opioid and strong but opioid medications. New approach to pain treatment aims to avoid using medication and what seems to be a promising way is use of virtual reality technology (VR). This paper aims to explore use of VR in alleviating pain experiencing in healthy participants. Feeling of pain was induced through use of bowl filled with water and ice cubes providing access to environment at CA. 0°C, and a bowl filled with water at 35°C. Measurements were performed in real environment and two virtual ones, displayed through use of HTC Vive HMD. Virtual sceneries were supposed to give sensations of environmental warmth and cold by showing two different rooms to participants. Sceneries were used in random order. During use of each scenery, the participant was supposed to submerge its hand in selected bowl. After selected time has passed, or when the participant could no longer keep its hand in water it was taken out, the pain sensation was reported by the participant, and while using thermometer we waited for the hand temperature to return to pre-measurement one.*

Keywords: Pain, Virtual reality, Pain alleviating, Sensory overload.

1. Introduction

According to GlaxoSmithKline (2020) survey, 93% of people surveyed experienced pain and 34% of them feel pain on a daily basis. Pharmacologically, pain treatment is classified based on its strength into no opioid; weak but opioid and strong but opioid medications (Msf.org, 2019). New approach to pain treatment aims to avoid using medication and what seems to be a promising way is use of virtual reality technology (VR). VR is a trending technical achievement, gaining progressively more and more recognition in fields of medicine and rehabilitation globally. Pubmed National Library of Medicine (pubmed.gov) informs, that in year 2002 there were 188 articles showing up as a result of entering "virtual reality" phrase into its search engine. Each year that amount increased, and in 2021 2.904 articles were showing up. Currently, VR is used not only for tackling phobias, training surgeons and doctors or enhancing physical rehabilitation (Wodarski et al. 2017), nowadays attempts at using it for purpose of alleviating pain are being performed as well (Fairclough et al. 2020). The basis for such use of technology is the fact, that human brain can process only limited amounts of stimuli in time unit, which leads to

[*] M.Sc. Eng. Romanek Justyna, PhD student: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[**] M.Sc. Eng. Gruszka Grzegorz, PhD student: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[***] M.Sc. Eng. Chmura Marta, PhD student: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[†] M.Sc. Ples Marek, PhD student: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[‡] Eng. Kieś Wojciech: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[§] EngD Wodarski Piotr: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

[¶] EngD Jurkojć Jacek: Faculty of Biomedical engineering, Silesian University of Technology, Roosevelta 40 st, 41-800 Zabrze, PL

theory, that drawing attention of a patient and making her/him focused on processing the virtual scenery can occupy brain to point, in which it becomes less capable of processing the pain sensation (Szarpak et al. 2020). Such applicability of VR is already in use, for example during taking blood samples from kids, which requires use of syringe and usually causes sensation of pain connected with panic, or when it comes to changing bandages of burn victims. In our research we intended to gain more insight into changes that exposure to virtual reality can induce in patients while focusing on aspect of perceiving pain, and if such exposure can be of significant influence when it comes to alleviating the pain sensation.

2. Methods

The measurements were performed in real and virtual environments. Each participant during trial for each type of environment had to submerge its hand in warm (35°C) and later cold water (0°C) while being exposed to either non-virtual world or to one of the two created virtual sceneries. The sceneries were supposed to give feelings of warmth and cold, caused by displaying a warm room with a fireplace, warm light and wall colors (warm scenery), and a cold room with cold light, uncovered bricks and white walls (cold scenery) correspondingly. The measurement with a hand submerged in warm water lasted for 60 seconds, while the measurement using cold water lasted until the tested person decided to remove its hand due to experienced pain. Experimental procedure consisted of following steps:

- Informing the patient about the experimental procedure and how the measurements were going to be performed; instructing them about the method of expressing their pain levels on scale of 1-10,
- Measuring patient's hand temperature with thermometer
- Patient submerges its hand in warm water for 60 seconds
- After the time passes, participant takes out its hand from warm water and expresses its pain level. Then wipes its hand with a paper towel and waits for the hand temperature to return to previous temperature
- Patient submerges its hand in cold water for as long as possible
- When patient can no longer keep its hand in cold water it takes it out and expresses its pain level
- Waiting for the hand temperature to return to pre-measurement one and switching the scenery, repeating measurements with warm and cold water.

Measurements were performed in all three sceneries (non-vr using, warm and cold ones, displayed in HTC Vive HMD) in random order.

The NRS (Numerical Rating Scale) was used to assess the perceived pain level. Statistical analysis was performed in the RStudio software. Heart rates, their differences, pain levels and times of submersion of the hand in the water were compared using the Wilcoxon pairwise test. The tests were performed for $\alpha = 0.05$.

2.1. Research group

Research group consisted of 16 participants with average age of 23 years. No participant expressed any concern about its health or declared existence of sort of illness that might have influenced the measurement in their opinion, after being informed about the measurement procedure.

2.2. Measurement equipment

The study was performed using VR HTC Vive HMD, ice cube maker, pulse oximeter, thermometer, and a water circulator. The VR application was prepared in the Unity 3D software and consisted of 2 simple sceneries.

Fig. 1: Example of scenery the subjects could see during measurements

3. Results

The questionnaire showed that only 25% of the study participants previously had contact with VR, and half of them reported, that use of this technology will have negative consequences on their mood.

Tab. 1: Heart rates before and after tests

Test:	Heart rate before test [BPM]			Heart rate after test [BPM]		
	Q1	Q2	Q3	Q1	Q2	Q3
Without VR, cold water	77,5	86	92,5	79,5	87,5	90
Without VR, warm water	79	88	97,5	78	91	100,5
Warm scenery, cold water	77,25	87,5	94,25	80,75	89	94,25
Warm scenery, warm water	79	85	95	77,25	89	96,25
Cold scenery, cold water	80	82	94,25	75,75	87,5	100,75
Cold scenery, warm water	78,75	83	92	81,5	90	95

In each case, the median of the heart rate measurements after the test was higher than the median before submerging the subject's hand in water ($p<0.05$). The highest difference was recorded during trial in which the cold scenery was displayed along with cold water trials, and it was amounting to 7 beats per minute. The two lowest differences were recorded in two trials: non-VR test using cold water and in warm VR scenery using cold water, with the median difference being 1.5 beats per minute (Tab. 1).

Tab. 2: Pain level reported by respondents

Test:	Pain level		
	Q1	Q2	Q3
Without VR, cold water	6	7	8
Without VR, warm water	1	1	1
Warm scenery, cold water	6	7	8
Warm scenery, warm water	1	1	1
Cold scenery, cold water	5,75	7	7
Cold scenery, warm water	1	1	1

When it comes to the pain level reported by the respondents, medians of majority of the trials in any given water, regardless of the scenery, were identical. The only differences between the trials with cold water were noticeable in 1st quartile during the trial in the cold scenery, when it was valued at 5.75, while

for other trials making use of cold water it was valued at 6, and 2nd quartile, which was valued at 7 in the cold scenery and at 8 for the remaining trials (Tab. 2).

The median time of hand submersion in cold water for the cold scenery was 70.5 seconds, while for the warm scenery and without virtual reality it was respectively 55 and 52.5 seconds.

4. Discussion

Other researchers, e.g., Fairclough et al.2020), in their studies have shown that the only statistically significant difference is between the cases associated with the presence of any form of distraction and the absence of it. Additionally, the Fairclough team used a VR game that had a purpose and therefore engaged the patient's attention. In our work we expressed a different approach, during which a virtual scenery was used, but the patients could only passively observe it. This could be the reason for difficulties in observing the expected relation. In subsequent studies, the possibility of replacing passive distraction with one that would engage the patient's attention more, and thus distract him from pain, should be considered.

The initial hand temperature and the speed of its normalization were highly varied, and thus the time taken for the examination was significantly different for individual patients. In addition, differences in temperatures of participants hands, even though the water temperature was kept constant, resulted in unequal temperature differences, which may have affected the level of pain. In order to reduce this factor, it is recommended to change the methodology in such a way as to first submerge the hand in water at a certain temperature, e.g., 35 °C, until it stabilizes, and then immediately test it in cold water. At the same time, it would allow shortening the waiting time for further tests.

Other factors that could influence the results are the patient's conditions. Due to cases of atopic dermatitis, one participant was dropped from the study. Two participants had tattoos on a large area of the body, and thus it can be presumed that their resistance to pain was greater than that of the other subjects, which could affect the results of the study.

5. Conclusions

Despite based on previous findings expectations of influence of the VR scenery presented to the participants on their pain perception, no statistical differences were observed between the cases using VR and non-VR ones. Neverthless, such an impact was noted during studies carried out by other researchers (Szarpak et al. 2020).

In this study, due to the small size of the study group (16 participants), it was decided to use the non-parametric Wilcoxon pair test, sensitivity of which is lower than that of parametric tests. In order to confirm the impact of VR on pain perception, it is necessary to increase the size of the research group, which would potentially reduce the standard deviation and will make possible to obtain a normal distribution, and thus the use of parametric statistics.

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