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Distraction of attention with the use of virtual reality. Influence of the level of game complexity on the level of experienced pain.

Abstract: *Research done in recent years shows that Virtual Reality (VR) can be an effective tool for distracting attention from pain. The purpose of this study was to test how the complexity of Virtual Environment (VE) influences the experienced intensity of thermal pain stimuli.*

A within-subjects design experiment was conducted, using cold pressor test for pain stimulation. Research was done on 31 students of Wroclaw Universities. Participants played games created for the purpose of the study, using head mounted displays and movement sensors. Two Virtual Environments differing in the level of complexity and non-VR control condition were used. The order of all conditions was counterbalanced.

Participants reported significantly lower pain intensity (Visual Analogue Scale) after playing the high complexity game, compared to the low complexity game. There were also significant differences between non-VR control condition and high complexity game, but not between non-VR and low complexity game. The pain tolerance (measured by time of keeping the hand in cold water) was significantly higher in both VR conditions comparing to non-VR conditions. However, no significant differences between VE's were found in pain tolerance ratings. Results of this study provide preliminary evidence that game complexity can be related to pain experience during VR interventions.

Key words: *Virtual Reality, Pain, Attention distraction, Cold Pressor Test, Video games*

INTRODUCTION

Virtual reality (VR) technologies are starting to be widely used in the treatment of pain. Numerous research studies confirm the effectiveness of this method (for review see: Botella et al., 2008; Wiederhold & Wiederhold, 2007; Malloy & Milling, 2010).

During VR treatment patients wear head-mounted displays (HMD) and have the opportunity to actively participate in a three-dimensional computer generated environment.

The analgesic efficacy of VR was tested both in clinical populations and in laboratory studies that used experimentally induced pain stimuli. Das et al. (2005) demonstrated effective use of VR in treatment of pain in children. Virtual Reality has been also used to reduce pain and stress associated with therapy in cancer patients (Gershon et al., 2004), dental treatments (Hoffman et al., 2001a) and during physical therapy for pediatric burns (Hoffman et al., 2001b; Schmitt et al., 2011). The analgetic effects of VR intervention did not diminish across eight weekly exposure sessions (Rutter et al., 2009), therefore ruling out the interpretation that results were due to novelty of the experience.

The mechanism of the analgesic effect of VR is supposedly based on the distraction of the patient's attention from painful stimuli (Gold et al., 2007; Botella et al., 2008). VR technologies may offer the possibility of more intensive (compared with other methods) involvement of the patient's attention – and thus can be a significantly more effective tool in distracting the patient's attention (Hoffman et al., 2000). Malloy and Milling (2010) provide a review of nine studies, where HMDs were used in eight of them, a significant pain reduction effect was found. In comparison, such an effect was not found in any of the two studies where a computer screen or very poor quality goggles were used. According to the authors, such pattern suggests that immersive technologies better distract attention than non-immersive

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ones. Additional support comes from the study by Hoffman et al. (2006), where the quality of HMD technology was related to the strength of pain reduction effect. In two studies comparing the videogame distraction with or without HMD it was found that looking at the game through the goggles resulted in an increase of pain threshold and pain tolerance, in comparison to playing while looking at a computer screen (Dahlquist, 2009, 2010b, see also: Li, 2011). Van Twillert et al. (2007) compared the effectiveness of VR distraction with other types of distraction - the results showed that only VR and watching television had an analgesic effect. However, the difference between VR and watching TV was not statistically significant.

It is hypothesized, that the greater effectiveness of VR comparing to other distraction methods is related to the immersive nature of this medium, and to the experience of presence – feeling and acting as if a person is located inside the VE (Gold, et al. 2007, Sanchez-Vives and Slater, 2005). Hoffman et al. (2004) investigated the relationship between the analgesic effects of VR and the strength of subjective presence in a virtual world. The results also showed that the strength of an analgesic effect is associated with the quality of graphics and sound, and the degree of possible interactions with the virtual world. However, the degree of presence was measured in this study using only the single question ("While experiencing the virtual world, to what extent did you feel like you went inside the virtual world?"). The relationship between presence and pain intensity was also found in a study by Gutierrez-Martinez et al. (2010), where a questionnaire adapted from Slater et al. (1994) was used as a measure. It was not found, however in a study by Dahlquist et al. (2010a). The authors of the above-mentioned study hypothesize that the presence may be a less important factor when fast paced VEs are used, which may more directly influence the participant's attention. The relationship between presence and analgesia was not found in previous studies done by us (Czub & Piskorz, in press; Czub & Piskorz, unpublished). Therefore, it is still not certain to what extent presence mediates pain tolerance or pain intensity during VR interventions. There is enough evidence however, to consider it as an important variable, and to use presence measures in studies on VR analgesia.

Currently only a few published studies have investigated how the content of virtual environments (VE) influences the analgesic effect. Mühlberger et al. (2007) studied the effect of different virtual environments on hot/cold pain stimuli endurance. Participants were immersed in "warm" and "cold" virtual environments, then hot and cold pain stimuli were applied to them. The analgesic effect achieved by VR distraction was similar, regardless of the virtual environment presented. However, some differences in "hot" and "cold" VE analgesic efficacy were found in a study by Shahrbanian & Simmons (2008), done in a group of post-stroke individuals. Hot and cold VEs differently influenced the experience of experimental thermal pain stimulus intensity, depending on the presence or absence of clinical pain symptoms in the patients. A study by Dahlquist et al. (2010a) evaluated the effect of the avatar point of view on cold-pressor pain tolerance in young adults. Participants

played two versions of a racing game "*Need for Speed 2*" – steering the car from first and third-person points of view. Authors of the study found no significant differences in pain-tolerance scores between first-person and third-person view distraction.

Parameters of VE that are important for pain alleviation seem to be less related to specific content of VE, and more related to the way the user interacts with the VE. Research carried out by Dahlquist et al. (2007) indicates that active participation in virtual environment is a more effective distractor from pain stimuli than passive observation of a recording where someone else is playing a game. Authors of the study used a "Jellyfish Race" game, that required participant to chase certain game objects and to avoid being hit by others. We used a similar structure in designing a game used in the current study. A between group design study by Wender et al. (2009) provides additional evidence that the level of interaction offered by VE is a parameter differentiating the effectiveness of analgesic influence. Participants in this study glided through a pre-determined path in a VE – but only one group could interact with the environment by looking around and shooting objects. The results showed large and significant reduction in pain unpleasantness in the interactive group compared to the passive group.

Level of interaction with a VR game can be manipulated by the use of different interfaces. But it can also arise from other parameters of the VE – fast paced games may stimulate and call for more interactive engagement. Similarly, complex games containing many meaningful elements may lead to a greater interaction than games where the user has to attend and react to only few objects. In the previous within-subjects study (Czub & Piskorz, 2012) we investigated if the level of dynamism in the game influences the pain tolerance and intensity. We used thermal (hot) pain stimulation and contrasted slow paced game (a particular location in the "Prince of Persia" game, where participants were walking in the natural landscape and listening to soothing music and sounds) with fast paced game (car racing "Split Second" game, with many explosions and crashes and loud dynamic sound effects). We failed to find a statistically significant difference between environments regarding the pain alleviating effect.   However, the lack of differences in the results could have been caused by many factors. We used commercial environments i.e. games, and therefore did not have control over the content of the environments. They could have differed not only with regard to the level of dynamism, but also complexity – defined as a number of meaningful elements in the game, or the number of elements that grab the participant's attention while playing the game.

The purpose of the current study was to selectively manipulate game complexity, using two variations of a similarly paced game. We used custom made VEs in order to have full control over their features. In the following within-participant experiment we test the hypothesis that game complexity influences the pain tolerance and pain intensity. Specifically, we hypothesize that games with greater complexity will lead to diminished intensity of pain and greater pain tolerance. The independent variable was

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the game complexity (two levels) operationalized as the number of elements within the game that the participant needs to attend to. Dependent variables were time the participants kept their hands in cold water (pain tolerance measure) and their subjective pain ratings on a VAS (pain intensity measure). Additionally, questionnaire data were collected (IPQ) to measure the feeling of presence in both experimental conditions.

METHOD

Design. A within-subjects design was used in the experiment. Each participant was placed in two experimental conditions (high vs. low complexity), and one control (non-VR) condition. The within-subjects design was chosen in order to minimize the influence of the uncontrolled variables on the outcome of the experiment. No separate control group was involved in the experiment. The participants' pain threshold established during a condition without VR distraction constituted the baseline-control measurement. The order of all three conditions was counterbalanced (Latin square).

Cold pressor test was used as a pain stimulus. This method is a commonly used paradigm in experimental pain studies and is considered a good approximation of chronic pain (Dahlquist et al., 2007; Dahlquist et al., 2010a; Rutter et al., 2009; Mitchell et al., 2004).

Participants. The research was carried out on 31 volunteers: students of Wroclaw universities. 19 females (average age: 21.37; SD 2.34; min 19, max 30) and 12 males (average age: 22.42; SD 1.51; min 20; max 24). Participants gave informed consent before the beginning of experimental session.

Apparatus

Virtual reality equipment. The participants received visual and aural stimuli from the game via virtual reality headset (HMD) - E-magin Z-800 - SVGA resolution – 800x600 pixels per display (1.44 megapixels), view angle - 40 deg diagonal FOV (which equals seeing 2.7 m diagonal movie screen from 3.7 m distance). The weight of the display set was 227g. Participants listened to stereo sound from the HMD's audio output.

The participants had an opportunity to look around in the virtual environment using an orientation tracking device Polhemus Minuteman. They were also able to rotate the avatar in the environment using the sensor held in their hands and move forwards/backwards with pedals from the USB Tracer GTR steering wheel.

Video game. The participants played games designed by the authors of the research. In the course of the game they moved a 3D arrow in a space filled with spheres. In the low complexity condition, the player's task was to hit white spheres with an arrow. For each accurate hit the player would receive one point. In the high complexity conditions, the player's task was also to hit white spheres with an arrow. Additionally, red spheres were interfering with completing the task and chasing the player. Each contact with the red sphere would result in subtracting one point.

The pain stimuli apparatus. Thermal (cold) stimulation was used in the study. Apparatus consisted of a container (25x35cm) filled with cold water (temperature 4.5 – 5.5°C). The container had 2 chambers connected to each other: one of them was filled with ice in order to maintain the proper temperature of the water and in the other one the participants were keeping their hands. The container was equipped with a water circulator in order to maintain constant temperature in both chambers. The water temperature was monitored by electronic thermometer. The apparatus was constructed by the authors of the study. Similar equipment was used in other previously published studies (Dahlquist et al., 2007; Forys & Dahlquist, 2007).

Measures

Visual Analogue Scale (VAS) – a subjective assessment of the experienced pain (pain intensity measure). The scale is built on the basis of a horizontal continuous line, 100mm in length. Each participant marks the strength of the experienced pain, expressed on the scale in millimeters where 0 stands for slight pain and 100 for extreme pain. Each participant filled in the scale three times: once without VR - to assess the pain threshold, and twice after exposure to pain stimulus during the immersion in high and low complexity of VE. VAS is the most frequently used pain scale in cold pressor task studies (see Birnie et al., 2012 for the review), and its validity was shown to be not different from other self-report measures (Ferreira-Valente et al., 2011).

Pain tolerance – the period of time during which participants kept their hand in cold water.
Igroup Presence Questionnaire (IPQ). A scale created by Schubert, Friedmann & Regenbrecht to measure the sense of presence experienced in the virtual environment. The scale consists of 4 subscales. The subscales are: Spatial presence – the sense of being present in VE; Involvement – the level of engagement in VE; Realism – the sense of realism of VE; General – an additional item measuring the general "sense of being there". Answers were given on a seven point scale, from: -3, to: 3. Reliability (Cronbach's Alpha) of IPQ is between .63 and .78 (Schubert, 2003).

Additionally, participants answered the question related to perceived pleasantness or unpleasantness of the experience. Answers were given on a seven point scale, ranging from: -3 (unpleasant) to: 3 (pleasant).

Procedure

Setting. The experiment was conducted in a room belonging to the Wroclaw University Institute of Psychology. During the non-VR condition participants were seated in a way enabling them to put their dominant hands in the container with cold water. During both VR distraction conditions participants changed the position of their bodies in order to put their non-dominant hands in the container with cold water. They played the game with their dominant hands.

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Participants were informed that the purpose of the experiment was to study how people feel their own body in virtual reality conditions. We consider it unlikely that participants would guess the hypothesised relationship between the type of VE and pain intensity. The difference between virtual environments was not large and did not suggest any relationship between the type of the environment and the pain experience. The participants were assured of the possibility to resign from the participation at any moment and without any particular reason. All participant gave informed consent. The participants were asked to fill in a short personal data survey prior to the experiment.

Then, they were familiarized with the equipment and the procedure. They put their hands in the cold water for five seconds in order to become aware of its temperature. They were also presented with thorough instruction on how to play the game in each virtual environment and were able to practise playing: to learn how to navigate the game and how to use the interface. The participants equipped with the HMD headset practised hitting white spheres with an arrow. The training phase ended with hitting five white spheres in a row. Then one of the two experimental conditions or the control conditions followed. During the experiment the participants were equipped with the HMD headsets and their heads were additionally covered with thin black scarves for the purpose of a better isolation from the peripheral visual stimuli. The participants were instructed to put their hands in the container with cold water and keep them there until the pain caused by the low temperature became difficult to bear (they were also supposed to inform about it verbally). They were also requested not to withstand overwhelming pain. The experiment was terminated after 4 minutes if the participant had not removed their hand earlier.

After one minute of playing the game the participants' non-dominant hands were put in the container with cold water while they continued playing. The one minute period was used in previous studies (Dahlquist et al., 2010a). In some studies even shorter adaptation times were used (Mühlberger et al., 2007). Upon finishing the trial (that is after removing their hands from the cold water) participants assessed the pain intensity with the VAS scale, and filled in the *Igroup Presence Questionnaire*. Finally, they answered the question related to perceived pleasantness or unpleasantness of the experience. In the next experimental condition participants played a different VR game (low vs. high complexity). Apart from that, the procedure of both VR conditions was identical.

Non-VR (control) conditions. As in the case of the VR conditions, the participants were equipped with the HMD headsets and covered with thin black scarves. However, no images were displayed and the participants could see only blank screen. Then, they were supposed to put their dominant hands in the container with cold water. As it was during the VR conditions, they were instructed to inform verbally and take the hands out of the container when the pain caused by the low temperature became unbearable. The trial was stopped after 4 minutes if the participant had not reacted earlier. Upon the end of the trial, participants assessed the level of experienced pain and reflected the results on the VAS.

Between each thermal stimulus (experimental and control conditions) participants were given at least a 15-minute-break during which they could warm up the cold hands. They also had the opportunity to put their hands in the container with room temperature water.

Statistics

Non-parametric statistics were used in the statistical analysis (i.e. Friedman's ANOVA, Spearman's Rank Correlation Coefficient, Wilcoxon's Signed Rank Test, Mann-Whitney U-test). Non-parametric statistics were used due to the lack of normal distribution as well as homogeneity of the results. Using the formula for non-parametric test of significance for dependent ($r = Z/\sqrt{N}$, where N is the number of observations) and independent samples ($r = Z/\sqrt{N}$, where N is the number of participants) the authors calculated the effect size. According to Cohen's assumptions (1988, 1992) the effect was considered small when $r = .10$; medium when $r = .25$; and big when $r = .50$. IPQ measures were tested with parametric statistics.

RESULTS

Preliminary analyses

The first stage of the analysis verified whether the order of experimental conditions influenced the pain intensity or the pain tolerance. The analysis tested the pain tolerance and intensity as a function of succeeding measurements. Order of measures did not influence neither tolerance to pain results (Friedman's ANOVA ($N = 31$; $df = 2$) $= .33$; $p = .85$) nor pain intensity ratings (Friedman's ANOVA ($N = 31$; $df = 2$) $= 2.99$; $p = .22$).

Main analyses

Pain tolerance. The results of the experiment confirmed the preliminary assumptions regarding positive influence of distraction caused by virtual reality on the level of experienced pain. The statistical analysis revealed the occurrence of main effect, that is significant differences between three tested conditions (non-VR and two VR conditions) with regard to the pain tolerance (Friedman's ANOVA ($N = 31$; $df = 2$) $= 13.15$; $p = .0014$).

Each VR condition was compared to the non-VR condition with the use of Wilcoxon's Signed Rank Test. The comparison revealed statistically significant differences between the low complexity VR condition and the non-VR condition ($T = 32.5$; $Z = 3.50$; $p = .0005$, $r = .50$). Participants of the experiment distracted by the low complexity virtual reality endured pain for a significantly longer time than in the non-VR conditions. Similar results were obtained in the comparison of the non-VR and the high complexity VR experimental conditions ($T = 41.5$; $Z = 3.10$; $p = .002$, $r = .45$). However, there was no significant difference in the pain tolerance between the two VR conditions. In both cases the participants were able to keep their hands in the cold water for a similar period of time ($T = 123.5$; $Z = .10$; $p = .92$).

Pain intensity. The results of the pain intensity in the VR and the non-VR conditions also revealed the occurrence of the main effect (Friedman's ANOVA ($N = 31$; $df = 2$) = 8.30; $p = .016$). Subsequently, results of the VR and non-VR conditions were compared with the use of Wilcoxon's Signed Rank Test.

The two VR conditions differed significantly in terms of pain intensity ($T = 87.0$; $Z = 2.45$; $p = .014$, $r = .33$). The participants reported experiencing significantly more pain in the low complexity virtual reality than in the high complexity virtual reality. This result supports the hypothesis of the study and suggests that the complexity of VE is related to the intensity of pain during VR intervention.

There was also a statistically significant difference between the pain intensity measure in the non VR and in the high complexity conditions ($T = 79.5$; $Z = 2.81$; $p = .005$, $r = .38$). The participants admitted having felt more pain during the non VR trials. However, somewhat unexpected results were obtained upon comparison of the non VR and the low complexity virtual reality ($T = 163$; $Z = .91$; $p = .36$). In both cases participants reported feeling similar intensity of pain (see Table 1).

Table 1. Descriptive statistics of pain intensity and pain tolerance in the non VR and VR conditions.

	Pain tolerance		Pain intensity	
	M	*SD*	*M*	*SD*
Non VR	81.77	88.44	6.65	2.0
Low complexity virtual reality	123.61	96.79	6.40	2.16
High complexity virtual reality	126.26	104.02	5.58	2.35

Other results. Subsequently, we searched for a correlation between the pain tolerance and the pain intensity measure. In the low complexity conditions the analysis revealed that the pain tolerance negatively correlates with the pain intensity ($r = -.44$, $p < .05$), which means that the longer participants kept their hand in cold water, the less intense pain they reported. In the high complexity conditions the analysis also showed a negative correlation between pain tolerance and the pain intensity ($r = -.49$, $p < .05$).

The correlations between IPQ questionnaire measures and experienced pain measures were investigated. The only significant (negative) correlation was found between the general immersion factor (g) and the pain intensity ($r = -.41$, $p < .05$) (see Table 2).

Participants rated high complexity game as significantly more pleasant than the low complexity game ($t = 2.19$, $df = 29$, $p = .036$, Mean high complexity = .9, Mean low complexity = - 1.3).

Table 2. Descriptive statistics of IPQ.

	IPQ	*M*	*SD*
High complexity virtual reality	Spatial presence	0.01	1.32
	Involvement	-0.13	1.19
	Realism	-2.14	0.54
	General	1.16	1.95
Low complexity virtual reality	Spatial presence	0.08	1.12
	Involvement	-0.38	1.13
	Realism	-1.10	1.07
	General	0.59	1.77

Pain sensitive and pain tolerant. In the next stage of statistical analysis participants were divided into two types: pain sensitive and pain tolerant. This was done on the basis of inspection of results distribution for the non VR conditions. The analysis of the distribution revealed its bimodal character. Only a few participants had results close to average and were placed in the center of the histogram. Upon the inspection of the histogram, the participants who kept their hands in the cold water for 100 seconds or less were classified as pain-sensitive, whereas those who kept their hands in the cold water for more than 100 seconds were classified as pain-tolerant. The first group consisted of 24 participants and the second one of only 7.

First, we tested for significant differences between the two groups with respect to the pain tolerance and the pain intensity. This was done separately for each of VR conditions, and the purpose of this comparison was to establish if the classification done on the basis of non-VR results is consistent with their results in both VR conditions. Both in the low and the high complexity conditions there were statistically significant differences between groups with regard to pain tolerance and pain intensity. In both conditions participants in the pain sensitive group displayed considerably lower pain tolerance than participants from the pain tolerant group (low complexity: $U = 16$, $Z = -3.19$, $p = .002$, $r = -.57$; high complexity: $U = 21$, $Z = -2.95$, $p = .003$, $r = -.53$). This means that division of participants for pain sensitive and pain tolerant is stable across conditions – participants classified as pain sensitive had also lower pain tolerance in both VR games and participants classified as pain tolerant had also higher tolerance in both VR games.

Also, the between group difference was stable for pain intensity ratings. Participants classified as pain sensitive rated the intensity of pain as significantly higher in both VR conditions, compared to participants classified as pain tolerant (low complexity: $U = 35$, $Z = 2.29$, $p = .022$, $r = .41$; high complexity: $U = 26.5$, $Z = 2.69$, $p = .007$, $r = .48$) (see Table 3 - See page 485).

There were no significant differences between the pain sensitive and pain tolerant groups with regard to IPQ scales (high complexity: General: $t = -.85$, $df = 29$, $p = .40$; Spatial presence: $t = -.80$, $df = 28$, $p = .43$; Involvement: $t = -.77$, $df = 26$, $p = .44$; Realism: $t = -.06$, $df = 27$, $p = .95$; low complexity: General: $t = .02$, $df = 29$, $p = .99$; Spatial presence: $t = -.40$, $df = 28$, $p = .70$; Involvement: $t = -1.23$, $df = 28$, $p = .23$; Realism: $t = -1.29$, $df = 29$, $p = .21$) (see Table 4 - See page 485).

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Table 3. Descriptive statistics of pain tolerance and pain intensity in the pain sensitive and pain tolerant groups.

		Pain sensitive group		Pain tolerant group	
		M	SD	M	SD
High complexity virtual reality	Pain tolerance	93.08	95.01	240	0
	Pain intensity	6.26	1.87	3.24	2.44
Low complexity virtual reality	Pain tolerance	90.50	84.48	237.14	7.56
	Pain intensity	7.03	1.50	4.24	2.76

Table 4. Descriptive statistics of IPQ in the pain sensitive and pain tolerant groups.

IPQ		Pain sensitive group		Pain tolerant group	
		M	SD	M	SD
High complexity virtual reality	Spatial presence	-0.08	1.29	0.40	1.46
	Involvement	-0.21	1.24	0.25	0.88
	Realism	-2.14	0.57	-2.13	0.47
	General	1.00	2.02	1.71	1.70
Low complexity virtual reality	Spatial presence	0.03	1.05	0.23	1.41
	Involvement	-0.50	1.15	0.13	0.93
	Realism	-1.23	1.02	-0.64	1.17
	General	0.58	1.77	0.57	1.90

DISCUSSION

The hypothesis of the study was partly confirmed by the results. Participants reported significantly lower intensity of pain while playing the game in the high complexity conditions, compared to the low complexity conditions.

However, the experiment results did not reveal any differences between the two used virtual environments with regard to pain tolerance. Participants in both the high and the low complexity conditions kept their hands in cold water for a similar period of time. This result does not confirm the initial hypothesis we had.

This discrepancy between the pain tolerance and the pain intensity is not easy to explain, especially when taking into account the results from other experiments we have done, where the opposite pattern of results was obtained (Czub & Piskorz unpublished). Why did the participants who declared lower intensity of pain remove their hands from cold water after a similar time as the participants who declared high pain intensity?

One possible explanation could link the obtained results pattern with the participants' attitudes towards the games. Participants rated the high complexity game as more pleasant than the low complexity one. Therefore, their mood could have influenced the way they rated the pain intensity.

This speculation can be supported by studies showing the existence of relationship between mood and pain (Wiech & Tracey, 2009). However, we did not measure the mood directly and relied only on the participants' ratings of game pleasantness.

It is also possible that the difference in the game complexity was not sufficient enough to elicit differences in pain related behavior. We are aware that results of this study provide only a preliminary and partial answer to the initial question we asked. The results may mean that game complexity influences only the subjective perception of pain but not the behavior. Alternatively, it may mean that game complexity influences both the pain intensity and tolerance, but that the difference in complexity between the VEs in this study was not large enough. The only difference between the VEs was the presence or absence of red spheres which needed to be avoided. Perhaps the sole experience of participating in the experiment, learning how to play the game or simply being immersed in VR caused enough engagement of the participants to make the difference between the two environments insufficient.

We also believe that VAS ratings may be more susceptible to potential confounding factors, like task demand, and that the difference obtained on VAS only needs to be interpreted with caution. However, the results of the current study do support the claim that game complexity is a potentially important factor in VR analgesia and provide preliminary evidence, justifying further investigation of this subject.

Participants declared a similar intensity of pain in the low complexity conditions and in the control conditions. This result may be linked with their ratings of game pleasantness and mean that a low complexity game was not interesting enough to grab their attention. However, this negative result is related only to self-reported pain intensity. Behavioral data (pain tolerance) show there was a significant difference between the low complexity conditions and the control conditions.

The results discussed above show that the pain tolerance and the pain intensity measures, although correlated and point to the same phenomenon of pain experience, may nevertheless reflect different aspects of pain. Such a claim may find support in meta-analysis of the relationship between behavioral and self-report measures of pain, where only moderate association was found between the two types of pain measurement (Labus et al., 2003). It is worth noting that the correlation between the pain intensity and tolerance seen in the results of the current study is consistent with correlations obtained in our previous studies, thus lowering the chance of this result being accidental (Czub & Piskorz, unpublished).

No correlation was found between the IPQ (measure of presence) and the pain indicators. Similar negative results were obtained in our other studies using IPQ (Czub & Piskorz, in press; Czub & Piskorz, unpublished) and also in the study done by Dahlquist et al. (2010a) where a single item was used to measure presence. The results of the present study can be interpreted as evidence for the lack of relation between the presence and the pain. But a different

interpretation, related to problems with measuring the presence is also plausible. It is possible that post-experience questionnaires are not the best method to measure this phenomenon and a better way of measuring the presence could be building the questionnaire into the VR game itself and using additional behavioral or physiological measures (see Slater, 2004). Additional problems with understanding the relationship between the presence, VR and pain come from the fact, that pain stimulation may negatively influence the feeling of the presence in VR when it is not consistent with the stimuli in other sensory modalities. It can be also speculated that pain stimulus can increase the presence when it increases multimodal coherence of the whole game experience.

     It is established that participants in cold-pressor test paradigm studies can be divided into two groups: pain sensitive and pain tolerant (Geisser et al., 1992). However, in published research studies on VR distraction which use CPT as pain stimulus this distinction was not yet analyzed. The results presented in this paper confirm data presented by Geisser et al. (1992): similarly to that study results, more participants were classified as pain sensitive. Additionally, sex distribution was similar (more males than females were classified as pain tolerant). Results presented in this paper also indicate that the division of people into pain sensitive and pain tolerant is relatively stable: participants grouped on the basis of the non-VR results have shown similar pain tolerance and pain intensity in both VR conditions.

Limitations

     There are two aspects of the sample used in the current study that may limit the conclusions – one is related to the small sample size which makes interpretation of negative results problematic. The second limitation is related to the sampling method, based on volunteers – which might have led only certain type of participants to enroll in the experiment. To arrive at a more general answer related to the influence of game complexity on pain, it is necessary to replicate the procedure using different, more varied groups of participants.

     Another possible limitation is related to the pain stimulus. Although the cold pressor test is considered a good approximation of chronic pain, it is not obvious to what extent results obtained in an experimental pain paradigm can be generalized to clinical settings and various clinical conditions.

     VAS scale used by us had "slight pain" at its lowest scale extreme. We decided to use "slight pain" rather than "no pain" assuming that the experimental procedure was designed to always evoke some amount of pain – the participants were asked to remove their hands from water when the pain became unbearable. However, such a scale construction makes it more difficult to compare our results with other studies using VAS scales, where the majority of scales had "no pain" as the lowest extreme level.

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