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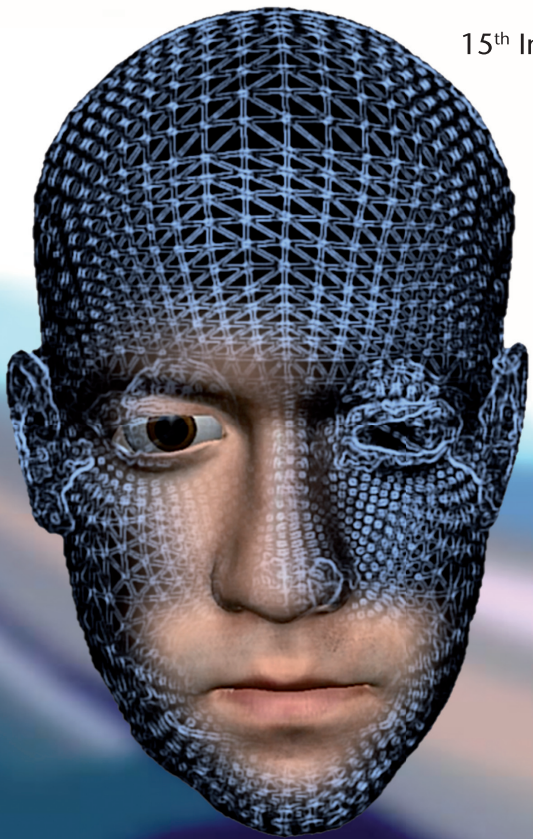

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Presence and Emotion: Changes in pain perception following virtual reality

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Abstract. Medical procedures often cause pain. Although conventional analgesics are typically used to relieve pain, they often have undesirable side effects, or limited effectiveness. Thus, it is important to develop complementary methods of pain relief. Attention diversion is one important pain relief method, and can be administered by employing Virtual Reality (VR). In this study, we examined the influence of presence on pain relief using VR (SnowWorld), as well as the influence of personality variables (locus of control, trait anxiety and empathy) on pain reduction. Forty healthy participants (20 women and 20 men) underwent two exposures to experimentally evoked thermal pain stimulation, one with and one without VR. Exposures were administered in the same session and randomly ordered. We predicted that VR would reduce sensitivity to pain, that presence would correlate with pain reduction and that locus of control, anxiety and empathy would influence presence and pain perception. We found significant pain reduction during VR for men but not for women. Two presence variables – Natural and Interface Quality were important in predicting pain relief using VR for men. External Locus of Control correlated with higher pain relief and higher presence, contrary to prediction. Trait anxiety also correlated with higher presence contrary to prediction, but with lower pain relief, as predicted. Empathy correlated with higher presence as predicted. To summarize: our findings found that employing VR for pain relief (using "SnowWorld") is more effective for men than for women, and that for men, Natural and Interface Quality are the most important presence variables.

Keywords. Pain, Locus of Control, Empathy, Trait Anxiety, Gender, Pain Analgesia

Introduction

Medical procedures are often painful. This pain may prevent patients from agreeing to undergo necessary procedures, or to terminate them prematurely (Ehde, Patterson & Fordyce, 1998; Hoffman, Patterson, Carrougher & Sharar, 2001). Additionally, during these procedures, the degree of pain and suffering the patient experiences may influence his /her level of functioning and result in the development of chronic pain (Patterson, Wiechman, Jensen & Sharar, 2006; Ptacek, Patterson, Montgomery & Heimbach, 1995). Opioids are currently widely employed for analgesia during medical procedures, however, their side effects limit their use (Cherny et al., 2001; Hoffman et. al., 2001; Perry, Heidrich & Ramos, 1981). Thus, developing alternative and non pharmacological analgesias is imperatitve.

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Cognitive Pain Analgesia

Psychological factors figure widely in pain perception. For example, if we experience pain during the treatment of a wound, following treatment of the same wound is likely to be painful as well (Hoffman, et. al., 2004b). Attention, beliefs regarding pain, expectations and attributions also affect pain perception (Turk, Meichenbaum & Genest, 1983). Fernandez & Turk (1989) performed a meta analysis on 51 articles published between 1960-1988 and found cognitive techniques to be effective in pain reduction in 85% of studies. Attention diversion (i.e., distraction) is the most common cognitive procedure used for pain analgesia (Gold, Belmont & Thomas, 2007).

Attention diversion can be obtained using auditory (music), visual (television) or interactive (computer games) stimuli. Diverting attention away from the sensations or emotional reactions produced by the painful procedures helps patients reduce pain responses (Hoffman, Patterson & Seibel, 2008). As we are limited in the amount of attention we can focus on a stimuli, diverting attention limits amount of attention on the painful stimuli (Wismeijer & Vingerhoets, 2005). Utilizing multiple senses in attention diversion is preferable to using just one sense (Diette, Lechtzin, Haponik, Devrotes & Rubin, 2003: Lee et al., 2004; Lembo et al., 1998). Ideal diversion is obtained using multiple sensory modalities (visual, auditory, kinesthetic), emotional reactions and active participation (Wismeijer & Vingerhoets, 2005). Therefore, VR is such an ideal diversion (Gold et al., 2007).

VR has been found to be an effective pain analgesic, as it effectively reduces pain experienced during chemotherapy, physiotherapy and burn treatment, as well as experimental evoked pain experienced by healthy subjects. Early case studies which included two teenagers with burn wounds supplied the first evidence that experiencing VR can be a potential non pharmacologic analgesic during daily wound care (Hoffman, Doctor, Patterson, Carrougher & Furness, 2000a). Hoffman et al (2000a) used a simple Nintendo game for VR. Following that, studies used a more sophisticated VR program (SnowWorld) which was developed specifically for wound care. Employing SnowWorld suggested that VR can be used as a powerful analgesic for pain treatments. It has been used for burn treatments (Patterson et al., 2006; Hoffman et al., 2004b), dental procedures (a single case study by Hoffman et al., 2001), physiotherapy following wound treatment (Hoffman et al., 2009) and short chemotherapy (Schneider, Prince-Paul, JoAllen, Silverman & Talaba, 2004). The use of SnowWorld was even adapted for hydrotherapy for burn care in a single case study. VR was employed with patients who are low on suggestibility for treatment of chronic pain as these patients rarely benefit from hypnosis as an analgesic (Oneal, Patterson, Soltani, Teeley & Jensen, 2008; Patterson et al., 2006).

Presence, Personality Variables and Pain

Immersion is an important aspect in VR use in general and in pain analgesia in particular (Steuer, 1992; Wallach, Safir, Samana, Almog & Horef, 2011). Thus, we expected presence to reduce pain.

The effect of Locus of Control (Rotter, 1966) on presence is unclear. Murray, Fox and Pettifer (2007) found a positive correlation between external Locus of Control and presence, however, Wallach, Safir and Samana (2010) found a negative correlation between the two. Internal Locus of Control correlates positively with pain endurance, and negatively with pain ratings. Individuals with Internal Locus of Control also required less analgesics during a painful medical procedure (Craig & Best, 1977; Roome & Humphrey, 1992; Williams, Golding, Phillips & Towell, 2003). We predicted that internal Locus of Control should correlate positively with pain endurance, pain threshold and presence.

Arntz, Dreesen & Merckelbach, (1991) suggested that anxiety causes release of endogenous opioids and endorphines which reduce pain. Boles and Fanselow (1991) claim that fear takes precedence over pain and thus reduces pain perception. On the other hand, Melzack (1973) clai-

ms that fear increases pain by "opening the gate" and enabling pain messages to reach the brain. Arntz, Dreessen & De Jong (1994) found that the level of felt pain was primarily influenced by the amount of attention to the painful stimuli. Anxious people pay attention selectively to feared stimuli (Rinck, Becker, Kellermann & Roth, 2003). Therefore, we should be able to reduce pain by diverting attention from it by using feared/phobic stimuli. Huber (2011) found that individuals with heightened trait anxiety experienced higher presence in a flight VRE. In the present study, the negative stimuli is not within the VRE, but the pain stimuli. Thus, since anxious people concentrate on pain stimuli, we predicted that trait anxiety would correlate negatively with presence, pain endurance and pain threshold, and postively with pain magnitude. We also predicted that anxious subjects would benefit less from the VR. Since Empathy (Baron-Cohen, 2003; Davis, 1980) correlates positively with presence (Nicovich, Boller & Cronwell, 2005; Wallach, Safir & Almog, 2009), we predicted a positive correlation in our study as well.

Presence, Personality Variables and Pain Analgesia in VR – the Present Study

Previous studies were either single case studies, or used a small number of subjects (up to 12). Most studies failed to examine gender differences as they used only men, or an unequal number of men and women. In addition, they did not consider personality variables. One study used a relatively large number of subjects (Dahlquist et al, 2009), however they employed a single question measure of presence rather than a presence questionnaire. Therefore, it is not surprising that a correlation between presence and pain was not found.

In contrast, we utilized a relatively large sample with equal numbers of men and women and examined personality variables. We predicted that: 1. VR would reduce sensitivity to pain; 2. Internal Locus of Control, high Empathy ratings, and low Trait Anxiety ratings would correlate with higher Presence ratings; 3. Presence would correlate negatively with pain perception; 4. Internal Locus of Control would correlate positively with pain endurance and pain threshold and result in higher pain reduction; 5. Trait Anxiety should correlate negatively with pain threshold, pain endurance and positively with pain ratings. Individuals high on Trait Anxiety should also benefit less from VR; 6. Presence should also mediate between personality variables and pain.

Methods

Subjects

Fourty students aged 20-35 (M=25.7±3.05), (20 male, 20 female), participated in the study. Exclusion criteria were: impaired hearing or sight, chronic usage of pain analgesics or psychiatric medication, epilepsy, and for women menstruation at the time of the study.

Apparatus and Software

VRE – SnowWorld (www.Vrpain.com, Hoffman, 2004a; Hoffman et al., 2009). The user skis in a 3D icy world and throws snowballs at snowmen, igloos, mamoths and penguins. Participants wore a high resolution (600X800 and 1024X768 XGA) hmd VR2000 (Virtual Realities, inc.), with a built in 360□ tracker, and 42□ SVGA field of view (see Figure 1).

Thermal Sensory Analyzer (TSA) – produces heat and cold pain through a 30X30 mm thermod (TSA-2001, Medoc, Ramat Ishai, Israel) connected to the palm. Pain threshold was tested using limits. Base temperature was 32ºc and was increased or decreased gradually one degree per minute. Temperature ranged from 0º-50ºc. Subjects pressed a lever to indicate when the sensation turned painful. Three measurements were taken for heat and three for cold. The average of each three was the pain threshold (see Figure 2).

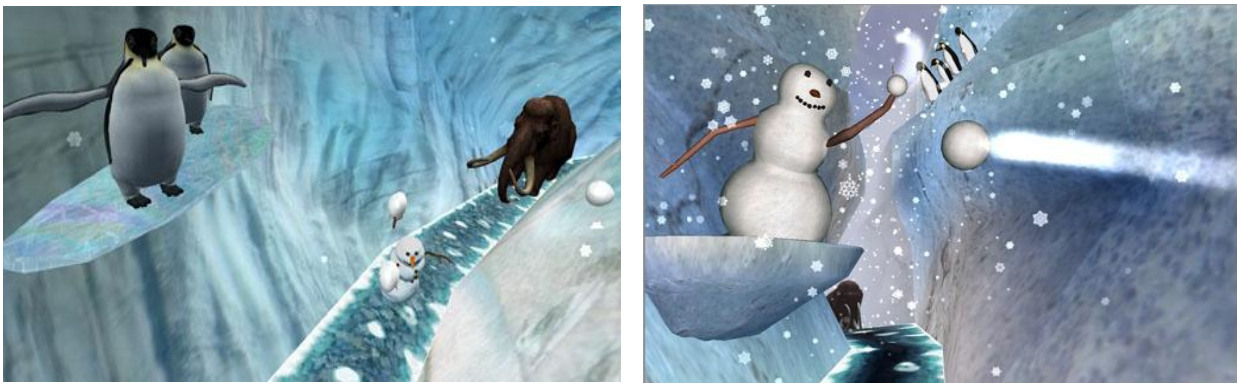

Figure 1. Snow World

Cold Pressor test–Tub filled with cold water, temperature is adjusted by ±0.5 °C (Heto CBN 8-30 Lab equipment, Allerod, Denmark). Subjects insert their dominant hand (palm open) into the water at 1°C and leave it there as long as they can. The time until they begin to feel pain is the cold pain threshold and the time till they spontaneously remove their hand is the cold pain tolerance. For safty reasons, subjects were not allowed to keep their hand in beyond 180 seconds. After extracting their hand from the water they rated pain on a Visual Analogue Scale (VAS) ranging from 0-100 (0 – no pain at all, 100- worst possible pain) (see Figure 3).

Questionnaires

Background – age, sex, pain history, analgesic medication usage, psychiatric medication usage, sight, hearing, epilepsy. For women – a question about menstruation status.

Presence – IPQ and PQ. IPQ (Witmer & Singer, 1998) – 19 questions answered on a 7 point Likert scale on three subscales: Involvement/Control (11 items) – felt control over and involvement in the VRE; Natural (3 items) – how natural the environment seemed; Interface Quality (3 items) – how distracting the technological aspects were. PQ (Schubert, Friedmann & Regenbrecht, 1999) – 14 questions answered on a 5 point Likert scale on four subscales: General (1 item) – how much the subject feels "in" the virtual world; Spatial Presence (5 items) – the feel of the spatial attributes and the degree can operate in it; Involvement (4 items) – how aware the subject was of the external environment while in the VRE; Experienced Realism (4 items) – how real the VRE seems.

Trait Anxiety **–** The Trait subscale (20 items) from the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch & Lushene, 1970).

Empathy **–**Fantasy subscale consists of 7 items – tendency to project onself into fictitous situations, scored on a 5 point Likert scale (Davis, 1980).

Locus of Control – Locus of Control (LOC) scale (Rotter, 1966) has 29 items comprised of two statements, one loads on internal LOC and one loads on external LOC, of which the subject chooses one.

Procedure

The study was approved by the Ethics Committee of the University of Haifa. Subjects signed informed consent, filled out the background questionnaire and underwent a short training test in order to familiarize them with the VR task, the devices (TSA and CPT), and the perceived sensations. The training tests were not included in the statistical analyses. Ten minutes later, sub-

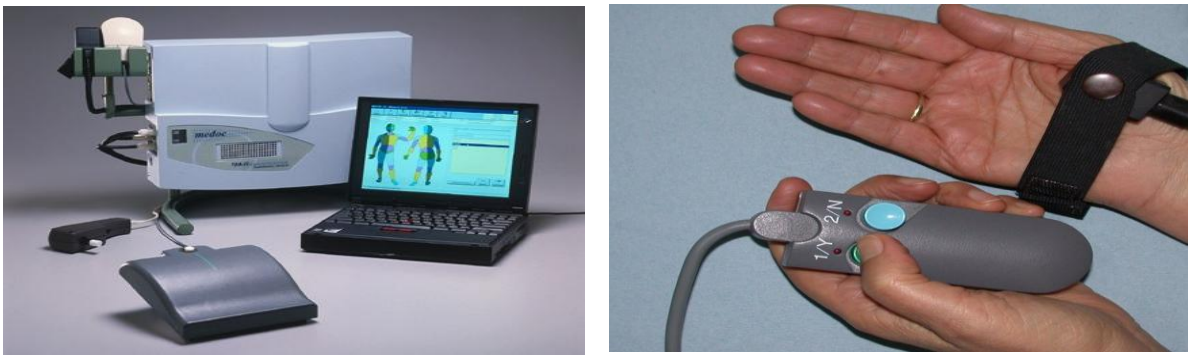

Figure 2. Thermal Sensory Analyzer (TSA)

jects filled out the LOC and empathy questionnaires and a battery of pain tests was performed to determine each participant's baseline sensitivity to pain. The battery included measuring heat pain threshold (TSA) as well as sensitivity to noxious cold (time to pain onset, tolerance and intensity) in order to determine each participant's baseline sensitivity to pain. Immediately following, each subject participated in two separate experimental conditions, presented in a random order: A) subjects were exposed to heat pain for 3 minutes using a thermode attached to their ankle. They were asked to give pain ratings on the VAS every 20 seconds; B) similar to A, and subjects were immersed in the VRE – they wore the HMD and played in SnowWorld. This exposure began one minute prior to pain induction, and pain ratings were measured every 20 sec.

Results

Gender differences in personality variables and pain perception

Women rated higher on Trait Anxiety, Empathy and Pain during VRE (Table 1).

VR Pain analgesia

Comparing pain ratings between condition A and B, using repeated measures two way ANOVA, demonstrated that VR significantly reduced pain ratings [$F_{(1,38)}$=8.58, p<.01], Gender was not significant [$F_{(1,37)}$=5.60, NS], however, the interaction was significant [$F_{(1,38)}$=5.19, p<.05]. A separate examination of men and women revealed that for men there was a significant reduction in pain [$t_{(19)}$=3.48, p<.01], but not for women [$t_{(19)}$=.49, NS] (Table 2).

Figure 3. Cold Pressor Test (CPT)

Table 1. Scores of Men and Women

	Women		Men		
	M	SD	M	SD	t
Trait Anxiety	42.98	9.63	36.65	10.34	2.00*
Locus of Control	5.08	2.80	4.65	2.37	0.53
Empathy	24.20	4.91	20.25	6.19	2.24*
IPQ – general	4.90	1.70	4.87	1.60	0.05
IPQ – Spatial (SP)	5.31	1.03	5.09	1.17	0.62
IPQ–Involvement (INV)	3.34	1.16	3.93	1.73	1.25
PQ-Involvement/Control (IC)	5.12	0.92	5.51	0.66	1.53
PQ – Natural (NAT)	4.55	1.65	5.01	1.03	1.06
PQ–Interface Quality (IQ)	4.87	1.05	5.23	1.28	0.97
Pain ratings, A	69.67	27.70	60.80	23.85	1.09
Pain ratings, B	67.85	32.09	46.23	26.62	2.32*

*Notes: *p<.05 **p<.01*

Personality Variables and Presence

Employing Pearson Correlations, we found a significant positive correlation between IPQ general and External LOC, and Empathy, as well as a positive correlation between PQ-NAT and External LOC, and a positive correlation between IPQ-SP and Trait Anxiety (Table 3).

Examining men and women separately, we found a positive correlation between IPQ-General and Empathy for men and a positive correlation between IPQ – SP and Empathy. For women, a positive correlation between IPQ – INV and Trait Anxiety was found (Table 4).

Table 2. Pain ratings

	Pain ratings A		Pain ratings B	
	M	SD	M	SD
Men	60.80	23.86	46.24	26.62
Women	69.67	27.70	67.85	32.09

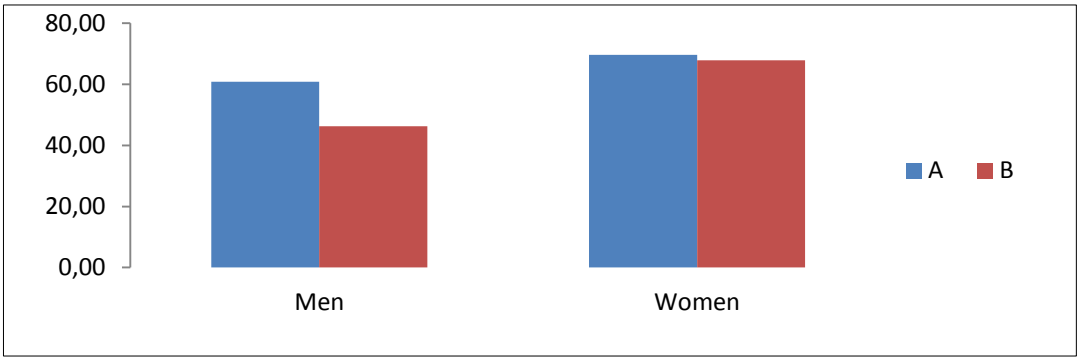

Figure 4. Pain Levels for Men and Women

Presence and Pain

No significant correlations were found between presence and pain ratings during condition B. When we examined men and women separately, we found that there was a positive correlation between PQ – NAT and pain for men (Table 5).

Table 3. Presence and Empathy, LOC and Trait Anxiety

	Empathy	Locus of Control	Trait Anxiety
PQ - Involvement/Control (IC)	-0.120	0.155	0.035
PQ - Natural (NAT)	0.018	0.310*	-0.041
PQ – Interface Quality (IQ)	-0.142	0.058	-0.025
IPQ – General	0.401*	0.322*	0.170
IPQ – Spatial Presence (SP)	0.166	0.155	0.302*
IPQ – Involvement (INV)	0.208	-0.017	0.205

*$p<.05$

Table 4. Presence, Empathy and Trait Anxiety

	Women		Men	
	Empathy	Trait Anxiety	Empathy	Trait Anxiety
PQ–Involvement/Control (IC)	0.105	0.231	-0.208	-0.033
PQ – Natural (NAT)	0.156	0.063	0.004	-0.057
PQ – Interface Quality (IQ)	0.062	0.234	-0.218	-0.158
IPQ – General	0.356	0.105	0.467*	0.228
IPQ – Spatial Presence (SP)	0.486*	0.310	-0.071	0.278
IPQ – Involvement (INV)	0.351	0.420*	0.277	0.207

*$p<.05$

Table 5. Pain ratings during condition B and Presence

	Women	Men
PQ – Involvement/Control (IC)	-0.223	0.171
PQ – Natural (NAT)	-0.281	0.497*
PQ – Interface Quality (IQ)	-0.163	-0.106
IPQ – General	-0.189	-0.174
IPQ – Spatial Presence (SP)	-0.085	-0.103
IPQ – Involvement (INV)	0.041	-0.166

*$p<.05$

Personality Variables and Pain

Examining LOC – no significant correlations with pain tolerance were found. External LOC correlated positively with pain reduction between condition A to B ($r=.30$, $p<.05$). This was also found for women ($r=.41$, $p<.05$) but not for men ($r=.30$, N.S).

Examining Trait Anxiety – a negative correlation was found with pain reduction using VR ($r=-.29$, $p<.05$) and a positive correlation with cold pain threshold ($r=.33$, $p<.05$). Correlations with pain tolerance ($r=.09$, N.S) and pain threshold for heat ($r=-.19$, N.S) were not significant.

Personality Variables, Presence and Pain

We performed Stepwise Regression separately for women and for men, using change in Pain Ratings during VR as the dependent variable, and presence, pain threshold for cold, pain threshold for heat, LOC, Empathy, Trait Anxiety were the independent variables. None of the independent variables explained the change in Pain Ratings for women. PQ – IQ was the only independent variable that was significant for men (Adj $R^2=.201$; $F_{(1,18)}=4.52$, $p<.05$; $\beta=.45$) (Table 6).

Table 6. Stepwise Regression for Men

Step	Variable	$R^2_{(adjusted)}$	F	R^2 change	β	t
1	PQ-Interface Quality	0.201	4.517*	----	0.45	2.13*

*$p<.05$

Discussion

We examined the efficacy of VR pain analgesia, as well as the impact of presence and personality variables (Locus of Control, Trait Anxiety, and Empathy). Women had higher pain ratings during VR (Condition B), as well as higher ratings on Trait Anxiety and on Empathy.

VR and Pain

In our study, VR exposure significantly reduced pain for men (24% pain reduction), but not for women (2% pain reduction). Previous studies either neglected to include women, or neglected to report on gender differences in pain analgesia. Only two studies included women. Hoffman et al. (2003) (14 women and 8 men), found that women benefited more from VR (59% pain reduction) than men (41% pain reduction). Demeter (2011) also found that women benefited more. Sharar et al. (2007) found no difference between men and women. Perhaps the answer lies in the VRE. We used a game ("SnowWorld") in which participants throw snowballs at penguins and other creatures. This is similar to many aggressive computer games that seem to interest men more than women. Perhaps, men found the VRE more interesting. If our assumption is correct, this VRE served as a better attention diversion for them than for women (Pfister, 2011).

In addition, in our study women had higher Empathy ratings than men, and for women Empathy correlated positively with Presence (Spatial Presence) but not for men. Spatial Presence does not relate to the environment per se, rather to the participant's activity in it. We may assume that women high on Empathy object to behaving in the VRE in a manner in conflict with Empathy (throwing snowballs at penguins). Previous studies that found women benefited more than men participated in a VRE that did not entail throwing snowballs (Hoffman et al., 2003a). Thus it appears that further research should attempt to tailor the VRE for the client, for gender - active and intensive for men, interactive and emotionally involving for women, or for specific personality traits, to determine if our supposition is correct.

Presence and Pain

Contrary to predictions, we found a positive correlation between Pain Reduction and Natural for Men – the more presence they experienced, the higher their Pain ratings. Thus, it appears that a VRE that is a preferable pain analgesic for men is an imaginary one that is not similar to the natural environment.

Presence and Personality Variables

We predicted positive correlations between Internal LOC and Presence. However, we found a positive correlation between External LOC and both General and NAT Presence ratings. Previous studies are inconsistent regarding LOC and Presence. Murray et al (2007) found a positive correlation between External LOC and Presence. Perhaps they anticipated individuals who feel they have little control over their lives; allow themselves to be "swept" away in the VRE. In contrast, Witmer and Singer (1998) claim that an Internal LOC is necessary to experience a strong sense of Presence. This finding was also supported in our previous research (Wallach, et al., 2010). Contrary to predictions, we found a positive correlation between Trait Anxiety and Spatial Presence for the total sample and a positive correlation between Trait Anxiety and Involvement

for women. Following Rinck et al. (2003) we expected Trait Anxiety would influence participants' concentration on the Pain Apparatus, resulting in a reduction of Presence. Perhaps concentration on the Pain Apparatus is related to higher levels of Trait Anxiety. Price and Anderson (2007) found the predicted correlation between Trait Anxiety, State Anxiety and Presence. However, their participants were phobic individuals, and thus had high levels of Trait Anxiety. Huber (2011) found the expected correlation between Trait Anxiety and Presence, but only for non-phobic individuals who experienced high levels of State Anxiety. It appears that in order to find a correlation between Trait Anxiety and Presence we should employ participants who either have high levels of Trait Anxiety, or high levels of State Anxiety. In the present study we did not examine State Anxiety.

As predicted, we found a positive correlation between Empathy and General Presence, between Empathy and General Presence for men and between Empathy and Spatial Presence for women.
Predicting Pain Analgesia

We predicted that Presence would mediate pain analgesia using VRE. We found that Interface Quality (IQ) significantly predicted pain analgesia using VRE only for men. This emphasizes the importance of Presence using VRE. IQ deals with the technical interface which may be distracting. Previous research found that the degree of update of the technical aspects was crucial in the effectiveness of VR (Barfield, Baird & Bjorneseth, 1998; Dahlquist, Herbert, Weiss, & Jimeno, 2009 ;Demter, 2011; Hoffman et al., 2006). Since males generally are more attracted to computer games, it is not surprising that technical aspects are more important for them than for females.

Limitations, Conclusion and Suggestions for future studies

We found significant pain analgesia under VRE for men, but not for women. Since most of the previous research neglected to examine gender effects on VRE pain analgesia, this finding is an important addition to the field, especially as the results of the study produced different patterns of reactions to pain analgesia, and suggest the importance of matching different methods for both sexes. Perhaps we need to use different VRE's for each group – active and intensive for Men, and emotionally engaging for Women. Researchers should continue to examine this issue in order to determine the ideal cognitive analgesic method best suited for women.

Presence correlated with pain analgesia for men (NAT) and was an important mediator of pain analgesia for men (IQ). External LOC, Trait Anxiety and Empathy all correlated positively with Presence. However, findings relevant to External LOC, and Trait Anxiety were contrary to predictions. In contrast to our predictions, External LOC positively correlated with pain analgesia under VRE. Perhaps individuals who have limited control over their life find it easier to immerse in a VRE. Likewise, we found a positive correlation between Trait Anxiety and Presence. However, Trait Anxiety was low among our sample. Perhaps it should be high, or it may be necessary to increase State Anxiety in order to interact with Presence. As predicted, Trait Anxiety correlated negatively with pain analgesia.

We must qualify our findings in that our participants were healthy University students – a homogeneous group in terms of age and education, who volunteered to participate in this study for a small payment (50 NIS).

Suggestions for future studies, and use of VRE for Pain analgesia

It is important to tailor the VRE for women, so that they will also benefit from VR pain analgesia. Therefore, future studies should try to build "non-violent" and "emotionally engaging" environments for women. This can be done by using various VRE's, and determining subjects' individual reactions, in addition to measuring presence and pain reduction. Our finding that external LOC correlated with reduced pain needs to be replicated. If it is, then it is important to ta-

ke that into consideration by either preselecting people high on external LOC for VR pain analgesia, or helping structure the environment so that it is more externally controlled. Trait Anxiety correlated negatively with pain reduction. This again needs to be replicated, and if it is, it may indicate that those high on Trait Anxiety do not benefit from VR pain analgesia. Alternatively, perhaps there are mediating factors (for example state anxiety) that need to be explored. As the present study included the highest number of subjects (40) to date, it is important to expand this research by using a larger subject group.

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