Investigating the role of individual differences in the hypoalgesic response to a virtual reality game: An exploratory analysis

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Background

Virtual reality (VR) has been shown to be a powerful method of redirecting attention away from pain and is increasingly used in clinical settings as a therapeutic tool for pain treatment.[1] Yet, little is known about the underlying factors that modulate the size of the hypoalgesic response to a VR game, such as the cognitive load of the game, the level of interactivity, the role of gender, and inter-individual differences in pain-related cognitions, emotion regulation (ER) difficulties, gaming skills, and executive functions (EFs).

Main hypotheses:

(1) An interactive VR game with a higher relative to a lower cognitive load leads to a larger hypoalgesic effect (i.e., higher pain thresholds).
(2) Female participants as compared to male participants show a larger hypoalgesic effect in VR, as shown in a previous study.[2]
(3) Better EFs as well as fewer difficulties with ER correlate with a larger hypoalgesic effect. [3]

Methods

Participants: 90 healthy young adults ($M \pm SD$ = 23.46 ± 3.28 years old; 45 identified as female, 45 as male) remained after the exclusion of 11 participants due to motion sickness or technical problems.

Measures

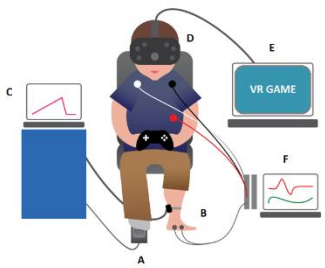
Questionnaires:

- Depression, anxiety, stress (DASS-21) [4]
- Pain-related cognitions: fear of pain (FPQ-III) [5], pain catastrophizing (PCS) [6], pain vigilance and awareness (PVAQ) [7]
- Difficulties with emotion regulation (DERS-SF) [8]
- Gaming skills and experience (GaPS) [9]

Executive functions:

- Corsi block tapping task: working memory
- Flanker task: inference control
- Go/NoGo task: prepotent response inhibition

VR Distraction paradigm



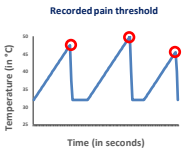
Participants were instructed to press a foot switch **(A)** as soon as the temperature of the thermal stimulator that was attached to the calf of their non-dominant leg **(B)**, and controlled by Medoc PATHWAY software **(C)**, became painful. Pain thresholds were assessed while participants were immersed in the VR world *Subnautica* (Unknown Worlds Entertainment, Inc.) **(D, E)**. During immersion in VR, we recorded the participant's electrocardiogram and electrodermal activity **(F)**.

VR conditions

In the LLC, participants had to follow a marked underwater route in the VR game *Subnautica*. In the HLC, participants followed the same route but, in addition, they memorized a sequence of eight single digits that appeared at fixed intervals along the route. The order of the LLC and HLC was alternated between participants.

Pain thresholds measurement

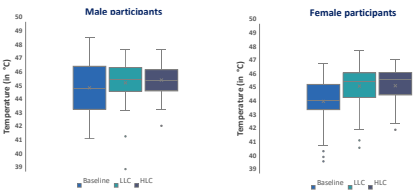
Participants completed 5 pain threshold measurements in the baseline condition, and 15 each in the LLC and HLC. In each trial, the temperature increased from 32°C with a slope of 0.5°C/s to a maximum of 50°C.



After the participant pressed a foot switch, the temperature was recorded as the pain threshold, and returned to 32°C with a slope of 10°C/s. Inter-trial interval time varied between 45 and 50 s.

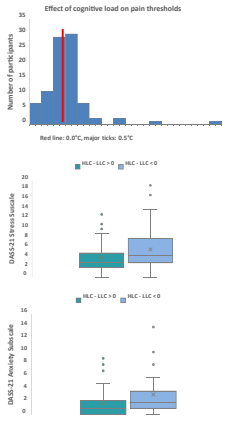
Results

Pain thresholds



An rmANOVA with the within-subject factor *condition* (baseline, LLC, HLC) and the between-subject factor *gender* revealed a significant main effect for *condition*, $F(2, 176) = 18.59$, $p < .001$, $\eta_p^2 = .174$, and a marginally significant interaction between *condition* and *gender*, $F(2, 176) = 3.29$, $p = .054$, $\eta_p^2 = .036$, but no significant main effect for *gender*, $F(1,88) = 2.37$, $p = .128$, $\eta_p^2 = .026$. Post hoc tests showed that pain thresholds at baseline were sig. different from pain thresholds in the LLC and HCL ($p < .001$), but not between the LLC and HLC ($p = .816$).

High load vs low load

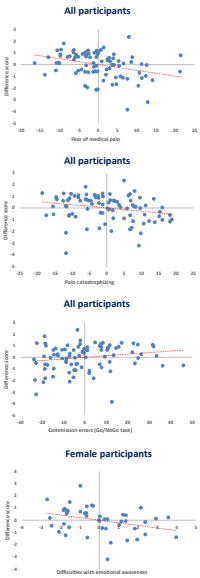


Surprisingly, $n = 44$ participants showed a negative effect of cognitive load, i.e., a higher pain threshold in the LCC than in the HLC (HLC-LLC < 0). Partial Spearman correlations with the order (LLC or HLC first) as covariate revealed that participants who showed a smaller or negative effect of cognitive load, self-reported more **anxiety and stress symptoms**, $r_s = -.246$ and $r_s = -.217$, respectively.

Boxplots (to the left) show a significant difference in self-reported stress and anxiety symptoms on the DASS-21 for participants with a negative and positive effect of cognitive load on pain thresholds.

Interactive conditions vs baseline

To assess the influence of interactivity, we computed the difference in pain thresholds between the average of the two interactive VR conditions and the baseline. **Difference score**: (LLC+HLC)/2 – baseline.



Two-tailed partial Spearman correlations (with the baseline as covariate) showed that the difference score was sig. neg. correlated with **fear of medical pain** ($r_s = -.315$) and **pain catastrophizing** ($r_s = -.222$). We also observed a positive correlation between the difference score and the percentage of **commission errors** in the Go/NoGO task ($r_s = .211$).

Furthermore, a lower score on the **awareness** subscale of the DERS-SF (i.e., more emotional awareness) was associated with a higher difference score only for female participants ($r_s = -.316$), but not for male participants ($r_s = .030$).

Discussion

Our findings suggest that participants were less sensitive to heat pain in an interactive VR environment as compared to a static passive condition (baseline). Moreover, less anxious and stressed individuals tended to benefit more from an additional cognitive load in VR.

In line with a previous study [2], female participants had a (marginally) lower average pain threshold at baseline than male participants, but did not differ in the interactive VR conditions, suggesting that they may benefit to a larger extent from pain distraction via VR.

Individuals with less fear of medical pain and less pain catastrophizing tended to have a larger difference score, presumably because they had less difficulties to direct (and maintain) their attention to the VR task.[10] Surprisingly, we also found that worse prepotent response inhibition abilities correlated with the difference score. A possible explanation would be that participants with worse inhibition abilities were more easily distracted from the pain threshold protocol by the VR environment.

We also found that higher emotional awareness was associated with a larger difference score in female participants, possibly because they were more accurate in evaluating their pain.[11]

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