INTRODUCTION

Virtual reality exposure therapy (VRET), which uses computer-generated images to immerse patients in a phobic situation, has been widely accepted as an effective alternative to one of the most efficient techniques to treat anxiety disorders in clinical psychology: in vivo exposure therapy or real-life exposure therapy (iVET) (Anderson et al., 2013; Botella et al., 2016; Bouchard et al., 2017, Carl et al., 2019; Freitas et al., 2021; García-Palacios et al., 2007; Raghav et al., 2016). iVET, by its nature, results in a direct confrontation with patients' fear stimuli in real-life, which can have greater financial and practical implications (e.g., having to take a plane in case of fear of flying or gathering a lot of people for social phobia related to for example public speaking). VRET is a more cost-effective alternative and has the opportunity for creating more controlled and complex interactions with different scenarios and in a safer environment (Boeldt et al., 2019; Bouchard et al., 2017). Moreover, some phobic patients even prefer VRET and clinicians have also reported positive attitudes towards adoption of VRET (Boeldt et al., 2019; García-Palacios et al., 2007, Ma et al., 2021; Rimer et al., 2021, Yoones et al., 2017). VRET can thus lower the threshold by simulating the real world and serve as an intermediate step in a psychologist's workspace before implementing iVET.

Crucially, a key element that must be present in all exposure exercises in order to have an effective psychotherapy, is the repeated confrontation with patients' fear-eliciting stimuli. Although there are many published studies assessing the effectiveness of VRET on both long- and short-term (see meta-analysis papers from Fodor et al., 2018; Opris et al., 2012, Carl et al., 2019), there are only a few about the impact of design elements in the virtual environment on anxiety psychotherapy. These design choices (such as different kinds of anxiety stimuli, or different levels of a virtual scenario) are, however, of utmost relevance for developing effective, evidence based VRET environments, preferably in collaboration with software developers, therapists, and patients.

User experience tests should be an essential part when developing a new VRET tool or when transferring a specific effective VRET treatment to another anxiety domain, providing specific design guidelines (Mozgai et al., 2020). For example, Igras-Cybulska et al. (2020) gathered feedback on different existing VR applications for fear of public speaking and found out that the 'responsiveness of the crowd' is an important design factor. Another interesting example is the inclusion of multisensory cues (visual + auditory + tactile + olfactory), as this has a great impact on the feeling of presence and immersion, which consequently has an impact on the effectiveness of fear elicitation, as reported by end-users (Peperkorn & Mühlberger, 2013; Marquardt et al., 2018; Song et al., 2021). Also, when designing VRET, the possibility of combining the treatment with other complementary elements of effective methods such as serious games (with different levels and challenges) could be considered, enabling the interaction with anxiety cues and the feeling of presence (Levy et al., 2016; Rizhan et al., 2021), as tested by Yoones et al. (2017) through the comparison of an active vs passive virtual scenario in eliciting social anxiety. However, when focusing on the impact of implementing different types of perceptual cues and configurations in VRET, this is usually not assessed. The present study will focus on design elements such as different kinds of anxiety cues and their exposure duration, which likely impact the fear elicitation in VRET, with people that have claustrophobic and panic tendencies.

VRET Design and Perceptual Fear Elicitation

Virtual reality exposure therapy relies on the assumption that fear is elicited, which happens through two pathways: a perceptual pathway and a conceptual pathway. In the perceptual pathway, fear is elicited by rather sensory-related fear-evoking cues (i.e., visual, auditory, touch, smell sensations), while in the conceptual pathway, fear is elicited by fear-related semantic information (Shiban et al., 2016). VRET mainly relies on perceptual cues to elicit fear, as it immerses the patient in a computer-generated environment or a 360-degree filmed video recording. However, it also offers the opportunity to use the conceptual pathway, by informing the patient about a feared object or situation outside the VR environment, even though less effective (Diemer et al., 2015). Current VRET environments offer the opportunity for psychotherapists to mainly manipulate the perceptual cues, creating the possibility to choose different scenarios or configurations, or even configure the environment itself before or during an exercise (Martijn et al., 2002). Typical configuration options are related to situational elements (e.g., underground, elevator, MRI, corridor, cave, basement, tunnel, maze) (Christofi and Michael-Grigoriou, 2016; Malbos et al., 2008; Rahani, Vard & Najafi, 2018), spatial elements (e.g., the size or openness of a room) (Bruce & Regenbrecht, 2009; Christofi & Michael-Grigoriou, 2016), functional elements (e.g., blocked elevator, turbulence in a plane, darkness of a room, locked room) (Botella et al., 1998; Brinkman et al., 2010, Bruce & Regenbrecht, 2009), temporal elements (e.g., weather, time of day) (Brinkman et al., 2010) or (less integrated) social elements (e.g., crowd, abandoned place) (Moore et al., 2002; Pelissolo et al., 2012; Vincelli et al., 2003).

Anxiety Cues for Claustrophobia and Panic Disorder

Although claustrophobia and panic disorder cause similar reported bodily sensations (Botella et al., 2000), the anxiety triggers are different. Claustrophobia is defined as the fear of enclosed spaces, suffocating, and restriction (Rachman and Taylor, 1993; Radomsky et al., 2006). Therefore, VRET for claustrophobia focuses on situational (e.g., small rooms) and cognitive (e.g., potential fear of suffocating) cues. Christofi and Michael-Grigoriou (2016), for example, investigated the impact of different types of virtual environments (i.e., open/closed, tidy/messy, and vivid/pale), and found that only openness/closedness had a significant impact on feeling claustrophobic (Christofi and Michael-Grigoriou, 2016). When designing a VRET for panic disorder, it is more difficult to use perceptual cues because it is not always related to a specific feared object or situation. Within a panic disorder the anxiety is more related to interoceptive cues such as bodily sensations (e.g., feeling an increased heart rate, blurred vision, or shortness of breath). Exposure therapy where interoceptive cues are induced to elicit fear, is a well-established treatment for panic disorder and is already applied in current exposure therapies. When implementing bodily sensations as cues in VRET, there are two possibilities: either using a biofeedback loop in which heart rate, respiratory, or sweating activity is used to adapt the VR experience (Donga et al., 2020), or by using artificial sensations (i.e., not related to the participant's body) that nonetheless mimic these bodily sensations. In practice, the latter is easier to implement and requires no wearables of any kind.

Previous research has studied the implementation of interoceptive cues for VRET, in which body sensations were replicated with visual and audio effects, such as fake quick-paced heartbeat (Villa Martin et al., 2007), panting (Villa Martin et al., 2007), blurred vision (Botella et al., 2007; Villa Martin et al., 2007), double vision (Botella et al., 2007; Villa Martin et al., 2007) and tunnel vision (Villa Martin et al., 2007). Other symptoms associated with panic disorder or claustrophobia such as dizziness (Simon et al., 1998), photo/light sensitivity (Bossini et al., 2009), tightness or pain in the chest, confusion and disorientation, or even the feeling of fainting (Rizhan et al., 2021), have not been explored yet. Furthermore, as stated by The American Institute for Cognitive Therapy, heat is another cue that also contributes to experiencing more anxiety in general (Tschinkel, 2018) and more specifically, in case of panic disorder (Leahy, 2009). As heat is known as a physical anxiety cue, making patients feel warm (through for instance warm bean bags or eating spicy food) is a technique already regularly adopted in iVET sessions through heat lamps (Schmidt and Trakowski, 2004). To the best of the researchers' knowledge, heat has not been applied yet in the context of VRET.

Hence, the present study contributes to four different aspects in the VRET research field. First, the effectiveness of new interoceptive cues (that target photo sensitivity and dizziness) in eliciting fear is studied. Second, because most studies focus on the effectiveness of the virtual environment as a whole - combining several anxiety cues - the researchers want to study which of the interoceptive cues specifically are the (most) effective in eliciting fear. Third, they want to look into the interaction by adding a physical cue (i.e., heat) to VRET. Finally, the researchers question how elicited fear by interoceptive cues and the physical cue changes over time (cfr. Shiban et al., 2016).

METHOD

Participants

For this study, people reporting subclinical claustrophobia and/or panic tendencies were recruited (i.e., not clinically diagnosed with any anxiety disorder, not seeking for psychotherapy, nor taking psychotropic medication). Recruitment was done with a call-to-action message that was visible on several screens in the city's library. The message was accompanied by a link and QR code where people could fill in an intake survey. The same survey was spread through several social media pages, including the library's Facebook page. The research design was approved by the Ethical commission of the research institute.

The intake survey assessed general anxiety levels with the Claustrophobia Questionnaire (CLQ) (Rachman and Taylor, 1993) and two subscales of the Panic Appraisal Inventory (PAI) (de Beurs, 2005), after which inclusion criteria were used to make a selection. A total of 24 participants fulfilled the selection criteria and were included in the analysis (9 males, 15 females). The average age was 33.77 years (*SD* = 14.75). Participants had average scores of 1.72 (*SD* = 0.68) for CLQ, 35.81 (*SD* = 17.98) for the anticipated panic subscale of PAI, and 20.63 (*SD* = 15.69) for the perceived consequences subscale of PAI. The majority (N = 22) of participants scored above the inclusion CLQ cut-off (i.e., 0.16 for males and 0.56 for females) (Napp et al., 2017), indicating that they had claustrophobic tendencies. Half (N = 12) of the participants scored above the required minimum of 37 on the anticipated panic subscale of the PAI, while three participants scored above the required minimum of 47 on the perceived consequences subscale of the PAI (Schulte-van Maaren et al., 2013). Together, this shows that all participants were eligible for the study.

Study Design

A within-subjects design was implemented, exposing every participant to all conditions (i.e., one baseline and five experimental conditions). The baseline condition consisted of an exposure to a (non-fear eliciting) neutral VR environment, without any anxiety cues (NEU-NW). The independent variables in the experimental conditions were the implementation of one physical (i.e., heat through an infrared lamp) and five interoceptive anxiety cues in VRET (i.e., tunnel vision, light flickering, heartbeat audio, blurred vision and dizziness). The experimental conditions consisted of exposure to the neutral environment while (1) being exposed to the physical cue 'warmth' (NEU-W), and exposure to a fear-eliciting VR environment with (2) both interoceptive cues and the physical cue absent (F-NINW), (3) interoceptive cues present but the physical cue absent (F-INW), (4) interoceptive cues absent but the physical cue present (F-NIW), and (5) both interoceptive cues and the physical cue present (F-IW).

Stimulus Materials

A non-publicly available VRET system was developed for the R&D project PATRONUS. For the virtual rendering, an Oculus Rift and two tracking sensors (but no manual controllers) were used. Two virtual environments were created: a neutral space and a space with a fear-eliciting scenario (figure 1a). Participants always entered the neutral room first before being exposed to a fear-eliciting scenario.

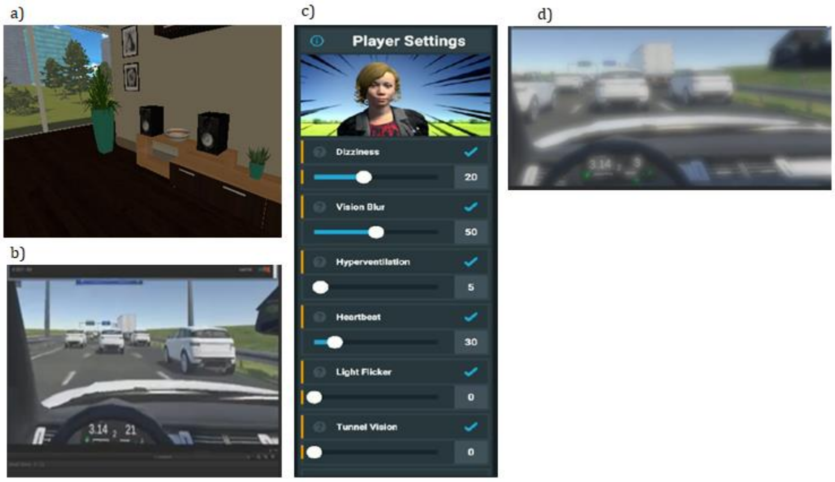

Figure 1. a) Neutral room of the virtual environment, used in the baseline condition. b) Fear-eliciting scenario of a traffic jam, used in experimental conditions. c) Configuration of interoceptive cues in the therapist dashboard d) Vision subject with blurred vision anxiety cue.

In the fear-eliciting scenario, participants always sat at the steering wheel of a car with no passengers, positioned in a highway tunnel. At first the car drove fast, but after 25 seconds a traffic jam emerged and from then on the car slowed down and was stuck in traffic (figure 1b). In the design of the virtual environment, the core aspects of claustrophobia were taken into account: participants slowly drive (and stand still) inside a tunnel of which they could not see the end, reflecting a closed space (Christofi and Michael-Grigoriou, 2016; Rachman and Taylor, 1993; Radomsky et al., 2006).

The VRET tool allowed for an easy configuration of a predefined set of parameters for every condition. In this tool the parameters could be turned on and off, separately or simultaneously, and intensity could also be adapted (figure 1c). Five interoceptive parameters - representing the core interoceptive feelings of panic disorder - were added in a specific order while being in the traffic jam scenario. Note that these sensory cues did not belong to the participant but were generated by the virtual reality application. These interoceptive parameters were (1) hearing a (fake) heartbeat at 180 beats per minute, (2) seeing light flickering every 3 seconds, (3) having tunnel vision, (4) experiencing unwanted body movement (referred to as dizziness), and (5) experiencing blurred vision (figure 1d). Light flickering and dizziness were new interoceptive elements that the current study wanted to explore.

Another cue that was explored was the physical presence of heat. In conditions where this physical cue was present, the participants felt warmth radiation (1500 Watt) generated by a heat lamp (Eurom Q-time 1500) 0.5 meters to the left from their seat (figure 2). This way, the feeling of becoming hot in a closed car with no fresh air in the tunnel was simulated.

Figure 2. Set-up for physical stimulation with heat lamp.

Procedure

First, participants filled in a questionnaire about fear-provoking bodily sensations. Next, they were placed in the neutral environment in order to guarantee a ‘stress-free’ introduction to virtual reality. In this baseline condition participants didn’t experience fear-eliciting cues (i.e., NEU-NW). This baseline was followed by an experimental condition with the same neutral room, but combined with the physical cue warmth (i.e., NEU-W). Then, four experimental conditions with a fear-eliciting scenario (i.e., F-NINW, F- INW, F-NIW, F-IW) were exposed to the participants in a counterbalanced order to avoid order effects. During the experimental conditions with interoceptive parameters, each parameter was turned on consecutively for 1 minute (never in a combined way). During the experimental conditions where the physical cue was present, the heat lamp was turned on for the entire duration. All conditions lasted 5 minutes each and were non-interactive, as this might have distracted them from experiencing fear. Participants were only required to rate their anxiety level every 30 seconds through self-report. After every condition the participants also completed a questionnaire assessing experienced physical symptoms and peak anxiety levels. In total, the exposure time in the virtual environments was 30 minutes, whereas the total testing time was 50 minutes. After completing all conditions in the experiment, participants received a 10 euro coupon as compensation for participation.

Outcome Measures

At the start, participants completed the Body Sensations Questionnaire (BSQ) (Chambless et al., 1984), which is a 17-item questionnaire that measures the fear of experienced bodily symptoms that are typical for anxiety on a 5-point scale ranging from ‘not anxious for this feeling’ to ‘very anxious for this feeling’. Next, during each condition participants were asked multiple times to rate their anxiety level on a scale from 1 (no anxiety) to 100 (most severe anxiety level ever experienced), using the Subjective Units of Distress Scale or SUDS (Lande, 1982; Wolpe and Lazarus, 1966). The researcher wrote down the score for the participants (i.e., 10 SUD scores for every condition). Additionally, participants were required to complete a questionnaire about the experienced physical symptoms after each test condition. These questions were based on the BSQ, but only involved eight symptoms that could have been activated by the virtual interoceptive cues (i.e., sweating, hot or cold flashes, having blurred vision, being nauseous, raised heart rate, light flickering, tunnel vision, and shortness of breath). Furthermore, participants also rated their peak anxiety level (i.e., highest level of anxiety they had experienced) during exposure was (0-100), and what the chances were of panicking if they had to redo the exercise they had just finished (0-100%).

RESULTS

Preprocessing and Manipulation Check

First, a manipulation check revealed that the fear-eliciting scenario effectively elicited self-reported fear in the sample of subclinical participants. To this extent, a paired samples *t*-test (NEU-NW vs. F-NINW) showed significantly lower absolute SUD scores, reflecting subjectively experienced anxiety level, reported in the neutral environment (M = 9.17, SD = 14.54) com- pared to the fear-eliciting scenario without cues (M = 20.95, SD = 21.81), $t(23) = 3.62$, $p = .001$ (figure 3). Second, significant lower scores were also reported for the experience of bodily sensations after the baseline condition (M = 1.35, SD = .46) compared to the fear-eliciting scenario without cues (M = 1.59, SD = .49), $t(23) = 2.35$, $p = .028$. Similar results showed for reported peak anxiety between the baseline (M = 13.79, SD = 24.71) and the fear-eliciting scenario without cues (M = 24.62, SD = 23.86), $t(23) = 2.29$, $p = .031$. And finally, there was no significant difference in the chance of panicking between the baseline (M = 14.92, SD = 25.84) and the fear-eliciting scenario without cues (M = 19.12, SD = 20.88), $t(23) = 1.24$, $p > .05$ (figure 4).

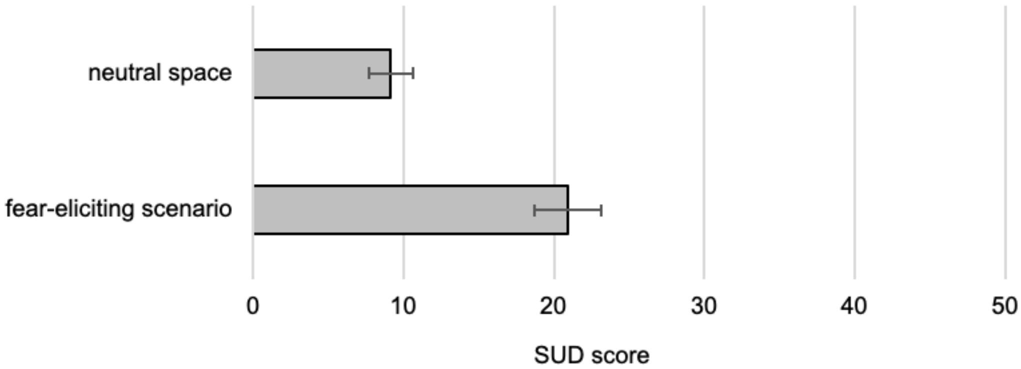

Figure 3. The effect of a fear-eliciting scenario in VR, reflected in the average reported SUD score (0-100)

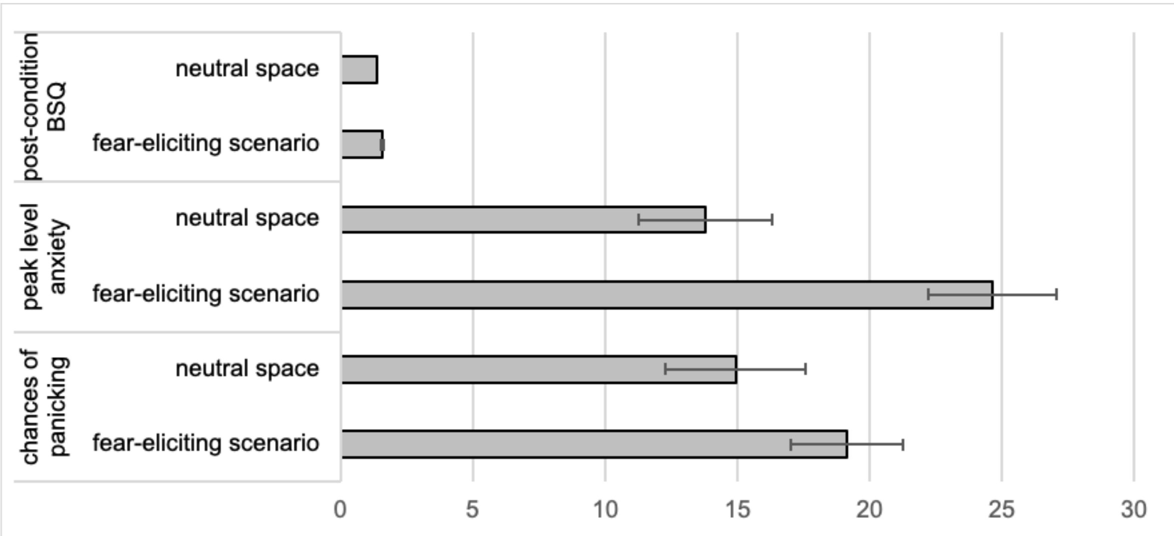

Figure 4. The effect of a fear-eliciting scenario in VR, reflected in average post-condition BSQ scores (1-5), peak level anxiety (1-100), and chances of panicking (0-100%).

Finally, as the reported SUD scores are based on a large scale-range (in this case 1 to 100), three types of biases could occur: contraction bias (i.e., when participating subjects avoid using the extremes of the scales), centering bias (i.e., tendency to use the center of scales), and range equalizing bias (i.e., when participants use the same range of responses independent of the range of stimuli) (Keimel, 2016). Consequently, it was decided to baseline all SUD scores in experimental conditions for each participant by subtracting their average SUD score reported in the baseline condition (i.e., NEU-NW in Table 1), and these values were used in following analyses (Mathôt et al., 2018). In terms of interpretation, a positive value indicates an increase in anxiety compared to baseline, whereas a negative value indicates a decrease in anxiety.

The Effect of Interoceptive and Physical Cues

Self-reported SUD Scores

For the main analysis on the baselined SUD scores, the researchers first investigated the effect of adding anxiety cues to the fear-eliciting scenario (i.e., F-NINW, F-INW, F-NIW, and FIW). Therefore, a repeated-measures ANOVA with factors "interoceptive cues" (absent vs. present) and "physical cue" (absent vs. present) was conducted. The dependent variable was the average across 10 reported SUD scores, subtracted by the average of the baseline condition (NEU-NW). The results showed a highly significant main effect of interoceptive cues, $F(1, 23) = 10.895$, $p = .003$. The main effect of physical cue was not significant but in the expected direction, $F(1, 23) = 2.480$, $p = .129$. The interaction between interoceptive cues and physical stimulation was significant, $F(1, 23) = 5.524$, $p = .028$ (figure 5). Post hoc comparisons with holm adjusted p values indicated that the effect of adding interoceptive cues to the virtual scenario holds in the absence of the physical cue (i.e., increase of 10.05 SUDs, $t = 4.04$, $p = .002$) as well as in the presence of the physical cue (i.e., increase of 10.77 SUDs, $t = 3.39$, $p = .007$), but the physical cue has no real added value. Finally, adding heat can have a desired effect on SUDS (i.e., increase of 6.70 SUDs, $t = 2.50$, $p = .068$) only when interoceptive cues are not present, but this result is only marginally significant (explored in more detail below).

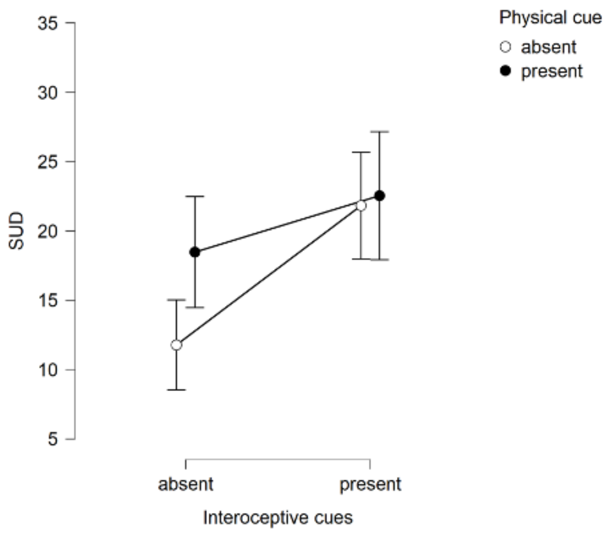

Figure 5. The interaction between "interoceptive cues" (absent vs. present) and a "physical cue" (absent vs. present) in a fear-eliciting virtual scenario. Dependent variable represents absolute change in SUD score from baseline.

Second, the researchers investigated specific effects of the different interoceptive cues, how they changed over time and whether they interacted with physical heat stimulation. Therefore, a repeated-measures ANOVA with factors "type of interoceptive cue" (tunnel vision, light flickering, heartbeat audio, blurred vision, and dizziness), "time range" (first 30 seconds vs. last 30 seconds of the duration of the cue) and "physical cue" (absent vs. present) was conducted. The dependent variable was the SUD score, subtracted by the average of the baseline condition (NEU-NW), reported in the conditions in which interoceptive cues were present (i.e., F-INW and F-IW). Mauchly's test indicated that the assumption of sphericity had been violated for the main effect and interactions of type of interoceptive cue (all ps < .05), therefore, the degrees of freedom were adjusted with Greenhouse-Geisser corrections for these F-values. The main effect of type of interoceptive cue was marginally significant, $F(1.95, 44.93) = 2.867$, $p = .07$. Post hoc comparisons with holm adjusted p values revealed that dizziness seems the most effective and tunnel vision the least effective interoceptive cue, with an average difference of 6.14 in the SUD scores ($t = 3.031$, $p = .032$). The main effects of time range, $F(1, 23) = 2.047$, $p = .166$, and again physical cue, $F(1, 23) = 0.105$, $p = .748$, were not significant. These results suggest that the reported SUD scores do not differ in the first or last 30 seconds of presentation of the interoceptive cue. With respect to the interaction terms, there was a significant interaction between type of interoceptive cue and time range, $F(2.79, 64.09) = 2.966$, $p = .042$ (figure 6). Post hoc comparisons with holm adjusted p values revealed that the SUD score difference between the dizziness and tunnel vision type was found in the last 30 seconds of presentation, with an average difference of 8.17 units ($t = 3.861$, $p = .009$). Thus, after 30 seconds, the effect of the interoceptive cue 'dizziness' is stronger than the effect of the interoceptive cue 'tunnel vision'. There were no significant effects for the other interaction terms (all ps > .05).

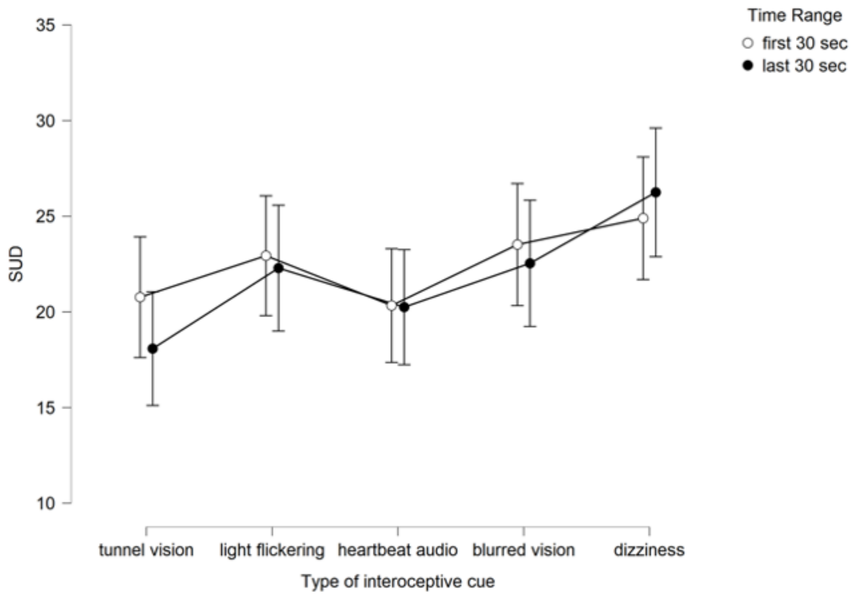

Figure 6. The interaction between "type of interoceptive cue" (tunnel vision, light flickering, heartbeat audio, blurred vision, dizziness) and "time range" (first 30 seconds vs. last 30 seconds of the duration of the cue presence) in a fear-eliciting scenario. Dependent variable represents absolute change in SUD score from baseline.

Third, the researchers investigated the effect of adding physical heat stimulation in the different scenarios and across time. Therefore, a repeated- measures ANOVA with factors "physical cue" (absent vs. present), "virtual scenario" (neutral room vs. fear-eliciting scenario) and "time range" (10 consecutive SUDS) was conducted. For this analysis, the dependent variable was the non- baselined SUD score, reported in the conditions without interoceptive cues (NEU-NW, NEU-W, F-NIW, F-NINW). Mauchly's test indicated that the assumption of sphericity had been violated for the main effect and interactions of time range (all ps < .001), therefore, the degrees of freedom were adjusted with Greenhouse-Geisser corrections for these F-values. The results showed a significant main effect for physical cue, $F(1, 23) = 12.160$, $p = .002$ and virtual scenario, $F(1, 23) = 22.159$, $p < .001$. These results confirm that the physical cue is able to increase SUD scores when there are no interoceptive cues present, and that SUD scores were overall higher in the fear-eliciting scenario (cfr. manipulation check of VR environment). The main effect of time range was not significant, $F(1.25, 27.44) = 0.823$, $p = .397$, indicating that SUD scores did not differ over time. The interaction between physical cue and virtual scenario was also not significant, $F(1, 23) = .784$, $p = .385$. Thus, the heat stimulation increased self-reported SUD scores in the fear- eliciting scenario, but also in the neutral space, on a similar level (figure 7). Next, the interaction between physical cue and time range was marginally significant, $F(2.15, 47.21)$

= 2.992, p = .056. Visually the effect of adding a physical cue is most prominent in the last minutes (figure 8), but post hoc tests did not reveal any significant differences (all ps > .05). Finally, the other interactions were also not significant (all ps > .05).

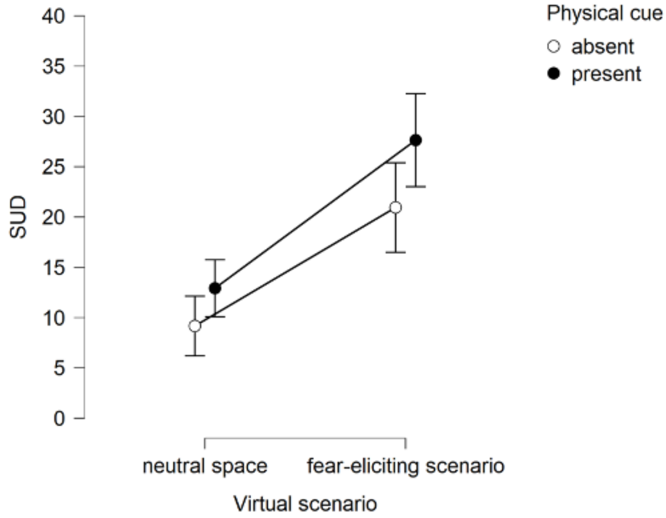

Figure 7. The interaction between "physical cue" (absent vs. present) and "virtual scenario" (neutral space vs. fear-eliciting scenario). Dependent variable represents absolute reported SUD score.

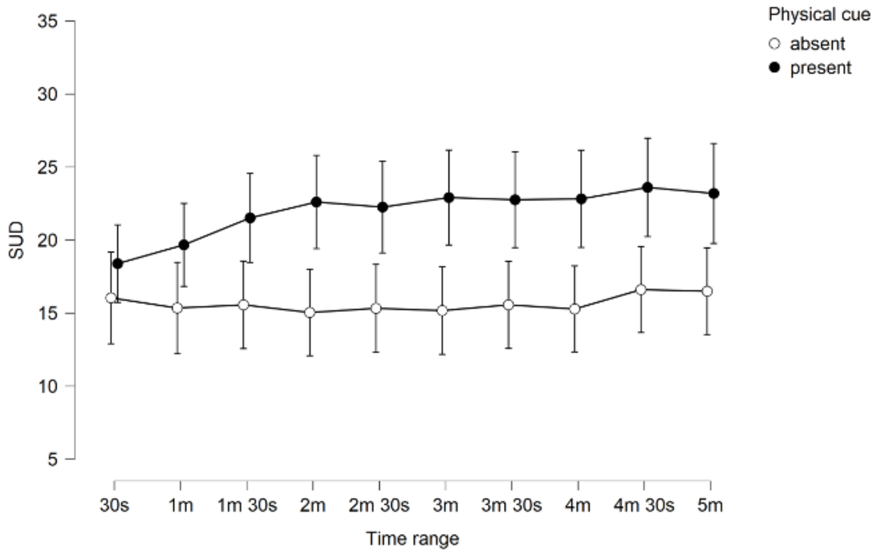

Figure 8. Interaction between "physical cue" (absent vs. present) and "time range" (10 consecutive time points). Dependent variable represents absolute reported SUD score.

Questionnaires After Each Test Condition

In addition to SUD scores, participants were asked some questions after finishing each experimental condition: whether they experienced bodily sensations (i.e., shortened BSQ), their peak anxiety level (1-100) and chances of panicking when redoing the exercise (on a 0-100% spectrum). The main effects of interoceptive cues and physical heat stimulation are investigated. Therefore, three different repeated-measures ANOVA with factors "interoceptive cue" (absent vs. present) and "physical cue" (absent vs. present) were conducted, for the three outcome variables. For these analyses, the post-condition BSQ scores, peak anxiety levels and percentages chance of panicking of the baseline condition (i.e., NEU-NW) are subtracted from the experimental conditions with a fear-eliciting scenario (i.e., F-NINW, F-INW, F-NIW, F-IW) in order to control for inter-individual differences. For experienced bodily sensations, the results showed a highly significant main effect of interoceptive cue, $F(1, 23) = 20.119$, $p < .001$, but a non-significant main effect for physical cue, $F(1, 23) = 2.437$, $p = .132$, and a non-significant interaction, $F(1, 23) = 0.020$, $p = .888$. For peak anxiety level, a significant main effect of interoceptive cue was observed, $F(1, 23) = 12.084$, $p = .002$, a non-significant main effect of physical cue and a marginally significant interaction effect, $F(1, 23) = 2.372$, $p = .137$ and $F(1, 23) = 3.674$, $p = .068$, respectively. Results were similar for chance of panicking, with only a significant main effect of interoceptive cue, $F(1, 23) = 14.333$, $p < .001$, and non-significant effects for physical cue, $F(1, 23) = 0.173$, $p = .681$, and the interaction term, $F(1, 23) = 0.759$, $p = .393$. When looking at the direction of the main effect of interoceptive cue, the conditions with interoceptive cues resulted in more reported bodily symptoms, higher peak anxiety levels and a higher percentage chance of panicking (figure 9). The physical cue presentation did not increase any of these variables reported after test conditions.

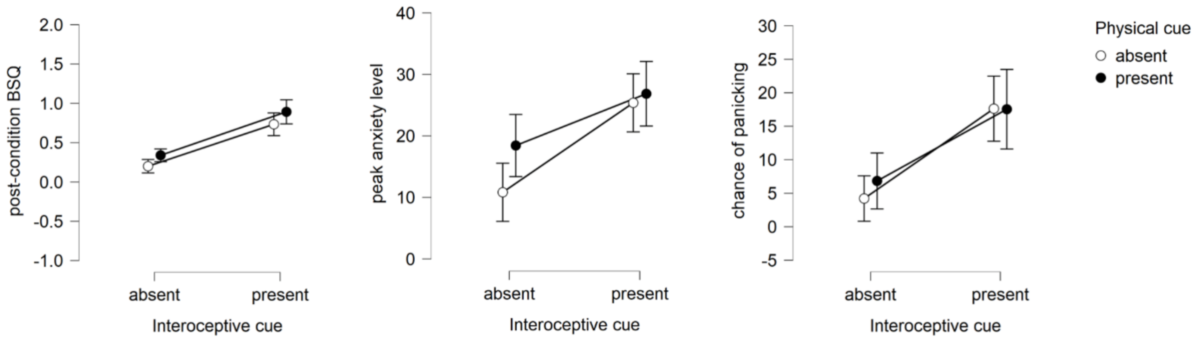

Figure 9. Interaction between "interoceptive cue" (absent vs. present) and "physical cue" (absent vs. present). From left to right, dependent variable represents post-condition reported BSQ score, peak level anxiety and chance of panicking, respectively.

DISCUSSION

The present manuscript investigated whether the implementation of some previously investigated (i.e., tunnel vision, heartbeat audio, blurred vision) and new (i.e., light flickering, dizziness) interoceptive anxiety cues to a VRET environment with a fear-eliciting scenario effectively elicited self- reported anxiety in subclinical people with claustrophobic and panic disorder tendencies. Furthermore, considering the importance of design choices, the researchers studied whether a particular type of these interoceptive cues would have a greater impact on the reported anxiety levels, and if effectiveness differed over time. Finally, the additional effect of another new anxiety cue was explored: physical heat stimulation. The manipulation of the fear-eliciting virtual scenario was successfully reflected in higher reported SUD scores, greater bodily sensations and peak level anxiety scores when compared to the neutral baseline VR environment.

Interoceptive Cues

Adding interoceptive cues effectively increased anxiety levels, both during test conditions (reflected in reported SUD scores) and after test conditions (reflected in post-condition BSQ score, peak anxiety level and chances of them panicking if redoing the exercise). This supports the findings of previous studies that used interoceptive cues like a fake quick-paced heartbeat, blurred vision, and tunnel vision in a VRET context (Botella et al., 2007; Villa Martin et al., 2007). However, these studies focused on multiple sessions of the virtual exposure and therefore could not isolate the effectiveness of an interoceptive cue, nor exclude confounding variables (e.g., psychoeducation, passing of time, relapse prevention, or meditation exercises). This study design established the immediate elicitation of fear reported in SUD scores every 30 seconds, which is highly relevant since fear confrontation is key in having effective exposure therapy.

Type of Interoceptive Cues

After 30 seconds, the effect of the interoceptive cue ‘dizziness’ was stronger than the effect of the interoceptive cue ‘tunnel vision’. As higher anxiety scores were reported for the ‘dizziness’ cue, this could indicate that it could be the best cue to implement in VRET. As far as the researchers know, this interoceptive cue has not yet been applied in other VRET research, suggesting that the further exploration of designing interoceptive cues in VRET is valuable and worth the cost and effort. Introducing (black) spots as a visual interoceptive cue in virtual scenario, for instance, can imitate distorted vision, which is a bodily symptom associated with anxiety (Chambless et al., 1984; Schmidt and Trakowski, 2004). Other symptoms associated with panic disorder or claustrophobia such as tightness or pain in the chest, confusion and disorientation, or even the feeling of fainting could also be explored (Rizhan et al., 2021).

Physical Cues

Considering the high cost of developing a realistic virtual reality environment, the added value of a physical cue outside of the virtual environment for fear elicitation in VRET was also explored. The feeling of bodily warmth and sweating was recreated, mimicking feelings of anguish. The physical warmth stimulation of the heat lamp appeared to be able to increase self-reported SUDs in a similar way in the neutral space and the fear-eliciting scenario, in the case where it was the only anxiety cue that was presented. However, this is a very unlikely situation in a VRET design to only use a physical cue. Results indicated that this physical heat cue could not have a real additional effect in the increase of self-reported anxiety levels during test conditions where interoceptive cues were presented too. Also, for reported bodily sensations, peak level anxiety and chances of panicking no significant effects were found of the physical cue presentation. Other types of physical or tactile cues, such as vibrating controllers imitating tingling hands or shaking, could be an interesting approach for future research (Schmidt and Trakowski, 2004).

Limitations and Recommendations for Further Research

First, the interoceptive anxiety cues were only presented for 1 minute each because this was necessary to keep the participant burden low and be able to compare different interoceptive cues in effectivity. Also, no feedback questions were asked to inquire how realistic and similar these virtual cues were to a real-life personal experience. Future research should investigate whether exposing phobic people to interoceptive cues for a longer duration (more than one minute) or making the cues even more realistic (and probably unpleasant), in co-creation with the patients and clinicians, could result in a greater significant difference between the different types of cues. In addition, in the current study interoceptive cues were never combined at the same time. As the simultaneous use of cues during a psychotherapy session is more prone to occur than using them separately, and an extensive library of different kinds of scenarios and anxiety cues will be provided, testing the impact of different meaningful combinations of cues on the anxiety level would also be an interesting direction for future research in this domain. These meaningful combinations of anxiety cues could also be suggested for personalised VRET sessions as patients are for example triggered or more intensely immersed by different kinds of (combinations of) cues in the virtual scenario, aligning the design of VRET with individual differences (as suggested by Song et al., 2021). A possible reason why the physical cue did not elicit more self-reported anxiety might be that the experienced warmth was found to be too unrealistic in the virtual setting because it only warmed one side of the participant’s face. With hindsight, adding multiple heat lamps would have been a better approach (Hülsmann et al., 2014).

In this study a subclinical sample was used, meaning that none of the participants was diagnosed with an actual anxiety disorder. Actually, this sample was a worthy alternative to real patients, which was confirmed by the manipulation checks for the virtual scenario and the anxiety levels reported. The researchers advise future research using prototypes as study material to do the same, especially when the prototypes have not been certified yet. However, this was still a subclinical sample and it is not unlikely that results might be different with a group of clinically diagnosed anxiety disorder participants. Also, the sample size could have been extended in order to get stronger conclusions. Another limitation is the use of self-report data as an indicator for anxiety (with commonly used scales by therapists).

Additional objective indicators (e.g., physiological measures) could have provided an added value for a somatic parameter for anxiety (cfr. Song et al., 2021).

With respect to general advice related to VRET sessions, the researchers would advise therapists to always let patients get used to the VR environment in a neutral setting before exposing them to a fear-eliciting environment. This ‘onboarding process’ is necessary, since VR is still not a mainstream medium and a lot of people do not have any prior experience. An additional advantage of this onboarding is the baseline measure (SUD score) in order to take the individual differences into account and measure potential anticipation anxiety.

Conclusion

To conclude, this study confirms that introducing interoceptive cues in VRET can be an interesting way to approach exposure therapy as they effectively induce fear in people with phobic and claustrophobic tendencies. Also, new interoceptive cues that target photo sensitivity and dizziness are proposed as interesting parameters for eliciting fear. Regarding the effectiveness of specific cue types alone, higher anxiety scores were reported for this new ‘dizziness’ cue, indicating that it could be the best cue to implement in VRET. Adding a physical heat cue to the design could not increase self-reported anxiety levels effectively. Further research is needed to identify which other types of interoceptive and physical cues work (most) effectively and compare other design elements of VRET.

Declaration of Competing Interest

The researchers wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Acknowledgements

Many thanks to each study participant. This study was funded by the imec.icon project PATRONUS (with support from VLAIO, the Flanders Innovation and Entrepreneurship agency).

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