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COLLABORATIVE VIRTUAL REALITY EXPOSURE FOR ACROPHOBIA: A MULTIPLE-BASELINE SINGLE-CASE STUDY WITH PSYCHOLOGICAL AND PHYSIOLOGICAL MEASURES

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Abstract

This study investigated the use of a collaborative immersive virtual reality environment (CIVE) for therapist-guided exposure in the treatment of acrophobia, integrating both psychological and physiological measures. Using a Single Case Experimental Design (SCED) with a multiple-baseline structure, three participants with a fear of heights completed repeated baseline sessions followed by therapist-guided virtual reality exposure therapy (VRET) sessions conducted in a shared virtual space. Our CIVE application enabled real-time interaction between therapist and client, dynamic adjustment of exposure intensity, and continuous heart rate (HR) monitoring via Bluetooth-connected sensors. Participants progressed through a height-simulation protocol inside a virtual elevator while completing validated measures of fear, anxiety, distress, and simulator sickness. Semi-structured interviews complemented the quantitative data to capture subjective experiences of the cognitive-behavioral therapy (CBT) process. The study aimed to examine how collaborative VR-based exposure, informed by real-time physiological feedback, could support individualized therapeutic work with acrophobia and provide deeper insight into psychological and physiological processes during guided VRET.

Keywords: *Collaborative immersive virtual environment, VR, exposure therapy, CBT, acrophobia.*

1. Introduction

Immersive virtual reality (VR) technology is increasingly utilized beyond entertainment, including for educational and clinical purposes. By presenting vivid, controllable environments, VR can elicit realistic emotional and behavioral responses (Checa & Bustillo, 2019). In psychotherapy, this control allows practitioners to expose clients to feared stimuli in a safe and repeatable fashion (Diemer et al., 2015).

Exposure to heights is a core intervention for acrophobia. During exposure, individuals confront feared situations to disconfirm catastrophic expectations and facilitate fear reduction (Craske et al., 2014). Evidence synthesized across trials shows that VRET produces outcomes comparable to those of traditional exposure for various specific phobias (Carl et al., 2019).

Many contemporary VRET systems employ preprogrammed scripts or position the therapist outside the virtual scenario. While automation can provide consistency, it may lack the warmth, flexibility and alliance that a live therapist offers (Buchholz & Abramowitz, 2020). Research on guided VRET suggests that therapist involvement can smooth physiological recovery even when self-reported anxiety is unchanged (Varšová et al., 2024).

CIVEs are networked VR platforms that allow multiple users to occupy the same simulated space, observe each other as avatars, and interact in real time. Their use has grown in education and training, yet applications to psychotherapy are limited (Zarei et al., 2024). The study summarized here explored whether embedding the therapist within a CIVE would enhance exposure outcomes for people with severe fear of heights. We anticipate that repeated sessions in a collaborative immersive VR setting with a therapist will gradually reduce participants' self-reported anxiety and lead to more adaptive physiological responses, such as lower peak HR and faster post-exposure recovery compared with baseline. We also expect participants to view the treatment as credible and to have positive expectations, with these attitudes remaining steady or improving over time. Finally, we predict that any gains in subjective anxiety and physiological regulation will persist at follow-up rather than fading immediately after the sessions.

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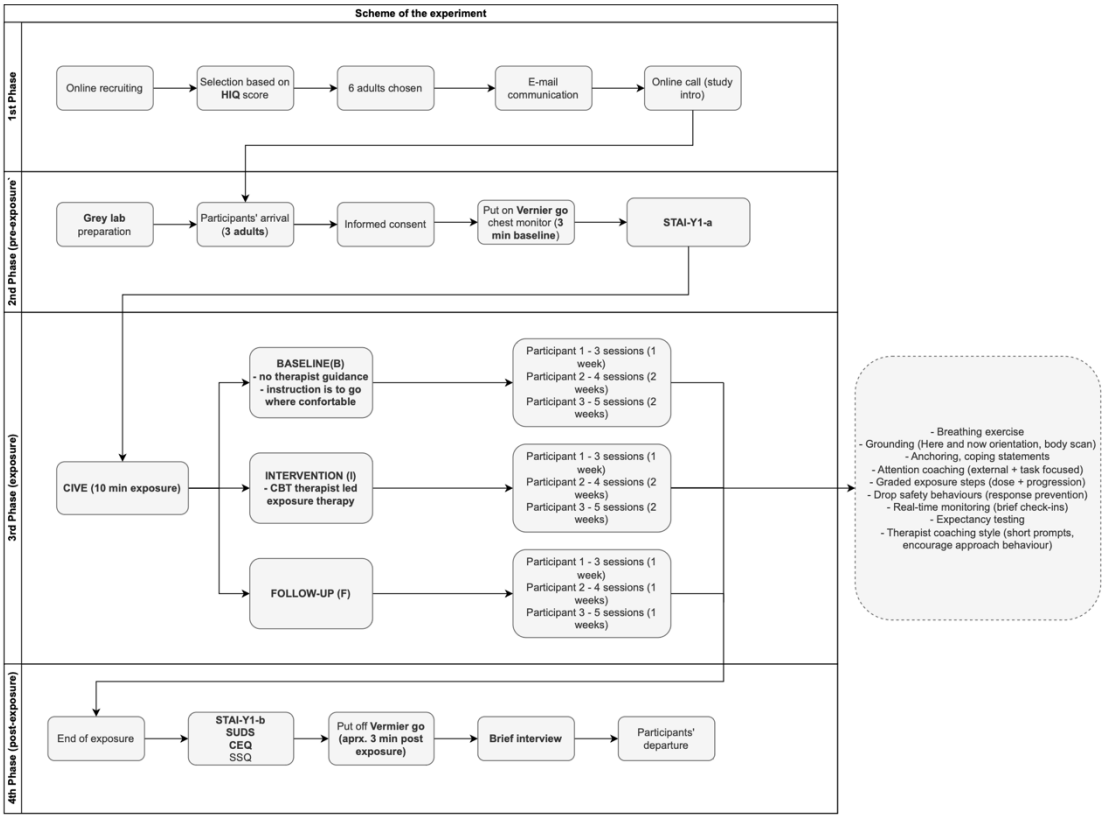
2. Methods

2.1. Participants and design

Three adults (two women, one man) with significant acrophobia responded to recruitment adverts and were screened to exclude other psychological disorders. A multiple-baseline SCED was used to control for time effects and to allow individual trajectories to be compared across staggered baselines (Kratochwill et al., 2010).

Each participant progressed through baseline (B), intervention (I) and follow-up (F) phases. Baseline consisted of three to five sessions in which participants explored a virtual skyscraper by themselves. During the intervention, a psychotherapist connected to the same environment using an avatar, delivering cognitive restructuring, coping instructions and encouragement while the participant ascended floors. The follow-up phase, scheduled after a delay, mirrored the baseline sessions but without the psychotherapist present. Whole course of the experiment is illustrated in Figure 1.

Figure 1. Overview of the experimental procedure.



2.2. Ethics

Ethical approval was obtained from Masaryk University's Faculty of Arts ethics panel, and the study complied with the Declaration of Helsinki. Participation was voluntary; each participant gave written consent and could withdraw at any point before data collection ended without penalty or loss of compensation, after which personal identifiers were destroyed. The study's aims, procedures and data handling were explained in full before enrollment. Although the VR sessions provoked anxiety, they produced no lasting changes in HR or other physiological measures.

2.3. Measures

The primary behavioral outcome was the subjective evaluation of distress, state anxiety, and highest floor participants ascended in each session. State anxiety was assessed using the State form of the State–Trait Anxiety Inventory (Spielberger, 1989) before and after each session. Distress was rated repeatedly using a 0–10 Subjective Units of Distress (SUDS) scale. Heart rate was recorded continuously via a chest-strap sensor. Participants also completed the credibility–expectancy questionnaire (CEQ; Devilly & Borkovec, 2000) and Simulator Sickness Questionnaire (SSQ; Kennedy et al., 1993) after each session.

2.4. Data analysis

Participants were de-identified (P1–P3) and sessions were coded into baseline (B), intervention (I) and follow-up (F) phases using staggered baselines (3, 4 or 5 sessions) and matched intervention lengths to support replication logic. Primary outcomes included maximum floor reached, state anxiety measured before and after each exposure (STAI-Y1-a and STAI-Y1-b, with ΔSTAI = STAI-Y1-b − STAI-Y1-a) and SUDS ratings recorded every five floors; SUDS were summarized per session as the mean across reached floors, and secondary outcomes (SSQ, CEQ) were analyzed at the session level. For each participant and phase we computed means, standard deviations and sample sizes for floor reached, STAI-Y1-a, STAI-Y1-b, ΔSTAI and mean SUDS, then visually inspected time-series plots with phase transitions to assess level, trend, variability, immediacy of effect, overlap and cross-participant consistency, summarizing phase stability as the proportion of points within ±15 % of the median. Phase contrasts were quantified using non-overlap effect sizes-NAP and PND-comparing baseline against intervention and follow-up in the direction of improvement. Within each case we fitted segmented regressions to estimate immediate level change at intervention onset and slope change during intervention for floor reached and ΔSTAI, and across cases we ran linear mixed-effects models with random intercepts and fixed effects for intervention and follow-up (baseline reference) for floor reached, mean SUDS, STAI-Y1-a and -b, SSQ and CEQ, aligning with standardized mean-difference frameworks and verifying model-based estimates using established single-case effect-size calculators. Physiological reactivity was assessed via the maximum cross-correlation between the elevator height profile and heart rate within a −10 to +30 s lag, with phase differences tested using the non-parametric Tau-U index to detect decoupling between stimulus and response. All analyses and figures were generated via reproducible Python notebooks, and brief semi-structured interviews before and after sessions captured subjective experiences such as anxiety tolerance, coping strategies, perceptions of therapist co-presence and perceived changes or learning across sessions.

3. Results

Descriptive analysis indicated that participant P1 averaged roughly 10 floors in B, dropped slightly during the I to 9 floors and then improved markedly at F (around 16), whereas P2 and P3 progressed from about 8 to 12 floors and maintained or improved further in F; change scores showed P1's state anxiety rising during the intervention (ΔSTAI≈15) but declining afterwards, while P2 and P3's anxiety decreased during the I and remained low. Patterns in pre- and post-session STAI scores mirrored these trends, with P2 and P3 declining across phases and P1's post-session anxiety increasing during the intervention but falling by F.

Visual inspection revealed stable B for P1 and P2 but instability for P3, immediate increases in performance for P2 and P3 and a decline then recovery for P1 during I, and high stability in F; SUDS for B and anxiety were unstable, with P2 and P3 showing decreases or stability during I and P1 improving mainly at F. Non-overlap metrics confirmed these differences, with weak floor improvements for P1 (NAP=0.28) versus strong improvements for P2 and P3 (NAP≈0.94–0.96) and anxiety reductions only in P2 and P3; comparing B to F showed complete non-overlap for floors for all and sustained anxiety reductions. Mixed-effects models yielded significant increases in floors (baseline mean 8.67, +2.67 floors during intervention, +6.11 at follow-up), significant reductions in SUDS and state anxiety, marked declines in SSQ and improved CEQ, indicating robust and persistent intervention effects. Segmented regressions showed P1 had an immediate negative level change followed by a positive slope, while P2 and P3 exhibited immediate and sustained gains; physiological analysis found strong HR–stimulus coupling for P1 (rmax=0.82) with no decoupling, low coupling and complete decoupling for P2 (rmax=0.34, Tau-U=–1.00) and moderate coupling with partial decoupling for P3 (rmax=0.65, Tau-U=–0.80). SSQ scores remained low and CEQ ratings high, suggesting good tolerance. Qualitative observations noted P1's transition from escape-driven patterns to deliberate pacing and stable HR, P2's reduction in gastrointestinal discomfort and increased control (with an anomalous bradycardic profile late in treatment), and P3's shift from anticipatory panic and freezing to active engagement supported by grounding, breathing and therapist co-presence, even though physiological processing remained effortful.

4. Discussion

The present study provides early evidence that placing a therapist in the virtual environment can enhance acrophobia treatment. The behavioral gains and anxiety reductions observed during the psychotherapist-assisted sessions are consistent with the idea that real-time feedback, reassurance and modelling of calm behavior promote inhibitory learning and reduce reliance on safety behaviors (Craske et al., 2014).

The observed reductions in HR–height coupling suggest that psychotherapist presence may support down-regulation of autonomic arousal. This finding resonates with research linking presence, fear and physiological responses in VR (Gromer et al., 2019) and with studies showing that supportive guidance reduces heart rate during VR tasks (Felnhofer et al., 2014).

Several limitations temper these conclusions. The small sample limits generalizability, and the multiple-component nature of the intervention (which combined therapist presence, cognitive restructuring and repeated exposure) makes it hard to isolate active elements. A nonconcurrent baseline design cannot rule out placebo effects or spontaneous remission. To better understand the mechanisms at play, future work should compare co-present and externally guided VRET in larger samples, measure therapeutic alliance, and test the approach with different phobias.

Despite these constraints, the findings illustrate the promise of CIVEs in psychotherapy. Advances in networked VR and decreasing hardware costs mean that therapists could share the virtual environment with clients more routinely, potentially strengthening the therapeutic relationship and promoting engagement (Buchholz & Abramowitz, 2020; Zarei et al., 2024). Integration with adaptive biofeedback and other technological innovations, as discussed by Moldoveanu et al. (2023), may further enhance outcomes.

5. Conclusion

Embedding a psychotherapist within a virtual exposure session appears to confer meaningful benefits for adults with acrophobia. In this multiple-baseline SCED study, psychotherapist involvement improved behavioral performance, lowered subjective anxiety and altered physiological responses. These promising results call for more rigorous studies to determine whether shared virtual presence reliably augments virtual reality exposure therapy and to explore its applicability to broader clinical populations.

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