Toward Virtual Animal Therapy: Evaluating Stress Reduction in VR-based User Interaction with a Virtual Dog*

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Abstract

Virtual reality (VR) may provide accessible support for short-term stress recovery. This study examined whether different levels of user involvement with a virtual dog influence anxiety following experimentally induced stress. In a between-subjects experiment, 31 participants were assigned to one of three five-minute VR conditions: viewing a natural environment without a dog, observing an NPC interacting with a virtual dog, or directly interacting with the dog. State anxiety was assessed at baseline, after stress induction, and after the VR intervention. An ANCOVA controlling for post-stress anxiety revealed a significant overall effect of condition on post-intervention STAI-S scores, although corrected pairwise comparisons were not significant. Descriptively, the direct user–dog interaction condition showed the largest reduction in anxiety, followed by NPC observation and scenery-only exposure. These findings suggest that the level of user involvement may be associated with short-term anxiety recovery in VR, but larger studies are needed to determine whether specific conditions differ.

Keywords

Virtual Reality, Animal-Assisted Therapy, Human–Animal Interaction, Stress Reduction, Affective Computing

1. Introduction

Short-term stress is increasingly common in modern academic and professional environments. While acute stress responses may temporarily enhance performance, repeated activation of stress-response systems can lead to long-term psychological and physiological consequences [1, 2]. As a result, accessible interventions that support emotional recovery from everyday stressors are an important research objective.

Animal-assisted therapy (AAT) has been widely recognized as an effective non-pharmacological intervention for reducing anxiety and improving emotional well-being. Interactions with animals, particularly dogs, have been shown to improve mood, enhance emotional resilience, and reduce physiological stress indicators such as cortisol levels [3, 4]. Despite these benefits, traditional AAT programs face several practical limitations, including the availability of trained animals, logistical constraints in clinical environments, and accessibility barriers for individuals with allergies or mobility limitations.

Recent advances in virtual reality (VR) offer new opportunities to replicate aspects of human–animal interaction in immersive digital environments. VR technologies have been successfully applied in mental health contexts, including exposure therapy, stress reduction, and mindfulness interventions [5, 6, 7, 8, 9]. Previous studies have explored various forms of virtual animal-assisted interventions, including virtual companion animals, mixed-reality pets, and interactive virtual dogs designed to provide companionship and emotional support. These studies suggest that virtual animals can increase feelings of companionship, enhance perceived social support, encourage self-disclosure, and improve user engagement in immersive environments [10, 11, 12, 13].

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Despite these promising developments, empirical evidence regarding the effectiveness of virtual animal-assisted therapy (VAAT) for short-term stress reduction remains limited. In particular, although previous studies suggest that virtual animals can enhance engagement and emotional experience, few studies have directly examined whether virtual animal interactions facilitate recovery from experimentally induced stress. Furthermore, little is known about how different levels of user involvement are associated with the effectiveness of virtual animal-assisted interventions. Although previous studies have reported positive outcomes of virtual animal-assisted interventions, little is known about how different levels of user engagement contribute to these effects. Specifically, it remains unclear whether stress-reduction benefits arise from exposure to a virtual environment alone, observing animal-related interactions, or actively interacting with a virtual animal.

To address these gaps, this study investigates the following research questions:

- RQ1: Can exposure to a virtual environment, observation of dog-related interactions, and active interaction with a virtual dog each facilitate short-term stress recovery following an experimentally induced stressor?
- RQ2: How are different levels of user involvement—environmental exposure, passive observation, and active user–dog interaction—associated with short-term stress recovery in VR?

To answer these questions, we investigate whether interaction with a virtual dog in VR can reduce short-term stress following an experimentally induced stressor. We conducted a controlled experiment comparing three VR conditions representing different levels of user involvement: exposure to a natural virtual environment, observation of a non-player character interacting with a virtual dog, and direct user interaction with the virtual dog.

This paper makes three contributions:

- We implemented a VR-based animal-assisted interaction system featuring a responsive virtual dog designed for stress-relief scenarios.
- We conducted a controlled experiment (N=31) to systematically compare three levels of user involvement and examine their associations with short-term stress recovery in VR.
- We provide empirical evidence regarding the role of user involvement level in virtual animal-assisted experiences, offering insights for the design of future VR-based stress-reduction interventions.

2. Related Work

2.1. VR-Based Stress Reduction

VR has been widely explored as a platform for psychological interventions due to its ability to create immersive, controllable, and repeatable environments. VR-based exposure therapy has demonstrated effectiveness in treating anxiety disorders and phobias [7, 8, 9]. Beyond clinical treatment, VR has also been increasingly used for relaxation, mindfulness, and stress management in non-clinical populations.

Previous studies have shown that immersive VR experiences can reduce perceived stress, improve mood, and support emotional recovery following stressful situations. Many of these interventions rely on environmental relaxation experiences, such as virtual nature exposure, forests, beaches, gardens, and other restorative environments designed to promote calmness and psychological restoration [14, 15, 16]. These approaches are attractive because they can be delivered on demand, repeated easily, and scaled to diverse populations [17].

However, many existing VR stress-reduction interventions primarily rely on passive observation of calming environments. Comparatively less attention has been paid to interactive or companion-based approaches that may support emotional regulation through engagement, agency, and social presence. This limitation motivates the exploration of virtual animal-assisted interventions as a potentially more interactive form of VR-based stress reduction.

2.2. Animal-Assisted Interventions

AAT involves structured interactions between humans and animals to promote emotional and psychological well-being. Previous studies have shown that interactions with therapy animals can reduce anxiety, improve mood, and enhance social engagement [3, 4]. Several mechanisms have been proposed to explain these effects, including increased oxytocin release, enhanced social bonding, and reductions in physiological stress responses [18]. These findings have motivated researchers to explore whether similar benefits can be achieved through virtual animal-assisted interventions.

Recent studies have explored a variety of virtual animal-assisted systems, including virtual companion animals, augmented-reality pets, mixed-reality pets, and virtual dogs designed to provide companionship and emotional support [11, 12, 19, 13]. These systems have demonstrated promising outcomes, including increased feelings of companionship, enhanced perceived social support, improved engagement, and greater willingness to disclose personal experiences [13, 19].

More recently, researchers have begun to investigate the use of virtual animals for stress reduction and emotional regulation. Studies involving mixed-reality virtual pets and augmented-reality companion dogs have reported reductions in self-reported stress and improvements in emotional well-being [10, 11]. However, existing studies primarily examine the general presence of virtual animals or compare virtual animals with non-animal conditions. Few studies have systematically investigated how different levels of interaction with virtual animals influence stress-reduction outcomes.

2.3. User Involvement in Virtual Animal-Assisted Interventions

In VR research, user interaction has been identified as an important factor influencing user experience and psychological outcomes. Active participation can promote greater engagement, agency, and emotional involvement than passive observation [20, 21, 22]. Previous studies have reported that interactive VR experiences can produce stronger effects on learning, motivation, rehabilitation, and emotional engagement than observational experiences [23, 24].

Despite the recognized importance of interaction in VR applications, its role in virtual animal-assisted interventions remains unclear. In particular, it is not yet well understood whether stress-reduction benefits arise primarily from exposure to a virtual environment, observing animal-related interactions, or actively interacting with a virtual animal. This distinction is important because these three forms of experience involve different levels of engagement, agency, and social involvement.

To address this gap, the present study compares three VR conditions representing increasing levels of engagement: (1) exposure to a natural virtual environment without a dog, (2) observation of an NPC interacting with a virtual dog, and (3) direct interaction with the virtual dog. This design enables us to examine how different levels of interaction may influence short-term stress recovery after an experimentally induced stressor.

3. Method

3.1. Participants

Thirty-one participants (11 females and 20 males) were recruited from the university community and the surrounding area. Participants had a mean age of 27.94 years (SD = 6.01). The final sample included 10 participants in the Scenery Only Group (SOG), 10 in the NPC Interaction Group (NIG), and 11 in the User Interaction Group (UIG).

An a priori power analysis was conducted in G*Power based on the effect size reported by Lim and Dong [19] ($\eta^2 = 0.3852$, $f \approx 0.79$). The analysis indicated that a minimum sample size of 12 participants would be sufficient to detect the expected effect ($\alpha = .05$, power = .95). The final sample of 31 participants exceeded this minimum requirement.

The study was approved by our institution's institutional review board (2024-I-49).

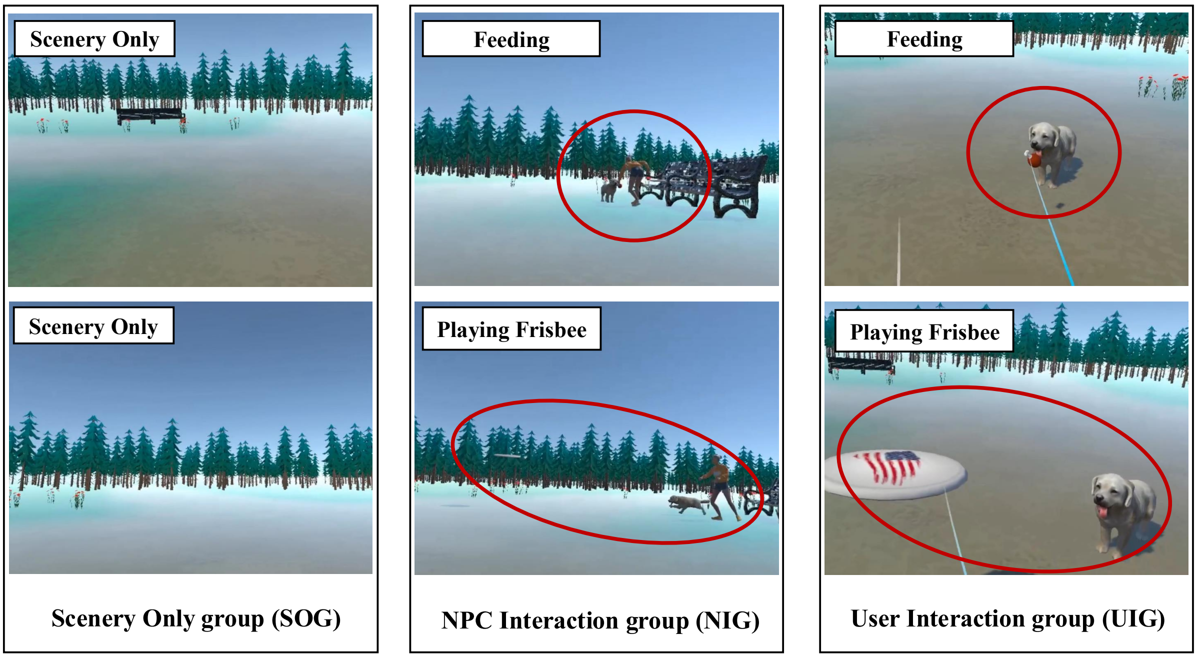

Figure 1: Experimental conditions with increasing levels of engagement: (a) Scenery Only Group (SOG), (b) NPC Interaction Group (NIG), and (c) User Interaction Group (UIG). Red circles were added for illustration to highlight the main interaction-related elements, including the NPC, virtual dog, and frisbee; these annotations were not visible to participants during the experiment.

3.2. Experimental Design

The study employed a between-subjects design with one between-subjects factor, Experimental Condition, comprising three levels: the Scenery Only Group (SOG), the NPC Interaction Group (NIG), and the User Interaction Group (UIG). State anxiety and subjective feeling were assessed at three time points: baseline, immediately after the stress-induction task, and after the VR intervention. The post-stress measures represented participants' emotional states immediately before the intervention and were used as covariates in the analyses of post-intervention outcomes.

Participants were randomly assigned to one of three experimental conditions (Figure 1).

The three conditions were designed to examine the contribution of different forms of user involvement to the therapeutic effects of virtual animal-assisted therapy.

The **Scenery Only Group (SOG)** served as a control condition in which participants were exposed only to the virtual environment. This condition allowed us to account for any stress-reducing effects associated with immersion in a natural virtual setting.

The **NPC Interaction Group (NIG)** introduced a virtual dog and an NPC interacting with the dog. Participants observed the interaction but did not actively engage with either character. This condition was designed to examine whether passive observation of human–animal interaction could influence emotional responses.

The **User Interaction Group (UIG)** provided direct interaction with the virtual dog using VR controllers. Participants engaged in activities such as feeding and playing frisbee with the dog. This condition represented the highest level of engagement and was intended to simulate the interactive component of animal-assisted therapy.

By progressively increasing the level of engagement across the three conditions, from environmental exposure (SOG), to passive observation (NIG), and finally to active interaction (UIG), the experimental design enabled us to examine whether greater involvement with a virtual companion animal is associated with greater reductions in stress and anxiety.

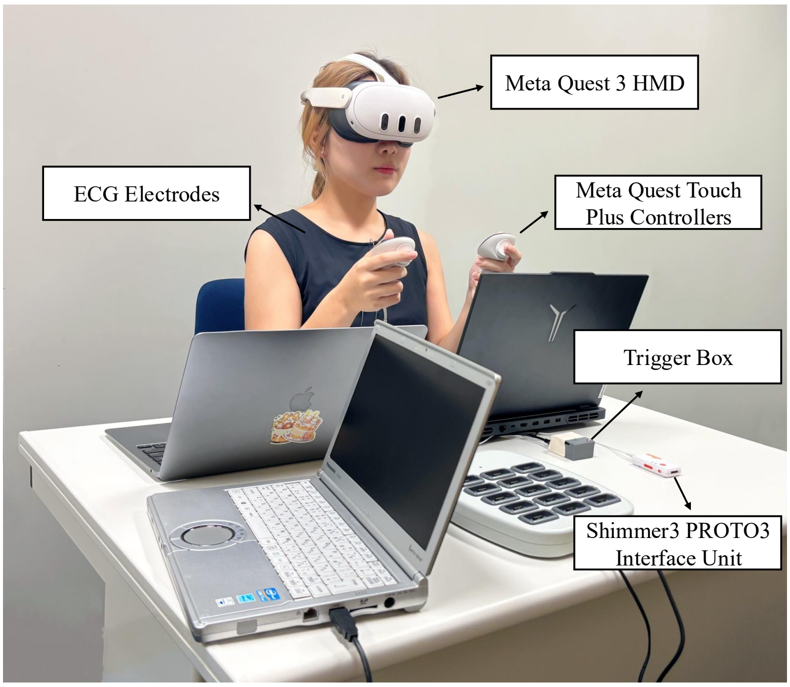

Figure 2: Experimental hardware setup. Participants interacted with the virtual environment using a Meta Quest 3 HMD and Touch Plus controllers. ECG signals were acquired using a Shimmer3 ECG system connected to a PROTO3 interface unit, and synchronization was achieved via a trigger box. Separate computers were used for VR control, physiological recording, and questionnaire administration.

3.3. Hardware and Software Setup

The experiment was conducted in a controlled laboratory environment, as shown in Figure 2. Participants remained seated throughout the experiment while wearing a Meta Quest 3 head-mounted display (HMD) and using Meta Quest Touch Plus controllers to interact with the virtual environment.

The VR application was developed in Unity 2022.3.59f1 and deployed on the Meta Quest 3 platform. The arithmetic stress-induction task was implemented using PsychoPy Builder v2024.2.4. Both the VR application and the stress-induction task were controlled using a Lenovo Legion Y9000P laptop.

Physiological signals were collected using a Shimmer3 ExG sensor system. ECG data were acquired through surface electrodes attached to the participant's chest and connected to a Shimmer3 ExG sensor worn at the waist. ECG electrodes were positioned according to the Lead-II configuration recommended in the Shimmer ECG User Guide. A Shimmer3 PROTO3 interface unit and an Arduino-based trigger box were used to synchronize physiological recordings with experimental events, following the setup described by Wei et al. [25]. Physiological data were recorded and monitored on a Panasonic ToughBook CF-NX2 laptop.

Questionnaires were administered using LimeSurvey on a MacBook Air (M1, 2020). Experimental data from the VR system, the physiological recording system, and questionnaires were collected through their respective platforms for subsequent analysis.

3.4. Measurements

Both subjective and physiological measures were collected to assess participants' responses throughout the experiment. Self-report questionnaires were administered at predefined stages of the procedure, while ECG signals were continuously recorded during the entire session.

State Anxiety. The primary outcome measure was the State version of the State–Trait Anxiety Inventory (STAI-S) [26]. The STAI-S consists of 20 items designed to assess transient anxiety levels and has been widely used in stress and anxiety research. Participants completed the questionnaire at three time points: baseline, immediately after the stress-induction task, and after the VR intervention.

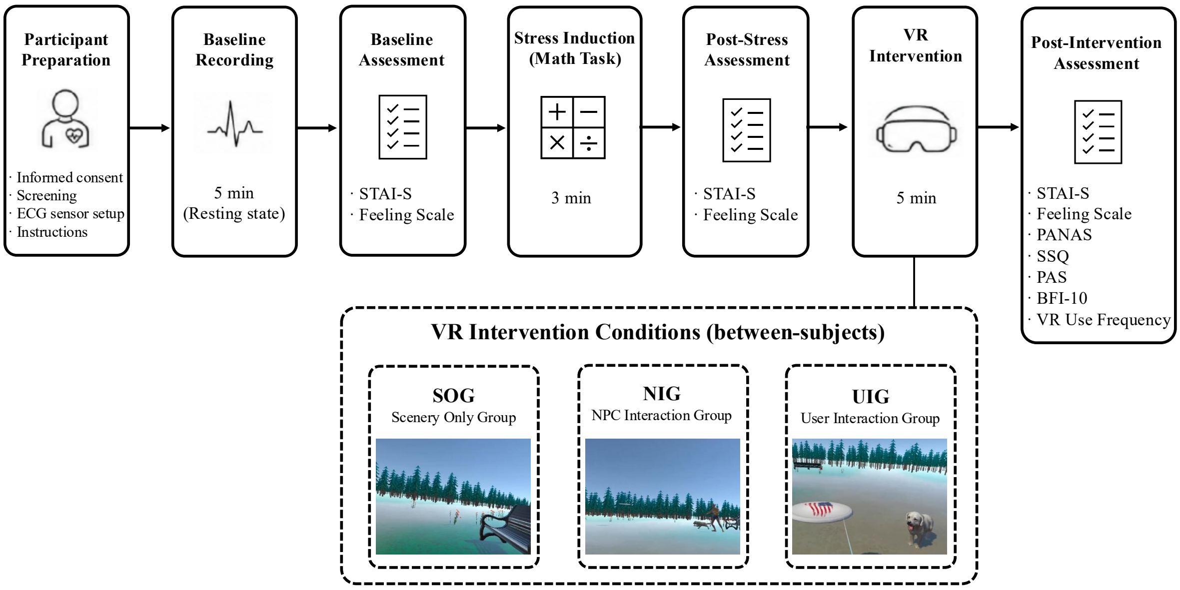

Figure 3: Experimental flow: An overview of the experimental design and data collection process. The entire experiment includes three main tasks and three conditions.

Affective Measures. To complement the anxiety assessment, participants reported their current emotional state using a single-item mood prompt ("How are you feeling now?") [27]. Positive and negative affect were further assessed after the intervention using the Positive and Negative Affect Schedule (PANAS) [28].

Individual Difference Measures. Participants completed the Pet Attitude Scale (PAS) [29] to assess attitudes toward companion animals and the BFI-10 [30] to measure personality traits. These measures were collected to explore potential individual differences that may influence responses to virtual animal-assisted therapy.

VR Experience and Simulator Sickness. Participants reported their prior VR use frequency and completed the Simulator Sickness Questionnaire (SSQ) [31] after the VR experience. These measures were included to assess familiarity with VR technology and potential discomfort associated with VR exposure.

Physiological Measures. ECG signals were continuously recorded using the Shimmer3 ECG system throughout the experiment. However, due to apparatus issues, the physiological data were excluded from the final analysis.

3.5. Procedure

All study sessions were conducted in a controlled laboratory environment to minimize external distractions and ensure consistency across participants. Participants remained seated throughout the experiment to reduce the risk of simulator sickness and maintain a stable posture during physiological recording and VR exposure.

The experiment followed a standardized procedure consisting of four phases: (1) preparation, (2) baseline recording, (3) stress induction, and (4) VR intervention. Self-report assessments were administered following the baseline recording, stress-induction task, and VR intervention to capture changes in participants' emotional states throughout the experiment (Figure 3). The entire session lasted approximately 45–60 minutes.

Preparation and Baseline Recording. Upon arrival, participants received an explanation of the study procedures and provided informed consent. ECG electrodes were attached, and the VR equipment was fitted and calibrated.

Participants then completed a five-minute resting baseline period while viewing a blank screen. This baseline period was included to allow physiological activity to stabilize prior to the experimental tasks [32]. Following the baseline recording, participants completed the STAI-S and the mood assessment questionnaire.

Stress Induction Task. Participants completed a time-pressured mental arithmetic task implemented in PsychoPy. During the task, arithmetic problems were presented sequentially, and participants were required to respond within a limited time. Incorrect responses triggered an error message accompanied by an aversive warning sound. Mental arithmetic tasks have been widely used to induce short-term cognitive stress in laboratory settings [32].

Immediately after completing the task, participants again completed the STAI-S and mood assessment questionnaire.

VR Intervention. Participants were randomly assigned to one of the three experimental conditions. Depending on the assigned condition, participants either explored the virtual environment alone (SOG), observed an NPC interacting with a virtual dog (NIG), or directly interacted with the virtual dog using VR controllers (UIG).

The intervention lasted approximately five minutes. Following the VR experience, participants completed the post-intervention questionnaire battery.

Upon completion of the questionnaires, participants were debriefed and thanked for their participation.

4. Analysis and Results

4.1. Data Processing

Questionnaire responses were scored according to the official scoring instructions of each instrument. For STAI-S, reverse-coded items were transformed before calculating total anxiety scores. Feeling scores were recorded on a single-item scale and analyzed directly.

PANAS, PAS, SSQ, and BFI-10 were scored according to their respective manuals and analyzed descriptively to characterize participants' affective responses, simulator sickness, attitudes toward animals, and personality traits.

4.2. Statistical Analysis

4.3. Statistical Analysis

To examine whether experimental condition was associated with post-intervention anxiety, a one-way analysis of covariance (ANCOVA) was conducted. The dependent variable was the post-intervention STAI-S score, and experimental condition (SOG, NIG, and UIG) was treated as the between-subjects factor. The post-stress STAI-S score, measured immediately after the arithmetic stress-induction task and before the VR intervention, was included as a covariate to account for individual differences in anxiety immediately before the intervention.

Prior to conducting the ANCOVA, the assumptions of normality of residuals, homogeneity of variance, and homogeneity of regression slopes were examined. The interaction between experimental condition and the post-stress STAI-S covariate was not statistically significant, $F(2, 25) = 2.20$, $p = .131$, supporting the assumption of homogeneous regression slopes. The residuals did not significantly deviate from normality, as indicated by the Shapiro–Wilk test, $W = .98$, $p = .791$. Levene's test was also not statistically significant, $F(2, 28) = 0.11$, $p = .895$, supporting the assumption of homogeneity of variance.

Following a significant omnibus effect of experimental condition, pairwise comparisons of adjusted means were conducted using Tukey correction for multiple comparisons. Statistical significance was evaluated at $\alpha = .05$.

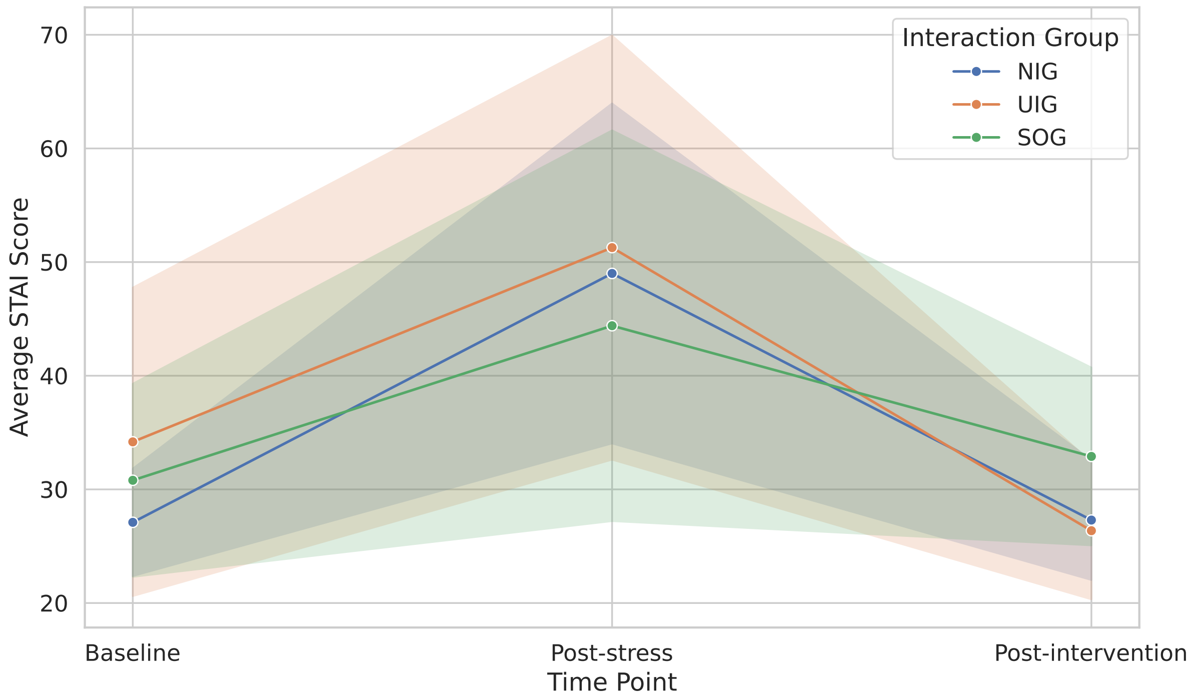

Figure 4: Changes in average STAI (State-Trait Anxiety Inventory) scores over time across three experimental groups: Scenery Only Group (SOG), NPC Interaction Group (NIG), and User Interaction Group (UIG). Scores were measured at three time points: baseline, post-stress, and post-intervention. Error bands represent standard deviation.

An identical ANCOVA was conducted for the Feeling Scale. The post-intervention Feeling Scale score was treated as the dependent variable, experimental condition was the between-subjects factor, and the post-stress Feeling Scale score was included as the covariate.

Due to technical issues with ECG acquisition, physiological measures could not be analyzed reliably and were therefore excluded from the inferential analyses.

4.4. Manipulation Check and Pre-Intervention Group Comparability

To examine whether the arithmetic task successfully induced anxiety, a paired-samples t-test was conducted to compare STAI-S scores at baseline and immediately after the stress-induction task. STAI-S scores were significantly higher after stress induction ($M = 48.32$, $SD = 16.74$) than at baseline ($M = 30.81$, $SD = 9.92$), $t(30) = 6.31$, $p < .001$. This result indicates that the arithmetic task successfully increased participants' self-reported state anxiety.

To examine the comparability of the experimental conditions, one-way analyses of variance (ANOVAs) were conducted. No significant differences in STAI-S scores were observed among the three conditions at baseline, $F(2, 28) = 1.37$, $p = .272$, or immediately after stress induction, $F(2, 28) = 0.44$, $p = .651$. These results indicate that anxiety levels were comparable across conditions before the VR intervention.

As illustrated in Figure 4, STAI-S scores subsequently decreased after the VR intervention across all three experimental conditions. Figure 5 presents the corresponding Feeling Scale scores. Participants reported lower Feeling Scale scores following stress induction, with subsequent recovery after the VR intervention across all three conditions.

4.5. Effects of Experimental Condition on Anxiety Recovery

To examine whether experimental condition was associated with post-intervention anxiety, an analysis of covariance (ANCOVA) was conducted. The dependent variable was the post-intervention STAI-S score, experimental condition (SOG, NIG, and UIG) was the between-subjects factor, and the post-stress

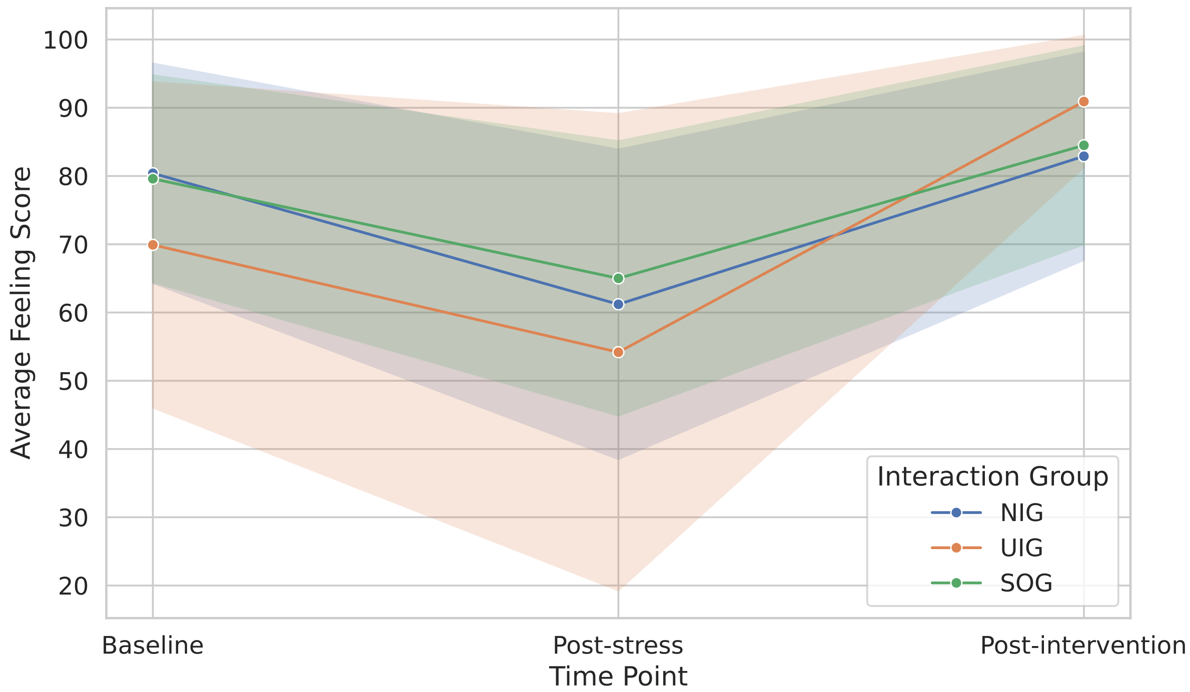

Figure 5: Mean Feeling Scale scores across the three assessment points—baseline, post-stress, and post-intervention—for the Scenery Only Group (SOG), NPC Interaction Group (NIG), and User Interaction Group (UIG). Error bands represent ±1 SD. Scores decreased after stress induction and increased after the VR intervention across all groups; between-group differences at post-intervention were not statistically significant.

STAI-S score measured immediately after the arithmetic stress-induction task was included as the covariate.

The ANCOVA revealed a significant overall effect of experimental condition on post-intervention anxiety scores, $F(2, 27) = 5.23$, $p = .012$, $\eta_p^2 = .28$. The covariate was also significant, $F(1, 27) = 8.27$, $p = .008$, indicating that participants' anxiety levels immediately after the stress-induction task significantly predicted their post-intervention anxiety scores.

As shown in Figure 4, STAI-S scores increased after the arithmetic stress-induction task across all three groups and subsequently decreased after the VR intervention. Descriptively, the largest decrease was observed in the User Interaction Group (UIG), followed by the NPC Interaction Group (NIG), whereas the Scenery Only Group (SOG) showed the smallest decrease.

To further explore group differences, post hoc pairwise comparisons of adjusted means were conducted with Tukey correction for multiple comparisons. No pairwise comparison reached statistical significance after correction. The largest observed adjusted difference was between the UIG and SOG conditions, with lower post-intervention anxiety in the UIG condition, mean difference = -13.41, 95% CI [-29.67, 2.85], $p = .121$. The adjusted differences between UIG and NIG and between NIG and SOG were also not statistically significant.

Although the pairwise comparisons were not statistically significant, the significant overall ANCOVA result and the descriptive pattern suggest possible differences in post-intervention anxiety across interaction conditions. However, because individual pairwise differences were not confirmed after correction for multiple comparisons, this pattern should be interpreted cautiously.

4.6. Effects of Experimental Condition on Subjective Feeling

To examine whether experimental condition was associated with participants' post-intervention subjective feeling, an analysis of covariance (ANCOVA) was conducted. The dependent variable was the post-intervention Feeling Scale score, experimental condition (SOG, NIG, and UIG) was the between-subjects factor, and the post-stress Feeling Scale score measured immediately after the arithmetic

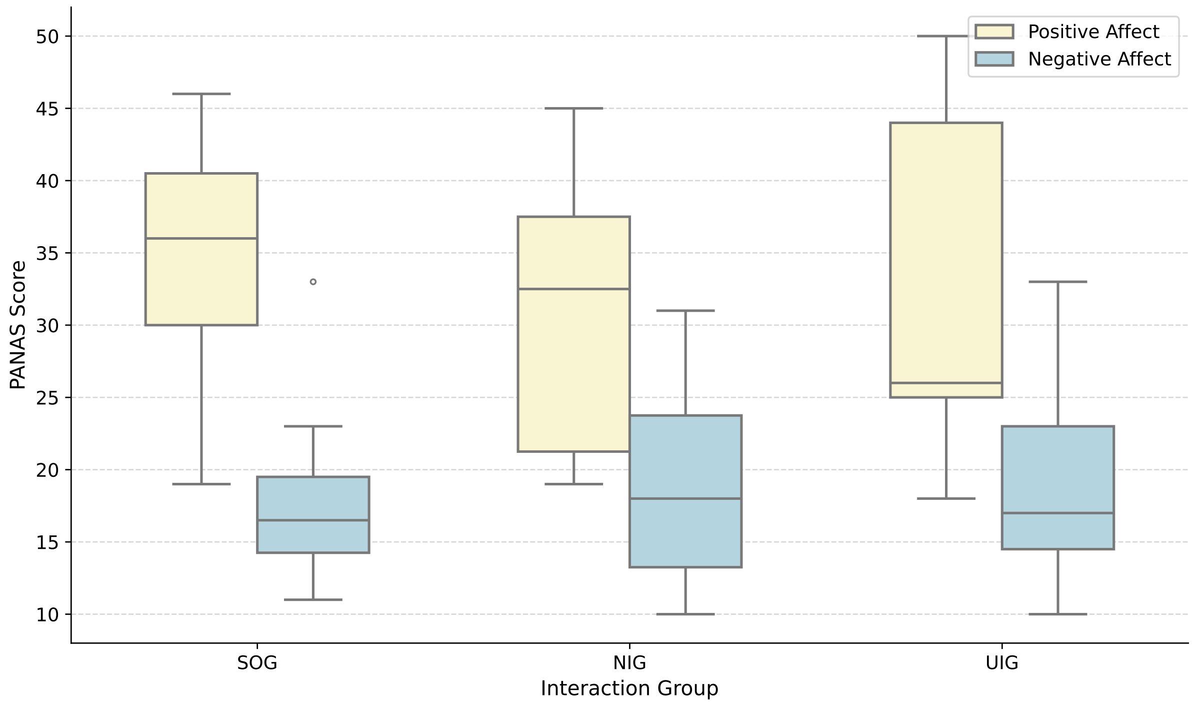

Figure 6: PANAS scores by group: Scenery Only Group (SOG), NPC Interaction Group (NIG), and User Interaction Group (UIG). Yellow boxes indicate Positive Affect (PA), and blue boxes indicate Negative Affect (NA). The UIG condition showed greater variability in both Positive Affect and Negative Affect scores, although no significant between-group differences were observed.

stress-induction task was included as the covariate.

The ANCOVA revealed no significant overall effect of experimental condition on post-intervention Feeling Scale scores, $F(2, 27) = 1.80$, $p = .184$. However, the covariate was significant, $F(1, 27) = 4.90$, $p = .035$, indicating that participants' subjective emotional state immediately after the stress-induction task significantly predicted their post-intervention Feeling Scale scores.

As shown in Figure 5, Feeling Scale scores decreased after the arithmetic stress-induction task across all three groups and subsequently increased after the VR intervention. Descriptively, the User Interaction Group (UIG) showed the largest recovery trend, followed by the NPC Interaction Group (NIG) and the Scenery Only Group (SOG). However, these between-group differences were not statistically significant.

Taken together, these results suggest that participants' subjective feeling generally improved after the VR intervention, but the degree of improvement did not differ significantly across interaction conditions.

4.7. Additional Questionnaire Results

To further characterize participants' experiences during the VR intervention, additional questionnaires assessing affective responses, simulator sickness, attitudes toward animals, and personality traits were analyzed.

Figure 6 presents the PANAS results across the three experimental conditions. Participants in the User Interaction Group (UIG) showed greater descriptive variability in both Positive Affect (PA) and Negative Affect (NA) scores than participants in the other groups. However, one-way ANOVA revealed no significant group differences for either Positive Affect ($p = .496$) or Negative Affect ($p = .650$). Therefore, the meaning of the observed variability remains unclear.

Figure 7 presents the Simulator Sickness Questionnaire (SSQ) scores across conditions. SSQ scores showed considerable variability and included several high-scoring observations. However, no statistically significant differences were observed between the experimental conditions. Because the score distribution included unusually high values, these results should be interpreted cautiously.

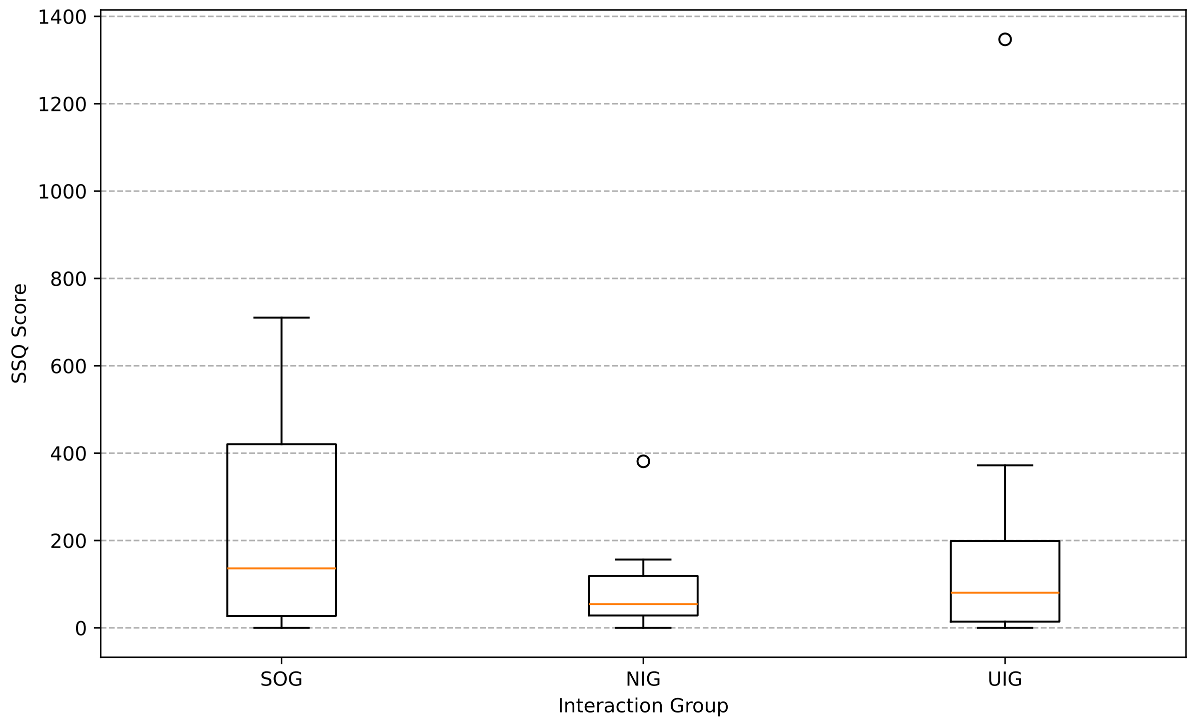

Figure 7: Simulator Sickness Questionnaire (SSQ) scores across the Scenery Only Group (SOG), NPC Interaction Group (NIG), and User Interaction Group (UIG). The distributions included several high-scoring observations, but no statistically significant between-group differences were found.

Attitudes toward animals, measured using the Pet Attitude Scale (PAS), were comparable across the three conditions. Similarly, BFI-10 personality profiles showed no notable group-level differences. These results suggest that participants' attitudes toward animals and personality characteristics were relatively balanced across conditions and were therefore unlikely to account for the observed differences in anxiety outcomes.

4.8. Physiological Measures

ECG signals were recorded throughout the experiment using the Shimmer3 system. However, a hardware configuration issue resulted in an insufficient sampling rate for reliable heart-rate variability analysis.

Consequently, physiological measures were excluded from the statistical analyses reported in this paper. Future studies should incorporate validated ECG acquisition procedures to enable multimodal assessment of anxiety responses.

5. Discussion

This study investigated whether different levels of user involvement with a virtual dog were associated with anxiety recovery following a stress-induction task in an immersive VR environment. The ANCOVA revealed a significant overall effect of experimental condition on post-intervention STAI-S scores after controlling for post-stress anxiety. However, corrected pairwise comparisons did not identify statistically significant differences between specific conditions.

Descriptively, participants in the User Interaction Group (UIG) showed the largest reduction in self-reported anxiety following the VR intervention. Nevertheless, because the pairwise comparisons were not statistically significant, this pattern should be interpreted cautiously. The descriptive result is broadly consistent with previous research suggesting that interactive virtual animal experiences may support emotional well-being and stress recovery [10, 11, 12].

One possible explanation for this effect is that direct interaction increases users' sense of agency and involvement within the virtual environment. Participants in the UIG actively engaged with the virtual dog through feeding and play activities, whereas participants in the NPC Interaction Group (NIG) only observed interactions, and those in the Scenery Only Group (SOG) experienced the environment without animal-related interaction. Active participation may have encouraged greater attentional engagement and distraction from stress-related thoughts, thereby facilitating emotional recovery. This interpretation is consistent with previous VR research indicating that interactive experiences can strengthen user engagement, presence, and perceived control, all of which have been associated with improved emotional outcomes.

Interestingly, the significant overall effect observed for STAI-S was not reflected in the Feeling Scale. Although all groups showed a decline in Feeling Scale scores following the stress-induction task and a subsequent recovery after the intervention, no significant differences were found between experimental conditions. One possible explanation is that the Feeling Scale captures a broader affective state, whereas the STAI-S specifically measures situational anxiety. However, the present results do not establish that a particular experimental condition was more effective in improving overall subjective feeling.

Additional questionnaire results provided further context for understanding participants' experiences. Although PANAS scores did not differ significantly between groups, participants in the UIG showed greater descriptive variability in both positive and negative affect. The meaning of this variability remains unclear. SSQ scores also showed considerable variability and included several high-scoring observations, but no statistically significant differences were observed between experimental conditions. Given the unusually high values, the SSQ results should be interpreted cautiously.

Taken together, the results suggest a possible association between the level of user involvement and post-intervention anxiety. Descriptively, the UIG showed the largest reduction in STAI-S scores; however, corrected pairwise comparisons did not confirm statistically significant differences between specific conditions. Further studies with larger samples are therefore required to determine whether active user-dog interaction provides benefits beyond passive observation or environmental exposure.

6. Limitations

Several limitations should be considered when interpreting the findings of this study.

First, although the final sample size exceeded the minimum estimated by the a priori power analysis, the number of participants per condition remained modest ($n = 10 - 11$). The ANCOVA revealed a significant overall effect of interaction condition on post-intervention anxiety scores; however, follow-up pairwise comparisons did not identify significant differences between specific conditions. Therefore, the observed pattern, including the larger anxiety reduction in the UIG condition, should be interpreted cautiously. Future studies with larger samples are needed to confirm the robustness of these findings and provide more precise estimates of effect size.

Second, physiological measures could not be included in the final analyses because of an ECG acquisition issue that resulted in insufficient data quality for reliable heart-rate variability analysis. Consequently, the present study relied primarily on self-report measures to assess anxiety and emotional responses. Future studies should incorporate validated physiological recording procedures to enable a more comprehensive multimodal evaluation of stress and recovery processes.

Third, the intervention consisted of a single short-term laboratory session. While the results suggest that interaction with a virtual dog may facilitate immediate anxiety recovery, it remains unclear whether these effects would persist over repeated sessions or in real-world therapeutic contexts. Longitudinal studies are needed to investigate the long-term effectiveness and sustainability of virtual animal-assisted interventions.

Finally, the study focused exclusively on a single type of virtual companion—a dog—and a limited set of interaction activities. Different virtual animals, interaction modalities, or social behaviors may produce different emotional responses. Future research should explore a broader range of virtual companions and interaction designs to better understand the mechanisms underlying VR-based animal-assisted interventions.

Despite these limitations, the present study provides preliminary evidence that active interaction with a virtual companion may support anxiety recovery in immersive virtual environments. Future work should recruit larger, more diverse participant samples, incorporate reliable physiological measures, and investigate long-term intervention effects to further establish the therapeutic potential of virtual animal-assisted experiences.

7. Conclusion

This study investigated whether different levels of user involvement in a virtual dog experience were associated with short-term anxiety recovery following experimentally induced stress. Participants experienced one of three conditions: viewing a natural virtual environment without a dog, observing an NPC interacting with a virtual dog, or directly interacting with the virtual dog.

The ANCOVA revealed a significant overall effect of experimental condition on post-intervention STAI-S scores after controlling for post-stress anxiety. However, corrected pairwise comparisons did not identify statistically significant differences between specific conditions. Descriptively, participants who directly interacted with the virtual dog showed the largest reduction in anxiety, followed by those who observed the NPC-dog interaction and those who viewed the scenery-only environment. Therefore, the relative benefits of the individual conditions remain inconclusive.

These findings suggest that the level of user involvement may be associated with short-term anxiety recovery in virtual animal-assisted experiences. Future studies with larger and more diverse samples are needed to confirm the observed descriptive pattern and determine which forms of user involvement, if any, provide additional benefits for anxiety recovery.

References

[1] B. S. McEwen, Protective and damaging effects of stress mediators, New England Journal of Medicine 338 (1998) 171–179. doi:10.1056/NEJM199801153380307.

[2] B. S. McEwen, T. Seeman, Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load, Annals of the New York Academy of Sciences 896 (1999) 30–47. doi:10.1111/j.1749-6632.1999.tb08103.x.

[3] J. S. J. Odendaal, Animal-assisted therapy—magic or medicine?, Journal of Psychosomatic Research 49 (2000) 275–280. doi:10.1016/S0022-3999(00)00183-5.

[4] J. Nimer, B. Lundahl, Animal-assisted therapy: A meta-analysis, Anthrozoös 20 (2007) 225–238. doi:10.2752/089279307X224773.

[5] D. Freeman, S. Reeve, A. Robinson, et al., Virtual reality in the assessment, understanding, and treatment of mental health disorders, Psychological Medicine 47 (2017) 2393–2400. doi:10.1017/S003329171700040X.

[6] J. L. Maples-Keller, B. E. Bunnell, S. J. Kim, B. O. Rothbaum, The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders, Harvard Review of Psychiatry 25 (2017) 103–113. doi:10.1097/HRP.0000000000000138.

[7] C. Botella, B. Serrano, R. M. Baños, A. Garcia-Palacios, Virtual reality exposure-based therapy for the treatment of post-traumatic stress disorder: A review of its efficacy, the adequacy of the treatment protocol, and its acceptability, Neuropsychiatric Disease and Treatment 11 (2015) 2533–2545. doi:10.2147/NDT.S89560.

[8] M. B. Powers, P. M. G. Emmelkamp, Virtual reality exposure therapy for anxiety disorders: A meta-analysis, Journal of Anxiety Disorders 22 (2008) 561–569. doi:10.1016/j.janxdis.2007.04.006.

[9] E. Carl, A. T. Stein, A. Levihn-Coon, et al., Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials, Journal of Anxiety Disorders 61 (2019) 27–36. doi:10.1016/j.janxdis.2018.08.003.

[10] Y. Choi, M. J. Kim, H. Kim, The effects of mixed-reality virtual pet interactions on reducing human stress, Frontiers in Veterinary Science 10 (2023) 1102937. doi:10.3389/fvets.2023.1102937.

[11] N. Norouzi, Y. Kim, S. Park, et al., A virtual dog can be your best friend: Augmented reality companion animals to reduce stress and increase social support, in: CHI Conference on Human Factors in Computing Systems, ACM, 2022. doi:10.1145/3491102.3501931.

[12] L. A. González, R. Andrade, Virtual companion dog for emotional support in virtual reality environments, in: Proceedings of the International Conference on Human-Computer Interaction, Springer, Cham, 2021, pp. 129–144.

[13] S. Y. Oh, G. J. Kim, Design and evaluation of empathetic virtual pets for enhancing human emotion, Computers in Human Behavior 127 (2022) 107047. doi:10.1016/j.chb.2021.107047.

[14] M. Annerstedt, P. Jönsson, M. Wallergård, G. Johansson, B. Karlson, P. Grahn, Å. M. Hansen, J. Wärnberg, Inducing physiological stress recovery with sounds of nature in a virtual reality forest—results from a pilot study, Physiology & Behavior 118 (2013) 240–250. doi:10.1016/j.physbeh.2013.05.023.

[15] M. H. E. M. Browning, K. J. Mimnaugh, C. J. van Riper, H. K. Laurent, S. M. LaValle, Can simulated nature support mental health? comparing short, single-doses of 360-degree nature videos in virtual reality with the outdoors, Frontiers in Psychology 10 (2020) 2667. doi:10.3389/fpsyg.2019.02667.

[16] A. Chirico, A. Gaggioli, When virtual feels real: Comparing emotional responses and presence in virtual and natural environments, Cyberpsychology, Behavior, and Social Networking 22 (2019) 220–226. doi:10.1089/cyber.2018.0393.

[17] M. V. Navarro-Haro, Y. López-del Hoyo, D. Campos, M. M. Linehan, H. G. Hoffman, A. García-Palacios, M. Modrego-Alarcón, L. Borao, J. García-Campayo, Meditation experts try virtual reality mindfulness: A pilot study evaluation of the feasibility and acceptability of virtual reality to facilitate mindfulness practice in people attending a mindfulness conference, PLOS ONE 12 (2017) e0187777. doi:10.1371/journal.pone.0187777.

[18] A. Beetz, K. Uvnäs-Moberg, H. Julius, K. Kotrschal, Psychosocial and psychophysiological effects of human-animal interactions: The possible role of oxytocin, Frontiers in Psychology 3 (2012) 234. doi:10.3389/fpsyg.2012.00234.

[19] S. Lim, S.-Y. Dong, Effects of interaction with virtual pets on self-disclosure in mixed reality, in: 2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), IEEE, 2023, pp. 1–9. doi:10.1109/ismar59233.2023.00014.

[20] S. Shchory, K. Nitzan, G. Harpaz, R. Doron, Not just a game: The effect of active versus passive virtual reality experiences on anxiety and sadness, Virtual Reality 28 (2024) 1–13. doi:10.1007/s10055-023-00925-6.

[21] Y. A. Sekhavat, P. Nomani, A comparison of active and passive virtual reality exposure scenarios to elicit social anxiety, International Journal of Serious Games 4 (2017). doi:10.17083/ijsg.v4i2.154.

[22] K. Tcha-Tokey, E. Loup-Escande, O. Christmann, S. Richir, Towards a model of user experience in immersive virtual environments, Advances in Human-Computer Interaction 2018 (2018) 7827286. doi:10.1155/2018/7827286.

[23] G. Makransky, G. B. Petersen, The cognitive affective model of immersive learning (camil): A theoretical research-based model of learning in immersive virtual reality, Educational Psychology Review 33 (2021) 937–958. doi:10.1007/s10648-020-09586-2.

[24] M. Slater, M. V. Sanchez-Vives, Enhancing our lives with immersive virtual reality, Frontiers in Robotics and AI 3 (2016) 74. doi:10.3389/frobt.2016.00074.

[25] X. Wei, H. Liu, Y. Hirao, M. Perusquia-Hernandez, K. Masai, H. Uchiyama, K. Kiyokawa, Electrooculography-based detection of refractive vision problems, IEEE Journal of Biomedical and Health Informatics (2026) 1–15. doi:10.1109/JBHI.2026.3652204.

[26] C. D. Spielberger, R. L. Gorsuch, R. Lushene, P. R. Vagg, G. A. Jacobs, Manual for the State-Trait Anxiety Inventory, Consulting Psychologists Press, Palo Alto, CA, 1983.

[27] A. Betella, P. F. M. J. Verschure, The affective slider: A digital self-assessment scale for the

measurement of human emotions, PLOS ONE 11 (2016) e0148037. doi:10.1371/journal.pone.0148037.
[28] D. Watson, L. A. Clark, A. Tellegen, Development and validation of brief measures of positive and negative affect: The panas scales, Journal of Personality and Social Psychology 54 (1988) 1063–1070. doi:10.1037/0022-3514.54.6.1063.
[29] D. I. Templer, H. Arikawa, The pet attitude scale, in: The Psychology of the Human-Animal Bond: A Resource for Clinicians and Researchers, Springer, New York, NY, 2011, pp. 335–359. doi:10.1007/978-1-4419-9761-6_19.
[30] B. Rammstedt, O. P. John, Measuring personality in one minute or less: A 10-item short version of the big five inventory in english and german, Journal of Research in Personality 41 (2007) 203–212. doi:10.1016/j.jrp.2006.02.001.
[31] R. S. Kennedy, N. E. Lane, K. S. Berbaum, M. G. Lilienthal, Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness, The International Journal of Aviation Psychology 3 (1993) 203–220. doi:10.1207/s15327108ijap0303_3.
[32] A. Bayro, H. Jeong, A systematic review of experimental protocols: Towards a uniform framework in virtual reality affective research, IEEE Transactions on Affective Computing 16 (2025) 1334–1348. doi:10.1109/TAFFC.2025.3554496.

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT (OpenAI) for grammar checking and language refinement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.