# Assessing the effectiveness of virtual reality tasks as stress-inducing environments

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## SUMMARY

Due to safety concerns, the impact of stress on cognitive readiness cannot be assessed in real-time hazardous work scenarios through many psychophysiological methods. This study aimed to evaluate the validity of a virtual reality (VR) simulation designed to replicate a critical situation, eliciting a significant level of stress. This approach enables the analysis of behaviours that may mirror those exhibited by workers in high-risk environments such as oil platforms, deep-sea diving, or bomb disposal units.

## KEYWORDS

Cognitive readiness, stress, virtual reality, hazardous environments.

### Background

The human brain's complexity allows for learning, task performance, and adaptive responses to stimuli. Cognitive readiness denotes a state in which alertness and mental preparation reach a level conducive to optimal performance (Fletcher, 2004; Crameri, 2019; O'Neil, 2013). This readiness becomes critical in complex and unpredictable environments. However, external factors like pressure and stress can impair cognitive readiness, posing long-term challenges in high-risk sectors, such as oil platforms, deep diving, or bomb disposal units, where workers often operate under adverse and dangerous conditions (Lafond, 2012; von Rosemberg, 2019; Chowdhury, 2025).

Innovative technologies capable of monitoring cognitive readiness through accessible, simple, and efficient tasks could help reduce work-related accidents in hazardous scenarios. However, for safety reasons, psychophysiological measures, such as electroencephalographic signals and electrodermal potentials, which provide valuable insights for developing such technologies, cannot be collected during real-time operations (Chowdhury, 2025). To address this experimental limitation, we evaluated the effectiveness of a virtual reality simulation involving a stress-inducing task, designed to emulate essential sensorimotor attributes of procedures performed in dangerous situations.

### Materials and Methods

Fifty adult volunteers were initially recruited from among university students. However, six participants were excluded from the analysis due to corrupted or missing data. The final sample comprised 44 participants (21 males and 23 females), aged 18 to 30 years.

All participants completed two tasks:

(i) Bomb deactivation simulation**:** In this VR task, participants played the game *Keep Talking and Nobody Explodes*, having to dismantle a bomb under a noisy environment, increasingly complex instructions, and time pressure. This game was selected for its intrinsic potential to elicit acute stress and anxiety.

(ii) Affective image presentation**:** After the VR task, participants viewed a five-minute sequence of either positive (P) or negative (N) images selected from the International Affective Picture System (IAPS; Lang, 2005) on a computer screen. Participants were divided into two groups (P and N) according to the nature of the images presented. They were instructed to observe the images without any additional task.

The State-Trait Anxiety Inventory (STAI) was administered in its two forms. The State form (STAI-S) was applied at three key points to assess overall anxiety: at the start of the experiment (pre-test), at the conclusion of the VR task (post-game), and immediately after the presentation of the affective images (post-images). The Trait form (STAI-T), along with the Visual Analogue Mood Scale (VAMS), was administered following each task (post-game and post-images) to evaluate levels of tension, anxiety, and nervousness.

Electrodermal potentials (galvanic skin response, GSR), heart rate (HR), and electroencephalographic activity (EEG) were recorded from all participants during the behavioural procedures. The data derived from these measures are still under analysis and will not be presented in this report.

## Results

This preliminary study focused on validating the stress-inducing VR environment by analysing the impact of the bomb deactivation task and the affective image sequences on participants' mood states.

Analysis of the STAI-S data (Figure 1) using a 2x3 two-way mixed-design ANOVA, with Group (positive vs. negative images) as a between-groups factor and Time (pre-test, post-game, and post-images) as a within-groups factor, revealed a highly significant main effect of Time ($F[84,2] = 20.33$, $p < 0.0001$, partial eta-squared = 0.326). A marginal interaction between the two factors ($F[84,2] = 2.548$, $p = 0.084$, partial eta-squared = 0.057) aligned with a post-hoc Holm's test, indicating no statistically significant differences between time points for the positive image group ($p > 0.095$). Conversely, a significant difference ($p < 0.001$) was observed between the pre-test and both post-game and post-images scores for the negative image group, with no significant difference between the latter two ($p > 0.99$).

A pairwise comparison (Holm's test) between the levels of the factor Time across the combined groups (P and N) confirmed the highly significant difference between pre-test and both post-game and post-images scores ($t > 4.829$, $p < 0.0001$), also with no significant difference between the latter two ($p = 0.957$).

VAMS data yielded similar findings. A 2x2 mixed-design ANOVA revealed a marginal interaction between factors ($F[41,1] = 2.843$, $p = 0.099$, partial eta-squared = 0.065), consistent with a non-significant decrease in anxiety scores only for the positive image group.

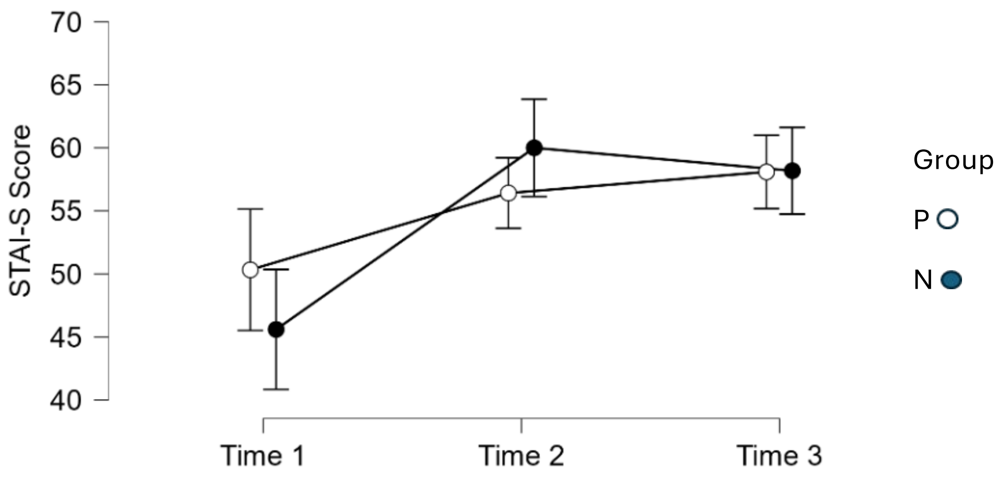


Figure 1: Mean scores from the State-Trait Anxiety Inventory scale (STAI-S). The lines show the STAI-S scores at three moments (Time 1 to 3 indicate pre-test, post-game, and post-images points in time) for both participant groups (P and N code the groups exposed to positive or negative images, respectively). Error bars denote 95% confidence intervals.

## Conclusion

Our findings indicate that the VR-simulated task successfully induced a substantial level of anxiety, persisting during the presentation of negative images but diminishing towards normal levels with positive images. While the experimental procedure closely mimicked tasks performed by bomb disposal units, the physiological and emotional effects observed may generalise to other high-pressure, stressful environments, such as oil platforms, deep-sea diving and air traffic control towers, among others.

Further validation is required to confirm the task's relevance as a tool for investigating psychophysiological responses in real-world scenarios. However, these preliminary results suggest that VR-based simulations offer promising avenues for studying stress and cognitive readiness in settings where real-time data collection is unfeasible.

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