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Original article

Design and implementation of a VR environment aimed at enhancing the Social Anxiety Disorder's (SAD) treatment. Evaluation of the sense of presence and immersion

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Abstract. *Background and aim:* We present here a novel approach to Virtual Reality Treatment (VRET) of Social Anxiety Disorders. It is based on a VR ecological scenario (that of a school room with desks) that can be personalized according to the actual fear level of the patient, adjusting the number of schoolmates that can be present together inside the room and the distance between the desks. *Methods:* We then conducted a user study to explore the sense of presence (Presence Questionnaire, PQ), immersive tendencies (Immersive Tendencies Questionnaire, ITQ), and subjective mental workload (NASA Task Load Index, TLX). The study evaluated 34 healthy students (average age: 24.558 years), of which 18 females. *Results:* Results from a usability trial are extremely positive. Our data suggests that participants mostly liked the high realism and sense of immersion of the Virtual Environment and the possibility to explore it widely. On the other side, the amount of workload of the task was evaluated very low, and therefore users can concentrate on the task. *Conclusions:* We conclude the article by discussing possible future directions for a large-scale pilot, that can lead to a solution that can be used at home to train under the guide and periodic supervision of a therapist (www.actabiomedica.it)

Key words: Virtual Reality (VR), Virtual Reality Treatment (VRET), Social Anxiety Disorders

Introduction

The concept of Virtual Reality (VR) was proposed several years ago (1). It is based on head-mounted stereo displays (HMD), a technology that has recently become broadly available. It provides users a virtual environment reproducing a real one, thus offering virtually several immersive experiences. Among these, HMDs allow users to practice and repeat different exercises (2). Key research areas related to VR are producing realistic scenarios and developing new interfaces. Recently, VR-based exercises have been frequently explored in rehabilitation of different patients' populations (3-6). We address here Social Anxiety Disorders (SAD), that are characterized by a marked fear or anxiety about one or more social situations in which the individual is exposed to possible scrutiny by others, embarrassed or humiliated (7). A lifetime prevalence rate for SAD has been reported as 13.3% amongst the general population, making SAD the third most reported mental health disorder after depression (17%) and alcohol dependence (8, 9). Age of onset is early (10), across countries SAD is associated with specific socio-demographic features (younger age, female gender, unmarried status, lower education, and lower income) and with similar patterns of comorbidity (11). Several epidemiological studies reported a close relationship between SAD and both general health and functional impairment (12). Such patients tend to avoid social situations that might produce anxiety or accept them with an excess of fear or anxiety with a resulting reduced quality of life.

Today, Exposure-based Cognitive Behavior Therapy is the gold-standard treatment for SADs with effects that last longer than those achieved through medication. On the other hand, SAD is associated with several treatment barriers such as a limited awareness of locally available services, the psychological and financial burden of entering a treatment, and the health care professionals' awareness of its clinical implication (13). VR has shown a large potentiality with these patients: a growing body of research on virtual reality exposure therapy (VRET) has shown its efficacy, allowing the patients to gradually face fear stimuli or stressors in a safe environment where her/his psychological and physiological reactions can be controlled by the therapist (14, 15).

From subjective rating, the sense presence is one of the key factors for the success of VRET. Presence is the "sense of being there", product of the interaction between sensory perception, environmental factors, that encourages involvement and enables immersion in the virtual world (16, 17). Interaction in VRET is going to be more and more "embodied," with insights from neurosciences to be implemented into the technology, for example, the use of hands with contactless device (i.e., without gloves) making the interaction in virtual environments more natural (14). The effectiveness of virtual environments (Ves) has often been linked to the sense of presence reported by users and immersion in the experience. An immersed individual concentrates on the event ignoring at the same time disturbing conditions in its surroundings. In the immersed state, she/he experiences intense positive and negative emotions with consequences for their real life. Although some studies indicated that multiple sensory modalities could improve the individuals' engagement and motivation in psychological and cognitive interventions others had pointed out the advantage of immersion using VR scenarios when eliciting emotions through simulation of real experiences. Therefore, currently, one of the foci of research in this area is the generation of realistic and ecological VR scenarios (18, 19).

The present study attempted to develop a cost-effective VR research/clinical software of a high enough quality for implementation in clinical trials. Thus, the present is pilot research to explore the user experience and usability of a new VR simulation designed to deliver psychoeducation and training to individuals suffering from SAD. The study's main purpose was to provide further support on whether VR can resemble physical reality to the required degree of quality to be a suitable framework for exploring real-life behavior inside the virtual scenario, which would indeed increase the effect of the treatment (18). Indeed, VR's potential to generally augment educational outcomes by improving knowledge retention and engagement presents a unique opportunity to teach these mental skills (19).

Therefore, we have set up an experiment in VR to explore social exposure in a non-clinical sample and measured the ability to immerse and feel of presence in our VR environment. Immersion and presence are not continuous and often break owing to fluctuations (20, 21). Immersion is an objective degree of sensory engagement provided by VR (22) and presence is a subjective sense of a user being "in" a place (23). While immersion and presence are distinct constructs, they are closely tied together and if immersion is significantly high, higher levels of presence will also be described. A high degree of presence seems the principal factor for behavioral realism (24) with an increased sense of presence in VR is positively correlated with the emotional reaction towards the virtual environment. The different sides of an individual's capacity for immersion and the "sense of being there" were investigated through the Immersive Tendencies Questionnaire (ITQ, 25) and the Presence Questionnaire (PQ, 26). Previous investigations on VR training simulations point towards a relationship between the sense of presence in VR and user performance (27). Additionally, we examined the associations between cognitive load and both presence and immersion (28, 29). Cognitive load is usually defined as the amount of mental effort that the working memory utilizes during a task and several studies have already provided evidence that immersive media elicit high degree of cognitive load (18, 30, 31). Consequently, considering that our experimental environment tends to reduce cybersickness, we anticipated that higher technological immersiveness should be connected to higher levels of spatial presence.

Materials and methods

Ethics

The study was conducted in accordance with the Helsinki Declaration and approved by the Research Ethics Board from the University of Parma on the 12th of July 2023. All participants gave their written informed consent prior to participating. The study was performed according to institutional ethics and national standards for the protection of human participants. Ethical considerations included informed consent, right to withdraw, and confidentiality. Exclusion criteria were epilepsy, use of medication, recent consumption of alcohol, intellectual disability, and mental health difficulties (e.g., requiring medication). Following completion of the exposure, participants were debriefed with an explanation about the study purpose.

Experimental design

The experiment was conducted as a between-conditions' sequence design. Participants visited the laboratory once time to complete baseline measurements, virtual exposure, and post-exposure data collection.

Enrollment and participants

The study group consisted of a convenience sample of 34 individuals (18 female, average age: 24.558 years; SD = 2.841, range = 20 - 30 years) with no physical or visual health problems. They were recruited through flyers distributed along university's sites. All the participants were Italian. There was no payment made for participation. All had normal or corrected-to-normal vision have normal or corrected-to-normal vision, and without a history of amblyopia (an imbalance between the two eyes that can lead to problems with stereo vision) or photosensitive seizures. All these participants who wore glasses did not remove them during the experiment. Among all participants, 4 had previous experience in using VR, and 2 owned a VR device. Thus, this was an experimental group with little experience using VR. The participants were exposed in a counterbalanced manner to the sequence of increasing social exposure/decreasing social exposure.

Apparatus and equipment

Meta Quest 2, also known as Oculus Quest 2 (Meta Platforms Inc. Menlo Park, CA, USA) HMD was used. Its dimension and weight are 22.4 × 45.0 cm and 503 g, respectively. In addition, it contains a rechargeable 3640 mAh lithium-ion battery. The main important technical features of this equipment are: a pair of LCD displays of 1832 × 1920, one per eye, with a display refresh rate up to 90 Hz; a Qualcomm Snapdragon XR2 as CPU, 6 GB of RAM, 128 GB of memory; four infrared cameras; two built-in speakers, and two Meta manual controllers. The HMD presents high-resolution displays and motion tracking to visually immerse the user from a first-person perspective. The user can look through the virtual world, move freely within a simulated environment, without being physically connected to several hardware devices. Instead, projection and sensor tracking technology are all contained within the headset itself, which can be used in conjunction with handheld controllers. Jensen and Konradsen (32) found that affective capabilities, cognitive and psychomotor skills can be better increased using HMDs, compared to other methods with a lower immersion level.

Scenario

We have designed the intervention according to the methodology proposed in Pirovano et al. (33). Moreover, we have considered that the content of all VRET interventions is most effective when they portrait situations frequently experienced by users (34). We chose to represent a school scenario, in which the user takes on the role of a student called to carry out a class assignment or an exam to her/his professor at school and is targeted to adolescents. In detail, the user must enter a classroom and take a seat at a desk, surrounded by other students represented by avatars. The scenario was constructed using Unreal Engine 5 (https://www.unrealengine.com/en-US) that has allowed to realize a prototype in a limited amount of time (35). We have designed the VR environment such that the intervention can be fully personalized to the participants (36): the digital scene is that of a typical classroom: the number of desks rows and the distance between desks and rows can be set by the experimenter to modulate the level of stress induced to match the severity of the disorder. Furthermore, VR investigation which includes social interactions with virtual characters, should reflect the quality of the 3D characters in terms of realistic appearance and behavior. Avatars have been realized using Metahumans plug-in (https://dev.epicgames.com/en-US/home) of Unreal to obtain a high degree of realism in their appearance and motion. At start of the experiment, the participant avatar enters in the classroom, chooses her/his desk, approaches it, and sits down. One, more or no other school mate stationed in the other desks according to the experimenter choice. After sitting down other school mates can enter inside the room and sit down closer or further to the user avatar. The virtual environment can be configured in various ways, varying the size of the classroom, the layout of the desks, the number of avatars and the distance between the desks, which is the foundation that lies under the development process of any training objectives. Through the task analysis during the design process, we have established the parameters and factors needs for the specific task. In this way, following the principle of gradual exposure, the individual can progressively face more stressful situations that could induce fear, in a controlled environment.

Self-report measures

Immediately after the VR exposure, users are requested to fulfill three questionnaires to assess participants' subjective experience. The Presence Questionnaire (PQ, 37) and the Immersive Tendencies Questionnaire (ITQ, 25) were used to explore differences in the tendencies of persons to feel presence and measure immersion in the mediated environment, respectively. PQ was applied at the end of the simulation to evaluate to what extent the participants felt present inside the VE. Subjects were required to score the quality of their VE experience according to their sense of presence, and a few factors pertaining to the VE's characteristics/system set-up, namely: sensory factors; level of realism; interaction factors; distraction factors; and display image quality. The PQ (37) uses a seven-point scale based on the semantic differential format, but also includes a midpoint anchor in addition to opposing descriptors and contains 24 items. Cronbach's alpha was .88.

The ITQ assesses an individual's level of engagement while being involved in life events, actions, and using traditional and/or digital media devices. A high score in the ITQ predicts the intensity of a person's sense of presence as well (Witmer & Singer, 1998). The ITQ contains 18 items and utilizes a scale of 1 (never) to 7 (often). It assesses the level of immersion in books, movies, and computer games through emotional engagement, the frequency of digital device usage, and the intense attention that leads to the neglect of the current background. According to Witmer and Singer (25), the reliability of the scale ranged between 0.75. The scale comprised four subdimensions, namely, attentional focus, involvement, emotions, and tendency to play video games.

The NASA Task Load Index (NASA TLX, hereafter called the TLX, 38) was used for assessing the subjective mental workload (MWL). It rates task performance through six dimensions rated individually on a 0-100 scale to determine an overall workload rating. The six dimensions are as follows: Mental demand (how much thinking, deciding, or calculating was required to perform the task); Physical demand (the amount and intensity of physical activity required to complete the task); Temporal demand (the amount of time pressure involved in completing the task); Effort (how hard does the participant have to work to maintain their level of performance?); Performance (the level of success in completing the task), and Frustration level (how insecure, discouraged, or secure or content the participant felt during the task). Participants were asked to rate their score on an interval scale ranging from low (1) to high (20) using 15 pairwise combinations designed to elicit the pair that has the greatest effect on workload while performing the task.

Procedure

In Figure 1. the screenshots showing the participant's perspective of the exposure conditions were depicted. The VR exposure took place in a laboratory. Upon arrival at the lab, participants were given a link to

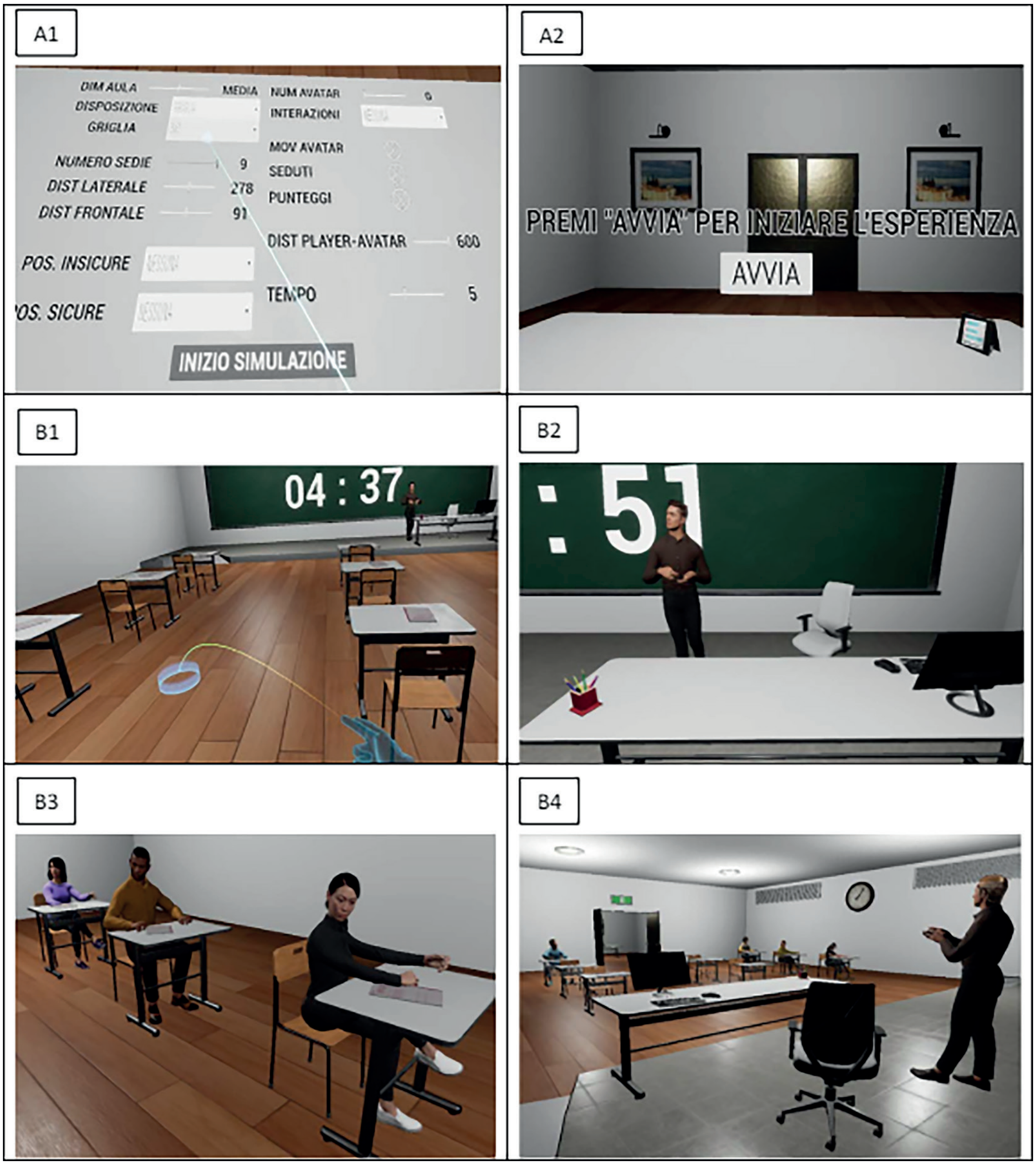

Figure 1. Screenshots from participant's perspective of the experimental conditions. Top row: Presentation mode of the setup (A1) and start of the participant's exposure (A2). Middle row: application of the navigation system founded on teleportation (B1) and detail from the VE in the increasing social exposure condition (B2). Bottom row: Avatar details (B3) and (B4) an overview of the larger room in the condition with decreasing social exposure (B2). For both conditions, participants walked around the room. Scenario characteristics and avatar amounts were performed using the Oculus Quest 2 controller.

the information sheet to read, and after they agreed to continue with the experiment, they were given a consent form to sign, and completed a socio-demographic questionnaire. Then they were asked to performing tasks consisting of grasping objects, interacting with the surrounding environment, moving in the virtual space, and evaluating the credibility and sense of realism of the environment and characters.

The total duration for the VR exposure was about of 50min, including break time, which falls within the suggested maximum duration range for VR sessions (39). The procedures of the specific experiment were as follows. First, the purpose and contents of the experiment were introduced, and the VR tool was explained. The informed consent was also clarified to the participants, including the fact that 1) the questionnaires are anonymous, 2) each session will take approximately 10 minutes, and will be 3 sessions, 3) the purpose of the experiment. Therefore, the participants can take a rest whenever they want to, and 4) participants can finish the experiment freely when they feel severe motion sickness.

Once the headset was on, the participant found oneself in an initial environment in which she/he was asked to turn and move their head to become familiar with the VR device. During the simulation, to prevent them from hitting the walls due to the confined space of the laboratory, the subjects had limited movement space. A fundamental interaction in the VR is navigation. Meta Quest 2 offers a play area of an acceptable size, which permits ecologically valid scenarios and interactions to be developed. Nevertheless, the VR play area is constrained to the limits of the physical space; therefore, it does not allow completely free navigation. A solution was the application of a navigation system developed for teleportation that allows navigation exceeding the limits of the VR play area and provides a greater sense of immersion, a pleasant user experience, and reduces the occurrence of any Virtual Reality Induced Symptoms and Effects (VRISE).

Participants individually performed one of two tasks. Firstly, they were the first to enter an empty classroom, secondly other avatars were already present in the VR scene. During the experience, the participants' bodies, within the visual world, were not visible and their hands were represented with virtual hands, moving synchronously with their own hands. Through the playback of a pre-recorded audio, participants were presented with a series of instructions to follow. First, they were asked to perform an exercise to explore the capabilities and real-time movement of the virtual arms. They were then asked to explore the simulation menu and then take their seat in the classroom. Finally, once the set simulation time expired, the participants were asked to pick up an object placed on the desk in front of them and bring it to the professor's desk.

To minimize the effect of motion sickness, the participants were given a 5-min break between two tasks. The reason for the break time is that motion sickness has often been reported to be severe as the exposure duration increases and has been reported to be severe after using the VR devices for a maximum of 15 min (40). To minimize the effect of the order of the tasks, task progression was counterbalanced among participants. Finally, when the experiment was completed, post-experience tools questionnaires were administered.

Statistical analysis

A score was computed for each dimension, by weighting the scores on the Likert scales of each questionnaires' dimension. Statistical analyses were performed using R (41). As the questionnaires originate from ordinal scales, we performed nonparametric tests for statistical evaluation. Correlations were computed to evaluate the direct relationship between each outcome variable through Spearman's Roh (rs).

Results

Descriptive statistics (Means and Standard Deviations) of the ratings on the three questionnaires is shown in Table 1. As can be seen, the PQ, mean total values exceeded the mid-point of the itemized scale, suggesting that users felt like they were really existing inside the virtual environment (VE). Data gathered reveal that: 1) the participants felt the VE high realistic (Mean = 4.987, SD =1.207), as well as engaged inside it; 2) the VE's sensory factors were very compelling (Mean = 5.676, SD = 1.165), therefore one can infer that the participants felt that their visual and auditory senses, as well as their perception that objects inside the VE were in motion; 3) subjects reported a high capability to analyze the scene (Mean = 6.059, SD = 0.923), i.e., that it is possible examine objects from multiple viewpoints; 4) the VE interaction factors were moderate (Mean = 5.676, SD =1.165), therefore one can infer that the participants believed to have had a satisfactory experience with the VE, and that they were able to control their movement with ease; 5) the users

Table 1. Means and Standard Deviations of the ratings on the three post-experience questionnaires.

	Mean score	Standard Deviation
Presence Questionnaire (PQ)		
Realism	4.987	1.207
Possibility to interact	5.676	1.165
Quality of interface	4.696	1.309
Possibility to examine	6.059	0.923
Self-evaluation of performance	4.588	1.506
Sounds	5.137	1.572
Haptic	5.191	1.333
Immersive Tendencies Questionnaire (ITQ)		
Attentional Focus	5.343	1.392
Involvement	4.343	1.314
Emotions	4.446	1.630
Tendency to play video games	3.373	1.980
NASA-TLX (TLX)		
Mental Demand	3.441	2.033
Physical Demand	3.000	2.045
Temporal Demand	3.265	2.767
Frustration Level	3.912	2.353
Effort	2.764	2.147
Performance	3.912	3.453

could easily concentrate on sounds (Mean = 5.137, SD =1.572), and manipulate objects (Mean = 5.191, SD =1.333). Examining the answers with respect to self-evaluation of performance (e.g.: questions 15 and 16), participants reported that they adjusted to the VE quite quickly (M=4.588; SD=1.506).

Concerning immersion, findings from ITQ indicated that mean total scores exceeded the mid-point of the scale in all sub-dimensions except the tendency to play video games (M=3.373; SD=1.980). Participants reported that they felt easily immersed in movies or tv dramas through an increased focus on what they are doing while being less prone to outside distractions (M=5.343; SD=1.392), when they became involved in several situations (M=4.343; SD=1.630). We evaluated the cognitive workload through the TLX questionnaire (hereafter called the TLX). We can observe that the workload reported by users seems to be very low. Looking at the ratings, the average ranged from an effort of 2.764 (SD=2.147) to a frustration level of 3.912 (SD=2.353). Table 1 also shows that the users' ratings of the TLX dimensions not varied substantially.

Explorative correlations

Table 2 presents the correlation matrix between the study variables, displaying Spearman's coefficient and significance level. To understand how the different aspects of workload relate to other scales, the relationships between the TLX dimensions were analyzed.

Only few dimensions showed correlation with the other measures. Mental Demand has a high positive intercorrelation coefficient with Physical Demand (r = 0.794) whereas Physical Demand is correlated with Temporal Demand (r = 0.744). However, a positive correlation between Mental Demand and Effort (r = 0.625) and Performance (r = 0.642) indicated that the workload was associated with effort and

Table 2. Correlations between the study variables. Spearman's coefficient and significance level are indicated.

Questionnaires' dimensions	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Realism (PQ)	---	0.319	0.359	0.536	0.092	0.192	0.381	-0.071	-0.022	0.030	0.050	-0.251	-0.153	0.004	-0.077	-0.245	-0.165
2. Possibility to interact (PQ)		---	0.182	0.536	0.092	0.192	0.381	-0.071	-0.022	0.030	0.050	-0.362	-0.282	-0.167	-0.372	-0.139	-0.144
3. Quality of interface (PQ)			---	0.344	0.505	0.410	0.510	0.021	0.349	0.233	0.235	0.022	0.132	0.204	-0.015	-0.027	0.040
4. Possibility to examine (PQ)				---	0.254	0.321	0.128	-0.044	0.144	0.083	0.054	-0.333	-0.447	-0.229	-0.029	0.025	-0.072
5. Self-evaluation of performance (PQ)					---	0.266	0.108	0.219	0.275	0.013	0.019	-0.009	0.189	0.121	0.221	0.261	0.153
6. Sounds (PQ)						---	0.242	0.049	0.147	-0.174	-0.049	-0.041	0.025	0.306	0.058	-0.081	0.103
7. Haptics (PQ)							---	-0.181	0.015	0.147	-0.064	-0.169	-0.034	0.145	-0.315	-0.210	0.003
8. Attentional Focus (ITQ)								---	0.606*	0.341	-0.072	0.067	0.197	0.016	0.444	0.078	0.042
9. Involvement (ITQ)									---	0.598	-0.022	-0.033	0.147	0.163	0.420	0.139	0.154
10. Emotions (ITQ)										---	0.030	0.150	0.139	0.088	0.165	0.078	0.036
11. Tendency to play video games (ITQ)											---	0.249	0.223	0.125	0.150	0.426	0.073
12. Mental Demand (TLX)												---	0.794*	0.524	0.376	0.625*	0.642*
13. Physical Demand (TLX)													---	0.744*	0.494	0.554	0.557
14. Temporal Demand (TLX)														---	0.422	0.352	0.649*
15. Frustration Level (TLX)															---	0.409	0.352
16. Effort (TLX)																---	0.619*
17. Performance (TLX)																	---

Note. N = 34. Significance levels $^{**}p < 0.01$, $^{*}p < 0.05$ (two-tailed).

performance. Furthermore, Attentional Focus showed a positive relationship with Involvement (r = 0.606). Finally, Temporal demand is positively linked to Effort (r = 0.649). The presence scale shows no relationship with other dimensions.

Limitations and future studies

This study, however, has some limitations. The implementation of novel technologies may result in more positive responses towards them. Synthetically, our VR scenario seems to deliver a pleasant testing experience without significant VRISE, which is necessary for collecting ecologically valid responses from users. A future study should also include a larger and more diverse population than the sample in this study. Caution is needed when generalizing these findings beyond this study's college student population or other subject areas. Regarding the quality of VR, the future version of the VR scenario should include a VR avatar that corresponds to the user's movements and actions. Also, the integration of better environments, and characters may be beneficial, which will additionally improve the user's experience. VR is not constrained to visual information, as the auditory, haptic, kinesthetic, and olfactory senses can be technologically modelled. Our system did not include audio and haptic feedback to the users during the interactions whereas a virtual environment simulating more sensory modalities has been demonstrated to enhance presence (42). Additionally, high-quality virtual content designs greatly improve VR training experiences.

This is a study of exploratory nature. A clinical trial with comparison groups is needed to verify the effectiveness of VR learning to compare an innovation with a traditional form of learning is appropriate because it allows one to determine if the tested innovation is worth implementing in everyday practice. Without being able to support claims with scientific evidence, one cannot prove that a virtual (or any other) training method is indeed effective. As virtual environments are used to train users to perform real-world tasks and procedures, it is also critical to compare real-world training with VR-based training. In general, real-world training has several limitations, Firstly, it could be time-consuming due to the efforts and time needed to set up the real-world training site and to travel to the site. Secondly, it could be expensive due to the cost of preparing real-world training materials and hiring human coaches. Thirdly, it could be unappealing and unintuitive due to the lack of visual hints such as 3D animations for illustrating skills and processes. We also plan that duration, frequency, and number of sessions of VR-based exercise should be established. Therefore, it can be suitable for future studies and clinical practitioners to compare different duration, frequency, and number of sessions of VR-based exercise for adults.

A last limitation consists in the use of subjective evaluation measures. A more rigorous approach requires the use of some kind of objective method such as psychophysiological indicators encompassing a large range of metrics, including cardiovascular and eye responses, which are among the most widely employed measures across various research domains (43). They can offer the benefits of being continuous, relatively non-invasive, real-time, and, to some extent, an objective assessment.

Conclusion

This study provided substantial support to the feasibility at an affordable cost of the development of an effective immersive VR that allow trainees to learn in the comfort of their personal space. Our findings showed that in complex situation, mental, and physical demand (load dimensions) improved, but our participants reported low mental and physical demand (44). The amount of cognitive load is a way of assessing the level of information being manipulated in working memory. The observed subjective workload is not consistent with the results of Oberhauser et al. (45) who indicated a higher workload in VR whereas correlations agree with a factor analysis suggesting one factor defined by mental demand, temporal demand, and effort (46). Contrary to our expectations, we did not detect evidence of a relationship between presence and performance. This does not conform to the findings of Grassini et al. (27) in which presence and performance were observed to be correlated.

Ethics Committee: REB - Research Ethics Board, protocol number and year 60-2023-N.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors Contribution: LS was the developer of VR scenario; he carried out the experiment. NAB contributed to the methodological aspects and the discussion of the results. OP: contributed to every aspect of this study, analysis, and interpretation of data, and drafting/revising of the manuscript. All authors read and approved the final version of the manuscript.

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