TITLE: Trial of a desktop virtual reality application as a method of exposure for test anxiety: a qualitative study

AUTHORS: Marta Serafini (ORCID: https://orcid.org/0000-0002-1310-1826), Luca Chittaro (ORCID: https://orcid.org/0000-0001-5975-4294)

AFFILIATION: Human-Computer Interaction Lab, University of Udine, via delle Scienze 206, 33100 Udine, Italy

ABSTRACT

Test anxiety involves feelings of discomfort, fear, and worry, impacting students' wellbeing and academic performance. Virtual reality exposure (VRE) shows promise in mitigating test anxiety, but existing applications concern only written exams. Few VRE applications simulate one-on-one interviews with examiners, and applications for public speaking focus on formal presentations before an audience. This paper concerns a trial of a VRE application that deals with oral exams, presenting a qualitative study of a sample of undergraduate students who autonomously used the VRE application in their homes over three weeks. The application exposes students to scenarios in which a virtual examiner displays friendly, partially friendly, or unfriendly behavior while asking questions selected from a pool defined by the student. Participants were interviewed to investigate their perceptions of and experience with the application. Thematic analysis of participants' interviews indicates that they perceived the VRE application as valuable not only for studying and practicing oral exams, but also for handling emotional aspects associated with the exam. Moreover, the application helped to increase confidence and awareness of preparation level among some participants. Finally, the paper describes participants' suggestions emerged from the study that can be used to inform the design of this type of applications.

KEYWORDS: virtual agent, virtual reality, test anxiety, exposure therapy, oral exams, qualitative study

1. INTRODUCTION

Test anxiety is characterized by subjective feelings of discomfort, fear, and worry that individuals experience before, during, and after an evaluative situation conducted by an external authority [1], [2]. This anxious emotional state can negatively affect [3] academic performance and wellbeing of students, and in severe cases can also lead to a social anxiety disorder. It is thus important to investigate techniques to help students cope with the psychological challenges of oral exams and the anxiety they elicit. In this context, virtual reality (VR) could be a promising solution. VR is a "computer-generated digital environment that can be experienced and interacted with as if that environment were real" [4]. VR can be categorized into two types: immersive VR, which isolates users from the real world using special hardware like head-mounted displays, and desktop VR, where the virtual environment is displayed on a standard computer monitor. Immersive VR fully immerses users in the virtual environment to a greater extent than desktop VR, which, in contrast, offers lower degree of immersion [5].

Virtual reality exposure therapy is increasingly used to treat various anxiety disorders (e.g., [6]) using both immersive and desktop VR. It involves exposing individuals to anxiety-inducing situations within a virtual environment over time. Through repeated exposure, individuals experience desensitization, resulting in reduced anxiety levels and a less fearful perception of the situation. Therefore, virtual reality exposure (VRE) applications for test anxiety should provide scenarios that elicit anxious responses in students to facilitate the desensitization process. However, the few existing VRE applications for test anxiety (i.e., TAVE [7] and the systems described in [8], [9]) are focused on simulating written exams, leaving a gap that concerns VRE for oral exams where students have to answer the questions of a virtual examiner. Oral exams elicit higher levels of test anxiety than written tests [10] and are central to the educational systems of some countries, such as Italy [11], [12], Germany [13], and Denmark [14]. Therefore, the availability of VRE applications for oral exams would be beneficial to the wellbeing of a large population of students worldwide.

The literature has proposed several VRE applications to alleviate anxiety related to public speaking (i.e., the formal and prolonged presentation of a speaker to an audience [15]) in students to enhance their ability to give a speech in academic settings (e.g., [16]–[24]). Some studies [18]–[23] have shown the effectiveness of these applications in reducing levels of public speaking anxiety. However, such scenarios are different from those required for test anxiety, which should instead replicate situations experienced by students during school exams. Such situations consists of one-on-one conversations between the student and the examiner without the presence of other individuals. The existing six VRE applications that simulate a one-on-one conversation with a character that asks the user questions [25]–[30] concentrate on reproducing job interview scenarios, using a virtual agent [25]–[29] or a 360° video with a recorded actor [30]. The 360° videos are limited by the fact that the sentences uttered by the character are predetermined [30] while the other applications are limited by the fact that they allow the virtual agent to interact with the user only through the control of another individual, i.e. the Wizard of Oz technique [25]–[29]. Thus, users cannot customize the interaction with the virtual agent according to their specific needs and/or cannot use such applications autonomously. Furthermore, these VRE applications have not been trialed at home by participants: all trials took place only in laboratory settings.

This paper aims to address these limitations, considering a desktop VR application for test anxiety that can be customized by the user and conducting a trial in naturalistic conditions, with a sample of students who freely used the desktop VR application at home for a three-week period. The application exposes students to different oral exam scenarios where a virtual examiner[1] (VX) asks them questions about a given subject while displaying a behavior that can be friendly, partially friendly, or unfriendly. Students use the application autonomously and customize the oral exam simulation to practice on any subject they need by defining a pool of questions from which the VX randomly selects the questions it asks. The study investigated students' perceptions and experience to assess whether the application provided possible benefits to them.

2. RELATED WORK

The literature presents only three VRE applications for test anxiety, involving scenarios that simulate exams [7]–[9]. More specifically, these applications expose users to scenarios representing a student's home before the exam [7]–[9], a journey to the exam place [7], a school entrance [9] or hallway [7], and a classroom where the

[1] The virtual examiner (VX) will be referred to with the pronoun "it" for the rest of the paper.

exam takes place [7]–[9]. Kwon et al. [8] and Alsina-Jurnet et al. [7] conducted user studies showing that their VRE applications are able to elicit anxiety in students. However, these applications focus on simulating written exams, their scenarios do not include the interaction with an examiner who asks questions to the participant as in oral exams. Moreover, a study by Whiteside et al. [31] compared imaginary verbal exposure and VRE for academic performance worry among adolescents, inducing anxiety that diminished with repeated exposures. The immersive VR condition did not simulate an actual exam but exposed students to a negative scenario where they received a failing grade on a written exam, while their classmates performed well.

Studies on applications like the Computerized Oral Proficiency Instrument have explored their feasibility as an alternative method for evaluating oral proficiency in foreign languages (e.g., [32]). These systems were designed as alternatives to traditional exams, with the aim of enhancing the oral assessment experience for students through technology. It should be noted that these systems do not expose students to oral exam simulations but serve as assessment tools to improve the overall evaluation process. A recent case study introduced a 360° video application designed to familiarize students with stages of an oral proficiency exam in the English foreign language (i.e., preparing for the exam, waiting to take the exam, and undergoing the exam interview) [33]. These application has not been assessed on users and is based on a pre-recorded video, which adhere to a predetermined script, thus providing a consistent experience to all the students.

Since, to the best of our knowledge, no trials in the literature have explored applications that simulate an oral exam with a virtual agent, this section focuses more generally on related studies of VRE applications that simulate one-on-one conversations within job interview contexts, where the user answers questions a person asks to assess his/her skills [25]–[30]. All these VRE applications involve first-person interactions where users engage in conversations with a virtual agent that asks work-related questions. In particular, Kwon et al. [27] investigated if the realism of the virtual agent had an impact on participants' anxiety levels during interview simulations. Findings indicated that participants' anxiety was more affected by the behavior of the virtual interviewer than its degree of realism. Four studies were conducted using the same VRE application [25], [26], [28]. Specifically, Hartanto et al. [25] and Morina et al. [26] showed the feasibility of eliciting anxiety through virtual social interactions, while Kampmann et al. [28] compared the VRE application with in vivo exposure therapy and a waitlist control group [28]. Results showed that both treatment groups improved social anxiety levels compared with the waitlist group, with in vivo exposure obtaining better results than VRE. Bouchard et al. [29] compared the same groups using a VRE application that offered participants various scenarios for training: public speaking, job interviews, conversations with supposed relatives, performing under the scrutiny of strangers, handling criticism, or managing insistence situations. Results showed that the VRE application was more effective than in vivo exposure in treating social anxiety. Furthermore, Zainal et al. [30] compared a VRE application that simulated job interviews and informal dinner party scenarios with a waitlist control group. Results showed a greater reduction in social anxiety symptoms, job interview fear, and trait worry among participants who used the VRE application, in comparison to the waitlist control group.

While the studies of Hartanto et al. [25] and Kwon et al. [27] focused exclusively on job interview scenarios, other authors explored different scenarios but none of them addressed oral exams. Among these studies, three involved participants experiencing all scenarios of the VRE application [25], [26], [28], while in the remaining studies, participants chose the scenarios for their training [29], [30].

The studies described in this section have the following aspects in common.

First, none of them concerns trials of VRE applications that simulate oral exams. The availability of such applications might benefit a large population of students worldwide who are affected by test anxiety at different levels of intensity. Indeed, the Organization for Economic Cooperation and Development found in its report on students' wellbeing that 56% of students worldwide experienced high levels of test anxiety, even when adequately prepared for tests [34]. Therefore, our study focuses on a trial of a desktop VR application that deals with oral exams simulations.

Second, the described VRE applications have never been trialed by participants at home and have only been tested in laboratory settings. Therefore, this trial study is conducted under naturalistic conditions, with a sample of students who freely used the desktop VR application at home for three weeks.

Third, the described studies are carried out on applications that require an additional person using the Wizard of Oz technique to control the virtual agent behavior [27], [28], [35], script [26], [28], [29], [35], [36], or response timing [25]. Only one trial involves an application that does not employ this technique, but it consists of 360° videos with actors following a predefined script[30]. In contrast, in our trial users can autonomously engage with the desktop VR application in their home. Indeed, the desktop VR application randomly chooses from a predefined pool of sentences to ask questions during the session or to greet the user at the beginning and end of the session.

Fourth, no existing trial considered applications that allow users to customize their conversations with the virtual agent. On the contrary, our desktop VR application lets users define a pool of questions that can be randomly selected during the simulated oral exam, providing a personalized experience that reflects the topics of their specific exam.

Taking into consideration the above mentioned limitations in the literature, this paper aims to explore students' subjective experiences when using a desktop VR application that simulates oral exams. The research question is how students' perceptions and experiences during exam simulations are influenced by their ability to customize the simulations through the definition of a pool of questions. Furthermore, the study explores whether the use of the desktop VR application may lead to behavioral changes and how these changes might influence the overall students' wellbeing.

3. MATERIALS AND METHODS

The capability of actually eliciting test anxiety of the desktop VR application used in this trial had been assessed in a previous laboratory study [37]. That feasibility study compared three oral exam scenarios with the same preset questions, but the VX respectively displayed friendly, partially friendly, or unfriendly behavior. Results confirmed the capability of the desktop VR application to elicit increasing anxiety levels as the friendliness of the VX behavior decreased. The increasing unfriendliness of the VX was found to elicit three increasingly negative participants' perception of the virtual examiner. Furthermore, the three types of behavior of the VX produced three different, decreasing counts of positive responses elicited (i.e., instants of time when participants felt at ease) and three different, increasing counts of negative responses elicited (i.e., instants of time when participants felt distressed).

The study goal of the current trial was to investigate students' perceptions and experience with our desktop VR application over three weeks. The choice of a three-week study length was made to allow participants to experience each week a different increasing level of difficulty: VX behavior was friendly during the first week, partially friendly during the second week, and unfriendly during the third week.

The study was conducted on a sample of undergraduate students who were asked to use the application at home on their personal computer at least once a week to ensure that they experienced all difficulty levels at least once. Then, they were interviewed at the end of the three weeks. A qualitative rather than quantitative method was chosen to obtain insights from participants because open answers can bring to light nuances in how each user experiences the desktop VR application and help improving the application to make it more useful to users and their wellbeing.

3.1 The desktop VR application

The desktop VR application was developed for Windows and MacOS operating systems, using Unity version 2021.3.3f1. It simulates oral exams scenarios in which students customize the pool of questions they might be asked by the VX. The application is organized in two main parts: exam customization and exam simulation. This section illustrates each of them.

3.1.1 Exam customization

The student customizes the exam simulation by defining the pool of questions through a specific interface that is displayed when the application is launched (Figure 1). For each question, the student can also specify the available time to answer the question, in a range between one and four minutes. By clicking the "Add" button, the question is added to the pool of questions.

Before an exam simulation, the application requires: (i) a microphone test (described in the following), (ii) at least ten questions entered. To ensure that in each simulation of the home trial the VX asked the student about the same number of questions (five) and each session had the same length (12 minutes), we introduced a third requirement: the answer times associated by students to their entered questions had to exhibit a variation, with the maximum difference in the number of questions sharing the same answer time being no more than one.

By clicking the "Confirm" button, the desktop VR application checks compliance with the question and time requirements described above. By clicking the "Start" button, if all requirements above are met, the exam simulation starts. If the microphone test has not been performed, the desktop VR application asks the student to read aloud a neutral sentence ("A square is a geometric figure with four equal sides") while the application analyzes the student's voice volume. The application detects the maximum sound volume and considers 75% of that value as the minimum sound level threshold to determine whether the student is speaking or not.

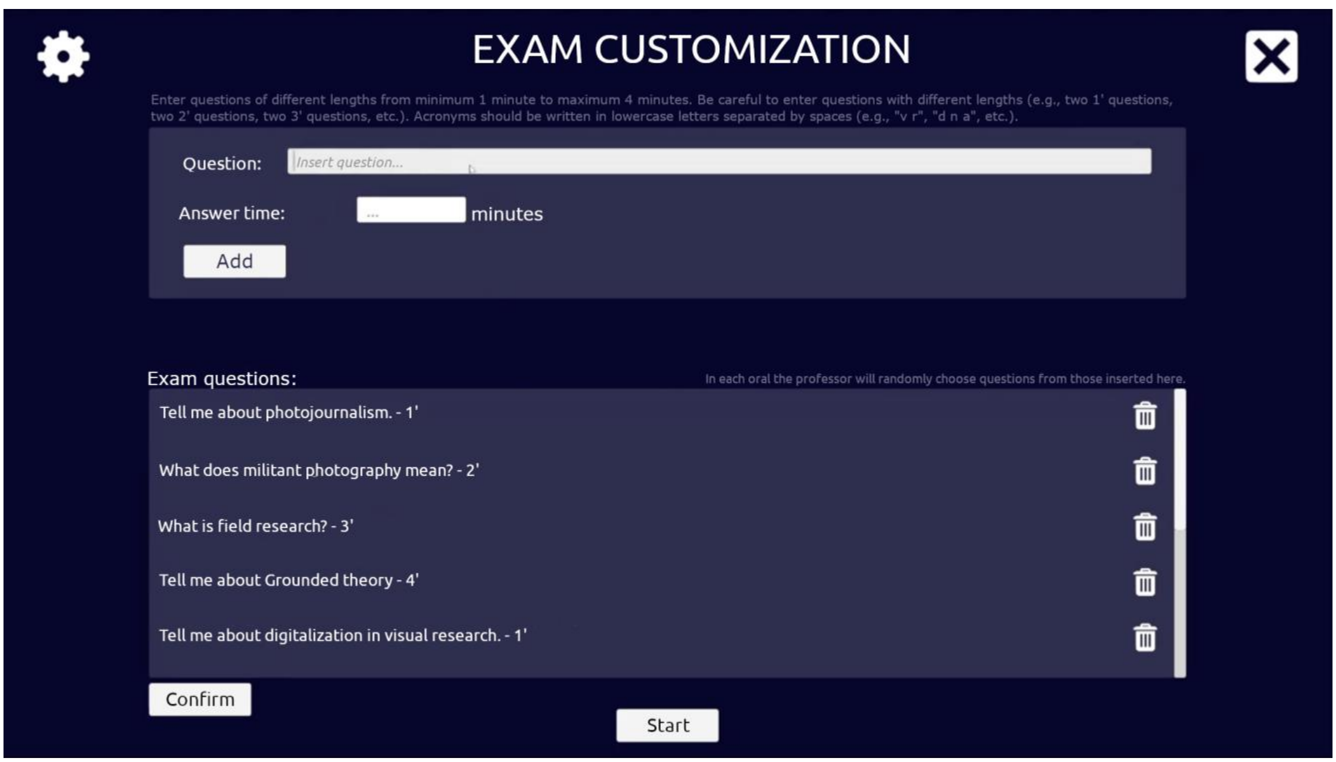

Figure 1. Exam customization in the proposed desktop VR application. For reader's convenience, the original Italian text has been translated here into English.

3.1.2 Exam simulation

In the exam simulation, the student is seated in a virtual office, facing a VX that sits behind a desk, as shown in Figure 2. The 3D model used for the VX is the "Business_Female_03" character from Microsoft Rocketbox library [38]. The VX speaks with the voice called "Elsa (Neural)" in the Azure Cognitive Services text-to-speech (with pitchDelta set to -12).

The simulation offers three levels of difficulty, aiming to elicit three different anxiety levels in users. Each level uses a different set of behaviors performed by the VX, which becomes increasingly less friendly as the level of difficulty increases. In the easiest level, the VX appears to be friendly, e.g., it nods and smiles; in the intermediate level, the VX is partially friendly, e.g., it shakes the head with a neutral facial expression; in the most difficult level, the VX is unfriendly, e.g., it checks the time on its wristwatch with an annoyed expression. The feasibility study of the application [37] provides a detailed description of the full sets of behaviors and shows their capability in eliciting three distinct, increasing anxiety levels.

Each simulation lasts approximately 12 minutes and consists of three steps. First, the VX greets the student and tells him/her to get ready to start with the exam. Second, the VX asks a set of questions chosen from the list defined by the student. Third, the VX informs the student that the exam is over and greets him/her. The questions asked to the student are semi-randomly chosen from the list to ensure that their number is approximately five and the answer times are different. After asking a question, the VX watches the user and, every 15 seconds, performs a behavior, taking it from the set of the selected difficulty, with an 80% chance. In the remaining 20% chance, it remains idle without performing any specific behavior. The behavior of the VX is influenced by the difficulty level, not by the content of the user’s answer. The desktop VR application monitors only the presence or absence of sound from the user’s side. The VX proceeds to the next question if the user remains silent for ten consecutive seconds, or if the available answer time for the current question is exhausted. To detect silence from the participant, the desktop VR application uses the computer microphone to capture sound, excluding any sound below the minimum threshold defined in the microphone test. Once the exam is finished, the desktop VR application displays again the exam customization interface.

Figure 2. Screenshot of the desktop VR application during a simulation session in which the VX has a friendly behavior.

3.2 Participants

The study was approved by the Institutional Review Board of the University of Udine, and involved 32 participants (16M, 16F). They were recruited through email among undergraduate students of the same university. They were invited to test the application on their own computer for three weeks and were informed that the application simulated an oral exam with a virtual examiner, allowing them to customize the questions asked. They were also informed that the application required a Windows or MacOS computer with a microphone and internet connection, and that they could keep the application as compensation for their participation. Participants were sought among those who were going to take an oral exam in the near future, as they could be more representative of the desktop VR application intended users. To ensure this, students who had already completed all the exams in their curriculum were not recruited. Recruitment resulted in the enrollment of 32 students from different faculties, and each of them consented to participate in the evaluation. After using the desktop VR application for three weeks, participants were invited via email to the final interview. Eleven participants could not attend the interview for the following reasons: four did not use the desktop VR application at least once a week as required, due to lack of time; one broke the computer during the evaluation period; and six did not answer the email. The 21 interviewed participants (6M, 15F) filled a demographic questionnaire in which they provided information about their gender, age range, and the number of oral exams they took during their university studies (Table 1).

Participant	Gender	Age range	Number of oral exams
P1	Female	18-20	4
P2	Male	21-23	4
P3	Female	35+	16
P4	Male	18-20	2
P5	Male	21-23	20
P6	Male	21-23	12
P7	Male	24-26	17
P8	Female	18-20	2
P9	Male	21-23	6
P10	Female	21-23	9
P11	Female	21-23	15
P12	Female	21-23	5
P13	Male	21-23	22
P14	Female	21-23	8
P15	Female	35+	10
P16	Male	18-20	6
P17	Male	21-23	10
P18	Female	24-26	6
P19	Male	21-23	5
P20	Female	24-26	11
P21	Female	35+	2

Table 1. Gender, age range, and number of oral exams of the interviewed participants.

3.3 Procedure

This study was conducted during the June-July exam period at our university to allow participants using the desktop VR application in the preparation of the oral exams they intended to take in that session.

Participants sent their signed informed consent via email and received the desktop VR application through a link provided via email. The study included two meetings with participants, one at the beginning and one at the end of the three weeks of use of the desktop VR application. To facilitate participation, the meetings were conducted remotely. In the first meeting, participants were individually contacted via video call. They were informed that the study aimed to evaluate an application that virtually exposes students to the oral exam before taking the actual exam with a real professor. They were instructed about how to use the application to experience simulated oral exams conducted in their language, i.e., Italian. They were invited to use the application when they preferred, but asked to ensure a minimum usage of at least once a week as the application automatically advanced its level on a weekly basis, presenting a virtual examiner whose behavior became progressively more challenging to engage with. The participant was also briefed about the anonymity of the collected data. Then, the experimenter assigned the participant a randomly generated ID code and a password to use the desktop VR application. The ID code was also used to save participants' data and guarantee that the trial would increase in difficulty each week, starting from the initial day of system usage over three weeks. The association between a code and the name of the participant was not saved by the experimenter to guarantee participant's privacy. At first access, after entering credentials, participants filled the demographic questionnaire, displayed within the desktop VR application. Then, they were told that the experimenter remained available to clarify any doubts. They were also informed that, after the three-week period, the desktop VR application was going to stop working, and they were going to be contacted for the final interview.

At the end of the three-week period, participants were individually video called for the second meeting. Participants were interviewed following a semi-structured approach to gather information about their experience (see Table 2 for the interview protocol). If necessary, further questions were asked to examine interesting issues spontaneously raised by participants. After participants' consent, the interviews were recorded and were saved with the assigned ID code to ensure participants' privacy. At the end of the interview, participants were thanked for their participation and their ID code was permanently reactivated as they could keep the desktop VR application as compensation.

1	For three weeks, you freely used the application to simulate oral exams. How did you use the application?
2	How was your experience with the application?
3	How did you feel and what did you think when you were using the application?
4	Do you think that these three weeks of using the application have affected you in any aspect?
5	In light of the three weeks of use, what is your opinion of the application?
6	What do you think are the pros and cons of the application?
7	Is there anything you would change or improve in the application?
8	The application increased the level of difficulty every week. Have you noticed any changes from week to week?

Table 2. Interview protocol. The interview was conducted in the participants' language (Italian); for reader's convenience, all items have been translated here into English.

3.4 Qualitative data analysis

The collected interviews resulted in 186 minutes of audio recordings that were transcribed verbatim. Then, following the method in [39], a thematic analysis was conducted to analyze transcripts, identifying and organizing common and prominent themes. The analysis involved: (i) reading the transcripts multiple times to familiarize with the data, (ii) coding interesting features in the transcripts and collating relevant data for each code, (iii) grouping all codes into potential themes, collecting all pertinent data for each potential theme, organizing themes into levels (e.g., main themes or sub-themes within them), and dividing large or complex themes into one or more sub-themes, (iv) defining the significance of the themes and sub-themes concerning the coded extracts and all transcripts, (v) refining each theme and subtheme, generating clear definitions and names.

The first author of the paper conducted these steps and coded the data. However, since the process of defining and applying the codes can be biased by subjective interpretation, the validity and reliability of the themes identified must be verified [40]. Therefore, following [41], an external independent coder, not involved in the authors' research, also coded the data using a provided codebook that included the themes and sub-themes identified with the thematic analysis. For each code, the codebook provided a label, a full definition, and an example extracted from the transcripts. The independent coder was informed that he could use multiple codes to the same text fragment. Coding was performed by the two coders with Taguette [42], an open-source web-based Computer Assisted Qualitative Data Analysis Software (CAQDAS).

4. RESULTS

The level of agreement among coders was assessed using Cohen's kappa [43], [44]. The overall kappa coefficient was 0.72, which indicates substantial agreement [45]. The results of the thematic analysis are organized into three topic areas:

- *Application*: themes related to desktop VR application features (Table 3);
- *Influence on the user*: themes related to aspects of the desktop VR application that have influenced the user in some way (Table 4);
- *Suggestions*: themes capturing participants' suggestions for enhancing the desktop VR application (Table 5).

A full description of the thematic analysis with sample extracts from the interviews is provided in Supplementary Material S1.

Theme	Sub-theme	Description	Participants
Merits	Exam preparation	The desktop VR application supports exam preparation both as a study method and in managing emotional aspects	P1, P4, P5, P6, P8, P9, P11, P12, P14, P15, P17
	Virtual human	The VX is a virtual human who listens to participants	P3, P5, P13, P15, P19
	Ease of use	The VRE application is simple to use	P7, P10, P18
	Silence detection	The VX moves on to the next question when the participant remains silent	P3, P8, P9, P15, P21
	VX way of speaking	The VX speaks in an appropriate and varied way	P11, P20
	Oral presentation	The desktop VR application trains participants to give oral presentations	P4, P6, P8, P12, P15, P17, P19, P21
	Customization of questions and answer time	The desktop VR application supports the customization of questions and answer times	P11, P15, P16, P17, P21
	Random-order questions	The VX asks questions in random order	P1, P3, P10, P13
Critiques	Answer time	Specific aspects of question answer time are criticized (e.g., the length of the maximum answer time)	P1, P4, P6, P14
	Questions balancing	Specific aspects of questions balancing are criticized (e.g., excessive constraints)	P2, P4, P5, P7, P10, P11, P13, P19, P20
	Graphical aspects	Specific graphical aspects are criticized (e.g., the look of the VX)	P9, P20, P21
	Interactivity	The level of interaction with the VX is low	P3, P16
Perception of difficulty level change	VX behavior	Participants perceived that the VX behavior changed over time	P1, P3, P5, P9, P10, P11, P12, P15
	Conversation pace	Participants perceived that the pace of conversation with the VX increased over time	P3, P4, P7, P17
	None	Participants perceived no change in the difficulty level over the three weeks	P2, P6, P8, P13, P16, P18, P19, P20, P21, P14

Table 3. Themes and sub-themes of the *Application* topic area.

Theme	Sub-theme	Description	Participants
Attitudes and behaviors	Awareness	The desktop VR application helped participants become more aware of their level of preparation for the exam	P1, P4, P11, P12, P14, P15
	Confidence	The desktop VR application helped participants feel more confident about the exam	P8, P10, P15
	Attention to language production	The desktop VR application led participants to pay more attention to language production during the oral exam simulation	P5, P11
	Encouragement to study	The desktop VR application motivated participants to study more	P2, P5, P9, P19
	None	Participants perceived no changes in themselves while using the VRE application	P3, P7, P13, P16, P18, P20, P21
Emotions and feelings	Emotion enhancement	While using the desktop VR application, participants experienced different emotions that improved over time	P8, P11, P15
	Feeling of real exam	When using the desktop VR application, participants experienced a feeling similar to taking a real exam	P1, P14
	Less anxiety	When using the desktop VR application, participants experienced reduced anxiety compared to what they feel during a real oral exam	P6, P18
	Time pressure	When using the desktop VR application, participants felt time pressure in answering the VX questions	P3, P14
	Tranquility	While using the desktop VR application, participants felt quiet	P2, P10, P11, P17, P20
	Comfort	When using the desktop VR application, participants felt at ease	P4, P8, P15, P16, P20
	Focus	When using the desktop VR application, participants were focused on the oral exam simulation	P2, P5, P19
	Oddity of talking with a virtual character	While using the desktop VR application, participants felt odd talking with the VX	P8, P12
Real experience		Participants report a real-life experience of how the use of the desktop VR application has affected their lives	P1, P9, P11

Table 4. Themes and sub-themes of the "Influence on the user" topic area.

Theme	Sub-theme	Description	Participants
Exam simulation	Artificial Intelligence	Add artificial intelligence to the VX to enhance the quality of conversations	P6, P16
	Move on to the next question	Provide alternative ways to move on to the next question	P8, P13
	Timer	Add a visible timer to track the elapsed answer time or the time spent in silence by participants	P3, P9
	Exam length	Increase the exam length	P6, P15
	Answer analysis	Add the recognition of the correctness of participants' answers	P2, P3, P21
	New features	Add specific new features to the exam simulation section	P2, P9, P17
Exam customization	New features	Add specific new features to the exam customization section	P7, P9, P12
	Answer time	Change specific aspects of answer time of questions	P3, P4, P6, P14, P15
	Questions balancing	Make the questions balancing constraints less rigid	P2, P4, P11, P13, P19, P20

Table 5. Themes and sub-themes of the *Suggestions* topic area.

In the final interview, some participants also provided details regarding their usage frequency of the application. They reported using it three times weekly (n=2), twice (n=2), or once a week and a few hours or days before the actual exam (n=2). Some participants also stated that they used the application to prepare for a single exam (n=8) or multiple exams (n=3).

The application received overall positive feedback (n=20). Participants highlighted its utility as a study method (n=11) and its merits for training in oral presentations (n=8) and in coping with emotions during exams (n=6). Positive aspects included customizable questions and answer times (n=5), detection of silence (n=5), interaction with the VX (n=4), user-friendly interface (n=3), and the way the VX spoke (n=2). However, 16 participants also expressed dissatisfaction with certain aspects of the application, citing rigidity of the question balancing requirements (n=9), answer time constraints (n=4), the look of the VX, the virtual environment, or the application (n=3), and limited interactivity of the VX (n=2). Eight participants noted changes in the VX behavior as the difficulty level increased or observed an accelerated conversation pace (n=4), while others observed no change (n=10).

Regarding influence on users, participants noted positive changes in awareness of their preparation level (n=6), study motivation (n=4), self-confidence (n=3), and presentation quality (n=2). Regarding emotions, some users reported feeling calm (n=5), at ease (n=5), or focused (n=3) during application use, with a few experiencing enhanced emotions over time during exam simulations (n=3). A few participants experienced the feeling of a real exam (n=2) or felt less anxiety than during a real exam (n=2). A few felt time pressure (n=2) or found it odd to talk to a virtual character (n=2). Three participants shared experiences in which the application positively affected their real exam performance.

Seventeen participants suggested improvements, including increased flexibility in entering questions (n=6) and answer times (n=5), new features such as recognizing the correctness of user's answers (n=3), alternative ways to move to the next question (n=2), a timer that indicates silences or time elapsed in answering the current question (n=2), integration of artificial intelligence to enhance conversations quality (n=2), and the extension of the total simulation duration (n=2).

6. DISCUSSION

Overall, the analysis of the interviews suggests that the desktop VR application might provide a valuable assistance to students in developing emotional skills to cope effectively with oral exams. Indeed, several participants reported benefits in this regard (n=9), noting improvements in awareness (n=6) and confidence (n=3). The improvement in participants' confidence and awareness is consistent with findings from a previous study where exposure to various social scenarios within a VRE application, including a job interview with a group of virtual interviewers, heightened participants' confidence [46]. In addition, three participants noted an improvement in their emotional state over time during the simulations, moving from an initial agitation to a gradual increase in confidence (e.g., "*The first times it felt a little strange because I knew that I was talking by myself, to a certain extent. After a while, the last week in particular, I felt more confident in the presentation and the last time [I felt] less pressure than the other times*"-P8). This improvement over time was also found in a previous study showing that exposure to verbal interactions with virtual agents leads to increased self-efficacy [47].

The desktop VR application was also considered effective as a study method (n=11), serving as a valuable tool for practicing oral presentation (n=8), promoting heightened attention to language production (n=2), and fostering increased study motivation (n=4). These aspects support the effectiveness of the desktop VR application in providing users with exam simulations similar to real-world situations. The customization of questions and their randomized presentation by the VX contributes to this realism, allowing users to train within a safe environment to develop cognitive skills, identify areas for improvement and address knowledge gaps.

The thematic analysis revealed key themes related to the features of the desktop VR application: question balancing (n=9), customization of questions and answer times (n=9), silence detection (n=5), and the presence of a virtual human (n=5). Regarding the customization of answer times, three participants found it beneficial to foster time-management skills, trying to answer exhaustively within the set time without exceeding it. In contrast, four participants found it restrictive and suggested either removing (n=1) or extending (n=4) the maximum answer time. Furthermore, nine participants expressed reservations about the question balancing requirement, and six of them would make it more flexible. It should be noted that both answer time and question balancing were added to the system for experimental purposes to guarantee that each session in the trial contained about five questions in a 12-minute simulation session. The regular version of the desktop VR application does not need to enforce balancing requirements. However, considering the appreciation of some users regarding the requirement of setting an answer time to each question, it is worth keeping it as an optional feature to enhance user customization.

Participants appreciated the silence detection feature. One participant found it beneficial in preventing wasted time, while the other four highlighted its utility in increasing awareness of silent intervals while thinking of responses (e.g., "*I have seen that when I finish a topic or if I don't know what to answer, [the VX] goes to the next question in ten seconds. […] During the oral exam, it seemed even less [seconds], because maybe if I was hesitant for a moment, it seemed like three seconds had passed and instead it [the VX] changed the question. So, this is another hint because it means that I am thinking too long*"-P3). This result is unexpected, as the original goal of silence detection was to facilitate the transition to the next question when the student had nothing more to say and a considerable amount of time remained available for that response. It suggests that silence detection may help improve students' awareness of their silence durations, helping in learning to answer more promptly to show greater preparation and confidence.

Participants also acknowledged the value of a virtual human presence, as they perceived that the VX was listening to them. This perception could foster a sense of trust between the student and the VX, thereby enhancing the student's perception that the VX cares about his/her educational progress, which is important to the student's overall wellbeing [48].

The emotions and feelings reported by participants, such as focus during the exam simulation, the sense of time pressure, and the feeling of a real exam, suggest that the desktop VR application can effectively simulate exams by eliciting emotions similar to those experienced during real exams. This is consistent with previous research showing that VR is a valuable tool for simulating written exams and eliciting emotional responses in students with high test anxiety [7]. Among the various emotions reported by participants, two of them explicitly mentioned experiencing less anxiety than a real exam. This result was expected as it is consistent with the study by Valls-Ratés et al. [22], which showed that a virtual audience in a VRE application for public speaking anxiety elicited lower anxiety levels than a real audience while effectively reducing anxiety levels in participants.

Eight participants noticed that the VX friendliness decreased over time. Since individuals may emotionally react to the behaviors of virtual agents [49], participants' awareness of these changes is noteworthy. The desktop VR application may influence participant's emotional state by adjusting VX behaviors positively or negatively [36]. Interestingly, four participants perceived that the VX moved quicker to the next question as the difficulty increased, although this did not actually happen. This fact motivates further research because it suggests that the unfriendly behavior of the VX may give participants the illusion that the VX is increasing the conversation pace.

Considering that three participants expressed reservations about the appearance of the VX or the virtual environment, future VRE applications for oral exams might consider allowing users to customize the appearance of the VX and the virtual environment. However, it should be kept in mind that an excessively detailed replication of the real professor's office is unnecessary for the exposure scenario to achieve effective results [50].

The thematic analysis presented in Section 4 (with more details in the supplementary materials) enabled the collection of numerous comments and suggestions that may be valuable in guiding the design of VRE applications for test anxiety. The gathered suggestions indicate participants' desire for an application providing comprehensive support for exam preparation through an intelligent VX. The VX would assess the correctness of participants’ answers (n=3) and propose additional questions based on their answers to previous questions (n=2). Other novel features were also suggested, such as recording sessions for later review (n=1), including a visible timer in the virtual environment to monitor elapsed time (n=2), and using a webcam to capture the participant during the exam simulation to intensify the feeling of being observed and elicit a higher level of anxiety, as one can experience during a real remote oral exam (n=2). Another participant suggested adding an always visible chat window in which a virtual audience of students would comment on the participant’s oral presentation to amplify his/her anxiety about giving a bad impression (n=1). Overall, the suggestions underscore participants' interest in an application that contributes to their comprehensive oral exam preparation, offering scenarios capable of eliciting anxiety to train them to manage their emotions and thus increase their overall wellbeing.

Real-life experiences shared by three participants provide further insight. For example, one participant highlighted the VX effectiveness in practicing the handling of negative facial expressions, citing the VX accurate replication of a professor’s expressions. She found this training beneficial during a real oral exam where the professor exhibited behaviors similar to those experienced in the desktop VR application (e.g., “*It just happened [after using the application] to me on an oral exam that the professor who made facial expressions while I was speaking. Since […] I was used to taking exams with a mask [because of Covid-19], this exam was different because it was the first one I took without wearing a mask, but I was already prepared [to handle different professor moods]. With the mask, the professor can make all the faces he wants and you can’t see them anyway, while [in this case] I could see them. So, the application helped me in this thing when it then actually happened [in the real exam])*” (P1). Another student reported receiving during a real exam some questions identical to the ones he had entered into the application. Another student reported that by using the VR application, she gradually gained confidence and calmness during exam simulations, and she thought this positively impacted the actual exam result, in which she scored high. This outcome is consistent with an earlier study in which students who practiced for a public presentation by speaking in front of an audience tended to outperform those who practiced alone [51].

To summarize, insights gathered from interviews suggest several features and aspects that participants would like to find in VRE applications for test anxiety focused on oral exams. Such applications should allow users to customize the pool of questions they wish to use for their training, giving them the freedom to decide whether to set an answer time for each question. The questions should be proposed in random order by the VX, and users should decide the total duration of the simulation, the difficulty level of the behavior the VX should display, and the number of anxiety-provoking elements in the virtual environment (e.g., a readable timer on the VX desk). Finally, the desktop VR application should include a feature to detect when users remain silent.

A limitation of our study lies in the absence of quantitative data regarding the duration of application usage by each participant, since we relied only on spontaneously self-reported data provided by participants during the final interviews. Future studies will incorporate automatic logging methods to precisely quantify the application usage, and other possible user's behaviors. This enhancement should aim to facilitate a more comprehensive assessment of the influence that application usage may have on participants' perceptions and feedback.

7. CONCLUSIONS

This paper presented the first trial of a desktop VR application for test anxiety focused on oral exams. The participating students freely used the application at home for three weeks and were interviewed at the end of the trial. Thematic analysis of the interviews indicates that the desktop VR application may be a valuable tool in helping students to develop emotional and cognitive skills for coping successfully with oral exams. The desktop VR application provides a safe environment that can positively impact users' confidence, awareness of their preparation, and encouragement to study. Experiences shared by participants reinforce the perceived usefulness of the desktop VR application. Since the desktop VR application works with hardware that is more commonly available, it should be accessible to a wide range of individuals. Conversely, a head-mounted display would restrict access to the application only to the minority who currently owns such a device.

Based on the encouraging results of the present study, two main future steps have been identified for the project: (i) introducing several suggested improvements into the desktop VR application, and (ii) conducting a quantitative study with the inclusion of a waitlist control group, to assess in detail the effects of the desktop VR application on students' test anxiety, self-efficacy, and wellbeing.

DISCLOSURE OF INTEREST

The authors report there are no competing interests to declare.

REFERENCES

[1] S. Irwin G., "Introduction to the study of test anxiety," in *Test-anxiety: Theory, research and application*, Hillsdale, NJ: Lawrence Erlbaum Assoc Incorporated, 1980, pp. 57–78.

[2] M. Zeidner, *Test Anxiety: The State of the Art*. Springer Science & Business Media, 1998.

[3] I. G. Sarason, "Test anxiety and intellectual performance.," *The Journal of Abnormal and Social Psychology*, vol. 66, no. 1, pp. 73–75, Jan. 1963, doi: 10.1037/h0047059.

[4] J. Jerald, *The VR Book: Human-Centered Design for Virtual Reality*. Morgan & Claypool, 2015.

[5] F. Pallavicini, A. Pepe, and M. E. Minissi, "Gaming in Virtual Reality: What Changes in Terms of Usability, Emotional Response and Sense of Presence Compared to Non-Immersive Video Games?," *Simulation & Gaming*, vol. 50, no. 2, pp. 136–159, Apr. 2019, doi: 10.1177/1046878119831420.

[6] E. Carl *et al.*, "Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials," *Journal of Anxiety Disorders*, vol. 61, pp. 27–36, 2019, doi: 10.1016/j.janxdis.2018.08.003.

[7] I. Alsina-Jurnet, C. Carvallo-Beciu, and J. Gutiérrez-Maldonado, "Validity of virtual reality as a method of exposure in the treatment of test anxiety," *Behavior Research Methods*, vol. 39, no. 4, pp. 844–851, Nov. 2007, doi: 10.3758/BF03192977.

[8] J. H. Kwon, N. Hong, K. (Kenny) Kim, J. Heo, J.-J. Kim, and E. Kim, "Feasibility of the Virtual Reality Program in Managing Test Anxiety: A Pilot Study," *Cyberpsychology, Behavior, and Social Networking*, vol. 23, no. 10, pp. 715–720, Oct. 2020, doi: 10.1089/cyber.2019.0651.

[9] D. Luo, X. Deng, Y. Luo, and G. Wang, "Design and Implementation of Virtual Examination System Based on Unity 3D," in *Proceedings of the 2019 International Conference on Artificial Intelligence and Advanced Manufacturing*, in AIAM 2019. New York, NY, USA: Association for Computing Machinery, Ottobre 2019, pp. 1–8. doi: 10.1145/3358331.3358404.

[10] J. R. Sparfeldt, D. H. Rost, U. M. Baumeister, and O. Christ, "Test anxiety in written and oral examinations," *Learning and Individual Differences*, vol. 24, pp. 198–203, Apr. 2013, doi: 10.1016/j.lindif.2012.12.010.

[11] S. Pastore and M. Pentassuglia, "Teachers' and students' conceptions of assessment within the Italian higher education system," *Practitioner Research in Higher Education*, vol. 10, no. 1, Art. no. 1, Oct. 2016.

[12] I. Rosalind, "Italian education: Between reform and restoration," in *Education and Europe: The politics of austerity*, London, UK: Radicaled Books, 2013, pp. 55–85.

[13] B. M. Kehm, "Oral Examinations at German Universities," *Assessment in Education: Principles, Policy & Practice*, vol. 8, no. 1, pp. 25–31, Mar. 2001, doi: 10.1080/09695940120033234.

[14] H. L. Andersen and S. M. Cozart, "Assessment Methods and Practices in Higher Education in Denmark," *Assessment Methods and Practices in Higher Education in Denmark*, 2014.

[15] D. D. Sellnow, *Confident public speaking*, 2nd ed. Belmont, CA: Thomson/Wadsworth, 2005.

[16] A. Davis, D. L. Linvill, L. F. Hodges, A. F. Da Costa, and A. Lee, "Virtual reality versus face-to-face practice: a study into situational apprehension and performance," *Communication Education*, vol. 69, no. 1, pp. 70–84, Jan. 2020, doi: 10.1080/03634523.2019.1684535.

[17] M. Denizci Nazligul *et al.*, “Interactive three-dimensional virtual environment to reduce the public speaking anxiety levels of novice software engineers,” *IET softw.*, vol. 13, no. 2, pp. 152–158, Apr. 2019, doi: 10.1049/iet-sen.2018.5140.
[18] S. Kahlon, P. Lindner, and T. Nordgreen, “Virtual reality exposure therapy for adolescents with fear of public speaking: a non-randomized feasibility and pilot study,” *Child and Adolescent Psychiatry and Mental Health*, vol. 13, no. 1, p. 47, Dec. 2019, doi: 10.1186/s13034-019-0307-y.
[19] F. Sarpourian, T. Samad-Soltani, K. Moulaei, and K. Bahaadinbeigy, “The effect of virtual reality therapy and counseling on students’ public speaking anxiety,” *Health Science Reports*, vol. 5, no. 5, 2022, doi: 10.1002/hsr2.816.
[20] S. Stupar-Rutenfrans, L. E. H. Ketelaars, and M. S. van Gisbergen, “Beat the Fear of Public Speaking: Mobile 360° Video Virtual Reality Exposure Training in Home Environment Reduces Public Speaking Anxiety,” *Cyberpsychology, Behavior, and Social Networking*, vol. 20, no. 10, pp. 624–633, Oct. 2017, doi: 10.1089/cyber.2017.0174.
[21] R. E. Sülter, P. E. Ketelaar, and W.-G. Lange, “SpeakApp-Kids! Virtual reality training to reduce fear of public speaking in children – A proof of concept,” *Computers & Education*, vol. 178, p. 104384, Mar. 2022, doi: 10.1016/j.compedu.2021.104384.
[22] I. Valls-Ratés, O. Niebuhr, and P. Prieto, “Unguided virtual-reality training can enhance the oral presentation skills of high-school students,” *Frontiers in Communication*, vol. 7, 2022, doi: 10.3389/fcomm.2022.910952.
[23] T. F. Wechsler, M. Pfaller, R. E. van Eickels, L. H. Schulz, and A. Mühlberger, “Look at the Audience? A Randomized Controlled Study of Shifting Attention From Self-Focus to Nonsocial vs. Social External Stimuli During Virtual Reality Exposure to Public Speaking in Social Anxiety,” *Frontiers in Psychiatry*, vol. 12, 2021, Accessed: Oct. 06, 2022. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fpsyt.2021.751272
[24] Y. Glémarec, J.-L. Lugrin, A.-G. Bosser, C. Buche, and M. E. Latoschik, “Controlling the Stage: A High-Level Control System for Virtual Audiences in Virtual Reality,” *Frontiers in Virtual Reality*, vol. 3, 2022, doi: 10.3389/frvir.2022.876433.
[25] D. Hartanto, I. L. Kampmann, N. Morina, P. G. M. Emmelkamp, M. A. Neerincx, and W.-P. Brinkman, “Controlling social stress in virtual reality environments,” *PLoS ONE*, vol. 9, no. 3, p. e92804, 2014, doi: 10.1371/journal.pone.0092804.
[26] N. Morina, W.-P. Brinkman, D. Hartanto, and P. M. G. Emmelkamp, “Sense of presence and anxiety during virtual social interactions between a human and virtual humans,” *PeerJ*, vol. 2014, no. 1, p. e337, 2014, doi: 10.7717/peerj.337.
[27] J. H. Kwon, A. Chalmers, S. Czanner, G. Czanner, and J. Powell, “A study of visual perception: Social anxiety and virtual realism,” presented at the Proceedings - SCCG 2009: 25th Spring Conference on Computer Graphics, 2009, pp. 167–172. doi: 10.1145/1980462.1980495.
[28] I. L. Kampmann, P. M. G. Emmelkamp, D. Hartanto, W.-P. Brinkman, B. J. H. Zijlstra, and N. Morina, “Exposure to virtual social interactions in the treatment of social anxiety disorder: A randomized controlled trial,” *Behaviour Research and Therapy*, vol. 77, pp. 147–156, 2016, doi: 10.1016/j.brat.2015.12.016.
[29] S. Bouchard *et al.*, “Virtual reality compared with in vivo exposure in the treatment of social anxiety disorder: A three-arm randomised controlled trial,” *British Journal of Psychiatry*, vol. 210, no. 4, pp. 276–283, 2017, doi: 10.1192/bjp.bp.116.184234.
[30] N. H. Zainal, W. W. Chan, A. P. Saxena, C. B. Taylor, and M. G. Newman, “Pilot randomized trial of self-guided virtual reality exposure therapy for social anxiety disorder,” *Behaviour Research and Therapy*, vol. 147, p. 103984, Dec. 2021, doi: 10.1016/j.brat.2021.103984.
[31] S. P. H. Whiteside *et al.*, “The feasibility of verbal and virtual reality exposure for youth with academic performance worry,” *Journal of Anxiety Disorders*, vol. 76, p. 102298, Dec. 2020, doi: 10.1016/j.janxdis.2020.102298.
[32] D. M. Kenyon and V. Malabonga, “Comparing examinee attitudes toward computer-assisted and other oral proficiency assessments,” *Language Learning & Techology*, vol. 5, no. 2, 2001.

[33] V. Eisenlauer and D. Sosa, “Pedagogic Meaning-Making in Spherical Video-Based Virtual Reality – a Case Study from the EFL Classroom,” vol. 14, no. 1, Art. no. 1, Oct. 2022, doi: 10.16993/dfl.191.
[34] OECD, “Are students happy?: PISA 2015 results: students’ well-being,” OECD, Paris, Apr. 2017. doi: 10.1787/3512d7ae-en.
[35] M. B. Powers, N. F. Briceno, R. Gresham, E. N. Jouriles, P. M. G. Emmelkamp, and J. A. J. Smits, “Do conversations with virtual avatars increase feelings of social anxiety?,” *Journal of Anxiety Disorders*, vol. 27, no. 4, pp. 398–403, May 2013, doi: 10.1016/j.janxdis.2013.03.003.
[36] C. Qu, W.-P. Brinkman, Y. Ling, P. Wiggers, and I. Heynderickx, “Conversations with a virtual human: Synthetic emotions and human responses,” *Computers in Human Behavior*, vol. 34, pp. 58–68, May 2014, doi: 10.1016/j.chb.2014.01.033.
[37] L. Chittaro and M. Serafini, “Desktop virtual reality as an exposure method for test anxiety: quantitative and qualitative feasibility study,” *Multimed Tools Appl*, Sep. 2023, doi: 10.1007/s11042-023-16917-2.
[38] M. Gonzalez-Franco *et al.*, “The Rocketbox Library and the Utility of Freely Available Rigged Avatars,” *Front. Virtual Real.*, vol. 1, p. 561558, Nov. 2020, doi: 10.3389/frvir.2020.561558.
[39] V. Braun and V. Clarke, “Using thematic analysis in psychology,” *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, Jan. 2006, doi: 10.1191/1478088706qp063oa.
[40] G. Guest, K. M. MacQueen, and E. E. Namey, *Applied Thematic Analysis*. SAGE Publications, 2011.
[41] J. T. DeCuir-Gunby, P. L. Marshall, and A. W. McCulloch, “Developing and Using a Codebook for the Analysis of Interview Data: An Example from a Professional Development Research Project,” *Field Methods*, vol. 23, no. 2, pp. 136–155, May 2011, doi: 10.1177/1525822X10388468.
[42] R. Rampin and V. Rampin, “Taguette: open-source qualitative data analysis,” *JOSS*, vol. 6, no. 68, p. 3522, Dec. 2021, doi: 10.21105/joss.03522.
[43] J. Cohen, “Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit,” *Psychological Bulletin*, vol. 70, no. 4, pp. 213–220, 1968, doi: 10.1037/h0026256.
[44] J. Cohen, “A Coefficient of Agreement for Nominal Scales,” *Educational and Psychological Measurement*, vol. 20, no. 1, pp. 37–46, Apr. 1960, doi: 10.1177/001316446002000104.
[45] J. R. Landis and G. G. Koch, “The Measurement of Observer Agreement for Categorical Data,” *Biometrics*, vol. 33, no. 1, pp. 159–174, 1977, doi: 10.2307/2529310.
[46] H. E. Kim, Y.-J. Hong, M.-K. Kim, Y. H. Jung, S. Kyeong, and J.-J. Kim, “Effectiveness of self-training using the mobile-based virtual reality program in patients with social anxiety disorder,” *Computers in Human Behavior*, vol. 73, pp. 614–619, 2017, doi: 10.1016/j.chb.2017.04.017.
[47] N. Morina, W.-P. Brinkman, D. Hartanto, I. L. Kampmann, and P. M. G. Emmelkamp, “Social interactions in virtual reality exposure therapy: A proof-of-concept pilot study,” *Technology and Health Care*, vol. 23, no. 5, pp. 581–589, 2015, doi: 10.3233/THC-151014.
[48] A. J. Cavanagh, X. Chen, M. Bathgate, J. Frederick, D. I. Hanauer, and M. J. Graham, “Trust, Growth Mindset, and Student Commitment to Active Learning in a College Science Course,” *LSE*, vol. 17, no. 1, p. ar10, Mar. 2018, doi: 10.1187/cbe.17-06-0107.
[49] E. Klinger *et al.*, “Virtual Reality Therapy Versus Cognitive Behavior Therapy for Social Phobia: A Preliminary Controlled Study,” *CyberPsychology & Behavior*, vol. 8, no. 1, pp. 76–88, Feb. 2005, doi: 10.1089/cpb.2005.8.76.
[50] G. M. Lucas *et al.*, “Customizing virtual interpersonal skills training applications may not improve trainee performance,” *Sci Rep*, vol. 13, no. 1, Art. no. 1, Jan. 2023, doi: 10.1038/s41598-022-27154-2.
[51] T. E. Smith and A. B. Frymier, “Get ‘Real’: Does Practicing Speeches Before an Audience Improve Performance?,” *Communication Quarterly*, vol. 54, no. 1, pp. 111–125, Feb. 2006, doi: 10.1080/01463370500270538.