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EDITED BY
Akrivi Katifori,
Athena Research Center, Greece

REVIEWED BY
Ushba Rasool,
Zhengzhou University, China
Muhammad Zammad Aslam,
University of Science Malaysia (USM), Malaysia

*CORRESPONDENCE
Xueni Pan,
x.pan@gold.ac.uk

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# Reducing foreign language anxiety through repeated exposure to a customizable VR public speaking application

Seonjeong Park[1], Damaris D. E. Carlisle[2], Zimu Cheng[1], Marco Gillies[1] and Xueni Pan[1]*

[1]Social, Empathic, and Embodied VR Lab, London, United Kingdom, [2]The Learning Centre, LASALLE College of the Arts, University of the Arts Singapore, Singapore, Singapore

This study investigated how repeated use of a customizable immersive virtual reality (VR) public speaking application could alleviate Foreign Language Anxiety (FLA) in English language learners, specifically native East Asian speakers. The goal was to explore how VR can serve as a tool to reduce FLA and enhance confidence in public speaking. Thirteen participants completed two blocks, each comprising three VR-based public speaking presentations. Participants customized their VR experience by selecting audience size, environment (classroom vs. conference room), and their avatar. Data collection included pre- and post-FLA questionnaires, Big Five personality traits, gaze tracking, performance evaluations, and semi-structured interviews. Results showed a significant reduction in FLA scores after six VR sessions. Behavioral evaluations indicated improved speech clarity, fluency, and confidence. Qualitative findings revealed different customization strategies, with some participants opting for challenging settings (e.g., larger audiences) and others preferring "safe" environments. Correlation analysis showed that introverted participants experienced greater FLA reduction. The study highlights VR's potential as a flexible tool for language learning and professional skill development, allowing users to manage anxiety and practice public speaking in a controlled, customizable setting. This research uniquely integrates customizable VR features with FLA reduction strategies, linking anxiety reduction to personality traits and demonstrating VR's potential for personalized learning and anxiety management.

KEYWORDS

**language learner, foreign language anxiety, virtual reality, avatar, virtual audience, personality traits**

## 1 Introduction

It is common for non-native English-speaking, international students to study at English-speaking universities. This can be a challenging and daunting experience as they must live and study in a foreign language environment. The challenge is even greater for students from East Asian countries due to the significant language and cultural differences between Western English-speaking countries and their own. For these students, it is especially stressful when they are required to give a presentation as part of their studies.

In the literature on language learning, this stressful experience associated with using a foreign language can be called foreign language anxiety (FLA). MacIntyre and Gardner (1994) define FLA as "the experience of worry and negative emotions resulting from learning or using a second language." One of the most stressful aspects of learning a language is speaking. Virtual reality (VR) environments have been shown to alleviate FLA in learners (Kaplan-Rakowski and Gruber, 2023; Gruber and Kaplan-Rakowski, 2020; Effiong, 2016). Due to factors such as anonymity, VR allows presenters to develop confidence in speaking in public. Several studies have demonstrated the effectiveness of virtual reality in treating, assessing, and managing anxiety associated with public speaking (Harris et al., 2002; Melchor-Couto, 2017; Safir et al., 2012). Increasingly, VR technology is used in education, particularly in language learning, where studies have demonstrated that learners enjoy using virtual reality when studying a foreign language (Dhimolea et al., 2022).

While research on VR and FLA has expanded in recent years, little attention has been given to the specific characteristics of virtual audiences—such as their size, appearance, and behavior—and how these factors affect learners' anxiety and performance. This study aimed to address this gap by examining how customizable virtual audience features impact FLA in VR environments. Over 2 weeks, participants delivered six presentations in a VR setting where they could adjust audience characteristics to simulate varying levels of public speaking challenges. By exploring these variables, the study sought to deepen the understanding of VR's role in mitigating FLA and its potential applications in educational and professional contexts. This research contributes to the development of innovative, VR-based language learning programs that equip learners with essential communication skills while alleviating the emotional barriers associated with FLA. The findings offer valuable insights for educators and developers aiming to create effectively tailored solutions for language learners in diverse contexts.

# 2 Related work

## 2.1 Virtual reality and language learning

VR technology allows learners, particularly those limited in their ability to travel abroad, to immerse themselves in an authentic language learning environment and culture (Christoforou et al., 2019; Chung, 2012). According to the systematic review conducted by Bahari (2022), studies on language in virtual environments have evolved from descriptive studies focusing on social interaction, learning outcomes, and affective domain to experiential studies that emphasize immersive spaces and simulated instructional environments. A variety of approaches have been shown to enhance language skill acquisition in virtual environments, including contextualized learning, immersive learning, increased engagement, interactive learning (Dhimolea et al., 2022), collaborative learning, and scaffolding (Greenwald et al., 2017).

Various aspects of language have been studied in VR settings, including vocabulary, listening, speaking, and writing. The development of speaking skills has received particular attention in VR. Research has revealed that listening and speaking skills are more commonly investigated than reading and writing skills, which are not well suited to virtual environments (Berns and Reyes-Sánchez, 2021).

## 2.2 Virtual reality and FLA

Public speaking anxiety is a type of social anxiety that occurs before and during a speech (Schlenker and Leary, 1982). It may trigger fear and the expectation that others will give the speaker negative feedback. Several studies have shown that VR can reduce public speaking anxiety through exposure therapy (Harris et al., 2002; Safir et al., 2012).

Public speaking anxiety is also common among language learners who fear being misunderstood or ridiculed due to accent, linguistic limitations, or grammatical errors when speaking in public (MacIntyre and Gardner, 1994; Kaplan-Rakowski and Gruber, 2023). This type of anxiety, known as Foreign Language Anxiety (FLA), is a common phenomenon that can hinder second language acquisition (Gardner and MacIntyre, 1993), particularly in situations that feel threatening to language learners (MacFarlane, 2004). Research by Woodrow (2006) found that students from Confucian heritage cultures, such as China, Korea, and Japan, reported higher levels of anxiety about speaking English compared to students from other ethnic groups.

A VR environment has been shown to reduce FLA in language learners. Gruber and Kaplan-Rakowski (2020) conducted a qualitative study in which 12 university students delivered eight presentations in English. The study explored how students perceived the virtual classroom, how virtual audiences behaved, and their attitudes toward practicing speaking in VR. Results indicated that high-immersion VR fosters a sense of presence and a plausibility illusion, both of which are beneficial for practicing public speaking. Consequently, practicing public speaking in VR has the potential to reduce FLA. However, this study did not include a quantitative evaluation.

In a more recent study, Yeşilyurt Özer and Görgülü, (2022) examined 129 young adolescents in Istanbul, Turkey. They revealed that virtual classrooms, as compared to traditional classrooms, significantly reduced FLA by enhancing students' control, providing less stress, and creating a more comfortable learning environment, particularly for those with high anxiety levels.

Other factors within VR environments can also influence FLA. Effiong (2016) investigated the impact of classroom social factors on FLA in virtual reality settings. The study revealed that Japanese learners experienced heightened FLA influenced by the teacher's age, tone of voice, self-representation, and dress code. Additionally, classroom environmental factors, such as peer gender, familiarity, laughter, and the overall quietness of the class, were found to contribute to increased anxiety levels.

FLA has been studied with different computer-mediated communication modalities, such as audio and video conferencing platforms, and virtual worlds (Kaplan-Rakowski and Gruber, 2023). The study examined how different settings, such as VR or Zoom, affected participants' FLA levels. Speaking in VR resulted in significantly reduced anxiety levels than practicing speaking on Zoom.

Repeated practice of speaking sessions can alleviate anxiety for participants. In a study by Melchor-Couto (2017), repeated VR

sessions for public speaking resulted in a reduction in speaking anxiety. Takac et al. (2019) corroborated this by showing that FLA levels decreased as the experiment was repeated. In terms of presence and plausibility illusion, experiments by Gruber and Kaplan-Rakowski (2020) also revealed that the more VR sessions a participant attends, the more convincing the virtual environment feels.

## 2.3 Virtual audience in public speaking

A VR experience simulates real-world interactions, where audiences play a significant role in influencing speaker behavior and anxiety during public speaking events. Interestingly, computer-generated audiences in VR are often perceived as social actors rather than simple computational entities (Denizci Nazligul et al., 2019). Initially, virtual audiences were introduced as a tool for treating public speaking anxiety, leveraging the immersive and interactive nature of VR to create a safe environment for practice. Bouchard et al. (2014) found that patients who received cognitive behavioral therapy (CBT) with virtual audiences experienced a significant anxiety reduction 1 year after treatment. Findings have shown that virtual audiences can alleviate patients' stress and fear of being judged (Lucas et al., 2014). In particular, Chollet et al. (2015) found that practising with virtual audiences improved participants' public speaking skills, such as reducing the use of pause fillers, being more confident, and improving overall performance.

Several studies have shown that the virtual audience's attitude impacts individuals' anxiety levels (Pertaub et al., 2002; Qu et al., 2015). Recent findings by Reeves et al. (2021) suggests virtual audiences that evoke emotion are more effective than neutral settings in reducing public speaking anxiety and related fears, highlighting the critical role of emotionally engaging virtual audiences in improving self-efficacy and reducing anxiety. Qu et al. (2015), found that virtual bystander attitudes influenced participants' self-efficacy and avoidance behaviors. Positive virtual classmates encouraged students to engage more, enhanced their self-efficacy, and reduced anxiety symptoms. Conversely, a negative attitude from the virtual audience negatively affected all aspects of the speaker's performance. Similarly, Pertaub et al. (2002) demonstrated that, despite knowing the audience was virtual, participants' behavior was still influenced by the responses of the virtual audience. Harris et al. (2002) further suggested that people often fear negative evaluations from others, and this fear persists even in virtual settings. Qu et al. (2015) also concluded that positive attitudes from virtual classmates boosted participants' self-efficacy, made their behavior more engaging, and helped alleviate anxiety.

The size of the virtual audience is an important factor in understanding people's social anxiety. In a study comparing virtual audiences of three, six, and fifteen members, participants reported experiencing greater stress when the audience size was smaller (Mostajeran et al., 2020). According to the Social Influence Model (SIM), once a group reaches five members, the influence of individual members diminishes, and adding more members has no additional impact (Tanford and Penrod, 1984). This shows that the perception of virtual humans is quite different from real-world perception. Certain aspects of VR technology, such as the limited field of view and low resolution of current headsets, may affect the perception of virtual humans. As a result, more distant virtual humans would appear less realistic due to fewer pixels available for displaying their facial expressions or behaviors.

## 2.4 Perception of virtual audiences

Social presence, also known as co-presence, is the subjective sense of being in the same place with someone who is "real" and experiencing the same thoughts and emotions (Biocca, 2006). The term was first introduced by Parker et al. (1978), who stated that intimacy and immediacy are two essential elements of social presence. Immediacy is the emotional distance between the participants, whereas intimacy is the sense of connection between two communicators during an interaction. Additionally, the social information process theory (SIPT) suggests that social presence is more dependent on the interactions between individuals than on the medium (Walther, 1992).

The significance of social presence has been well-established in prior research. Since social presence directly influences social interactions, it plays a particularly critical role in virtual environments featuring social actors. Studies have demonstrated that social presence contributes to several positive communication outcomes, such as increased persuasion and interpersonal attraction (Fogg and Tseng, 1999; Lee et al., 2006).

Several studies have also examined factors that contribute to social presence in virtual environments. The appearance of communication partners plays an important role in determining social presence in virtual environments (Harris et al., 2009). Most studies have examined whether a virtual representation is present and the extent to which it incorporates visual realism. Visual realism is typically defined by three components: photographic realism (how lifelike the representation appears), anthropomorphic realism (how humanlike it looks), and behavioral realism (how naturally it behaves). Behavioral realism in a virtual representation can be evaluated by its ability to exhibit natural behaviors, such as blinking, shifting positions, or simulating breathing (Oh et al., 2018).

Public speaking anxiety can significantly hinder performance (Wortwein et al., 2015), as anxious speakers often experience an elevated heart rate (Porter and Burns, 1973), increased self-focus (Daly et al., 1989), and difficulty envisioning successful outcomes (Bodie, 2010). During a speech, speakers may direct their attention toward the audience, themselves, or a combination of both (Daly et al., 1989). However, cognitive limitations constrain the amount of attention they can devote to any single aspect (Duval and Wicklund, 1972). When anxious speakers focus excessively on themselves or their surroundings, they tend to neglect the audience, which often leads to a decline in their overall performance.

Research by MacIntyre and MacDonald (1998) further examined this relationship, revealing that speakers with high anxiety levels reported improved perceptions of both their own competence and the audience's receptiveness after delivering their presentations. This finding suggests a direct correlation between a speaker's anxiety and their perception of the audience.

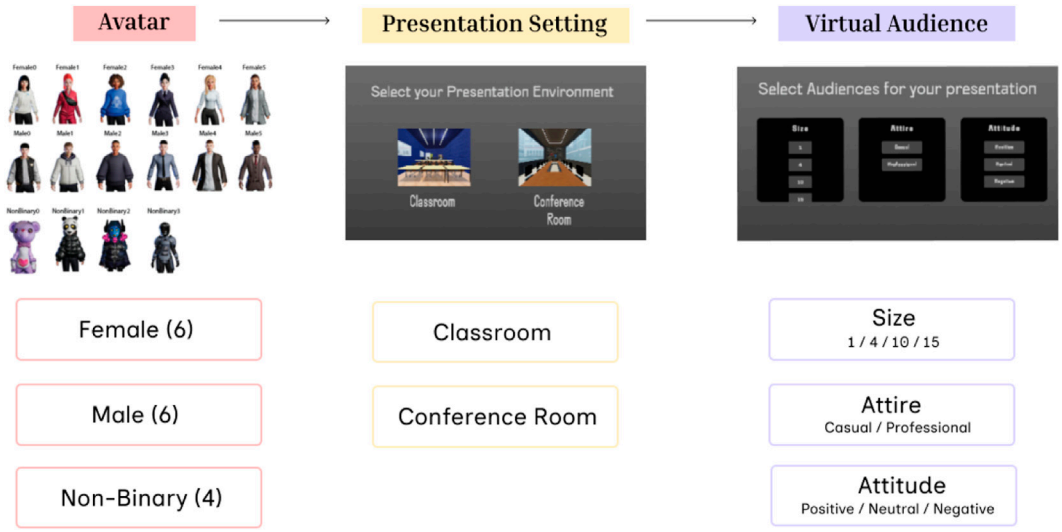


FIGURE 1
User selection procedure.

## 2.5 Virtual avatars and body ownership

Users in virtual environments are represented by avatars, which serve as digital proxies for their physical selves (Waltemate et al., 2018). Avatars act as a "second self," reflecting users' personalities, behaviors, intentions, and styles, and are often treated with care and protection. This phenomenon, known as the illusion of virtual body ownership (IVBO), describes the acceptance and identification with virtual body parts (Peck et al., 2013; Gonzalez-Franco et al., 2024). This illusion can occur even when the virtual body differs significantly from the user's real body (Jo et al., 2017). Notably, the first-person perspective in VR environments is particularly effective in generating strong IVBO effects (Slater et al., 2010).

VR allows users to customize their avatars, providing an alternative way to represent themselves (Aymerich-Franch et al., 2014). Waltemate et al. (2018) found that allowing users to customize their avatars significantly enhances their sense of virtual presence, dominance, and immersion (Lugrin et al., 2015). Realistic appearances are not essential for IVBO; overly realistic appearances can lead to the "uncanny valley" effect, where near-human likenesses cause feelings of eeriness or discomfort (Mori et al., 2012). Furthermore, Melchor-Couto (2018) demonstrated a strong relationship between self-efficacy beliefs and the anonymity effect. When self-efficacy beliefs are high, anonymity has a negative impact. This means that students with high levels of self-efficacy do not need to feel shielded by their avatars.

The *Proteus* effect suggests that an avatar's appearance can influence a user's behavior, attitudes, and emotional engagement (Yee and Bailenson, 2007). Several studies have shown that avatar appearance influences behavior in various ways, including gender (Jo et al., 2017), posture (de la Peña et al., 2010), figure (Normand et al., 2011), skin color (Peck et al., 2013), age (Banakou et al., 2013), and size, as well as the degree of realism and anthropomorphism (Lugrin et al., 2015). Similar findings were made by Baylor (2009), who found that representations of ourselves in virtual environments significantly influence verbal, nonverbal, and task-related behaviors. More recently, Mal et al. (2023) highlighted that congruence between an avatar's appearance and the virtual environment significantly enhances avatar plausibility, a key factor in enriching the virtual experience.

## 2.6 Personality traits

Personality traits can have a significant influence on everyday behavior, shaping how individuals interact with their environment and respond to various situations. The five commonly agreed traits (extroversion, agreeableness, conscientiousness, neuroticism, and openness to experience) are understood through the Big Five Inventory of Personality, which provides a framework for predicting behavior (Rammstedt and John, 2007). There is a substantial body of literature that examines the characteristics and profiles of these personality traits (Crockett et al., 1971; John and Srivastava, 1999). Extroverted individuals, for instance, tend to seek out social interactions, display higher levels of enthusiasm, and are more likely to participate in group activities. Individuals with higher levels of neuroticism often exhibit heightened emotional sensitivity, which can lead them to avoid stressful situations and display anxious or self-conscious behaviors. Agreeable individuals are typically cooperative and supportive in their relationships, preferring harmony and often working to resolve conflicts, while highly conscientious individuals tend to be organized, dependable, and focused on achieving long-term goals through careful planning. Openness to experience, on the other hand, is linked to creativity and a willingness to engage with new ideas or unconventional experiences, nurturing behaviors that reflect curiosity and adaptability. A person gaining a low score on any of these traits would likely display opposite behaviors. Personality traits can be used to determine how individuals approach tasks, relationships, and challenges.

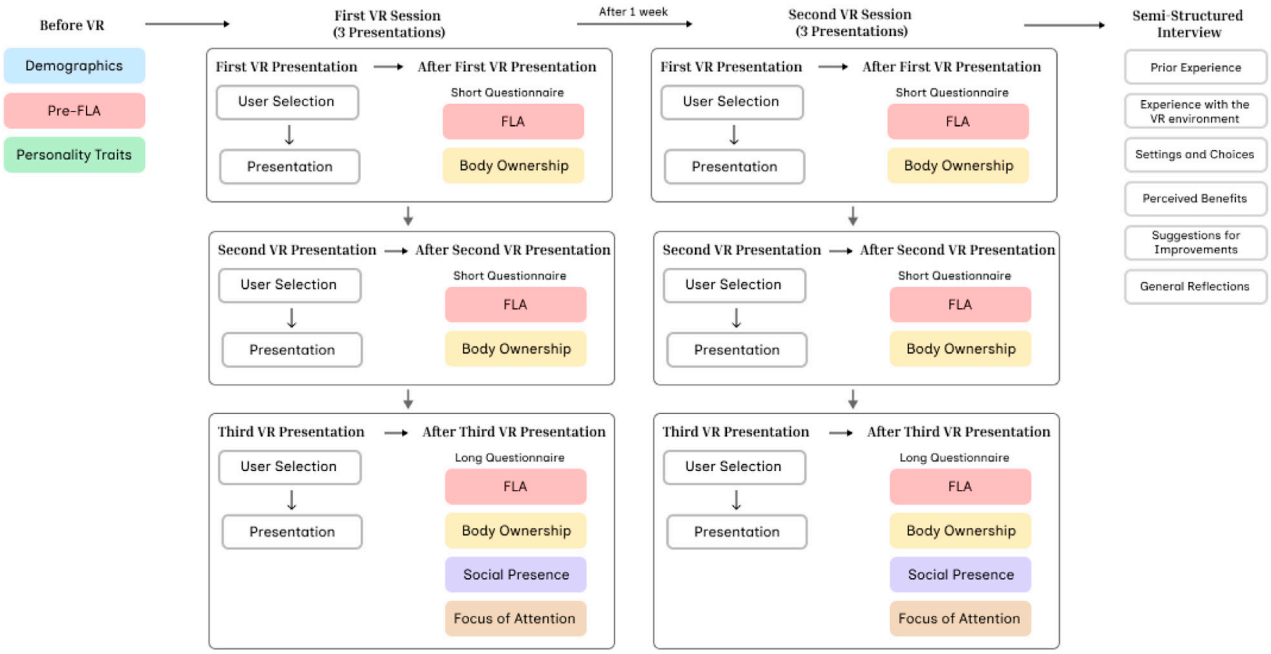


FIGURE 2
Experimental procedure.

# 3 Experimental design

## 3.1 Interdisciplinary expertise and its influence on study design

The authors of this study bring a diverse range of expertise and personal connections to the research topic, which informed both the design and execution of the study. Three authors specialize in VR technology and its applications, enabling the development of the customizable VR tool used in the experiment. Another author has a background in linguistics and second language acquisition, providing insights into the challenges faced by non-native English speakers, particularly those from East Asian cultures, which shaped the study's focus on Foreign Language Anxiety (FLA). Additionally, the team comprises researchers experienced in qualitative and mixed-methods research, ensuring a holistic approach to data collection and analysis. The authors' shared interest in exploring innovative ways to use VR for education and anxiety reduction directly influenced the study's objectives and methodology, and their international and interdisciplinary perspectives ensured cultural sensitivity and methodological rigor.

## 3.2 Hypotheses

Many studies have explored the potential benefits of VR as a tool for practicing public speaking skills. However, most have focused on one-off sessions or repeated sessions conducted in identical settings. The ultimate goal of using VR for addressing FLA is its potential application in home settings, where participants can repeatedly engage with the tool and tailor the experience to their preferences. In this study, we aimed to simulate this process by allowing participants to customize their VR environment and use it multiple times. Therefore our first hypothesis is:

**H1:** Using a customizable VR application, participants' self-reported FLA levels will improve significantly over six VR presentation sessions.

Here, we are interested in how the participant would subjectively report their level of improvement and their actual presentation performance. Our second hypothesis is:

**H2:** Participants' performance will significantly improve over six VR presentation sessions.

Further, we are interested in exploring individual differences in participants' subjective and performance improvement. Here we hypothesise:

**H3:** There will be significant correlations between participants' subjective performance improvement and their personality traits.

We conducted a small-scale user study with repeated VR exposures. Importantly, participants could freely customize their VR application at the beginning of each session. We collected questionnaire data and videotaped their performance for analysis. We also collected interview data for qualitative analysis.

## 3.3 Participants

An email was sent to postgraduate students at Goldsmiths, University of London, inviting volunteers who experience anxiety when giving public presentations. Eligible participants needed to

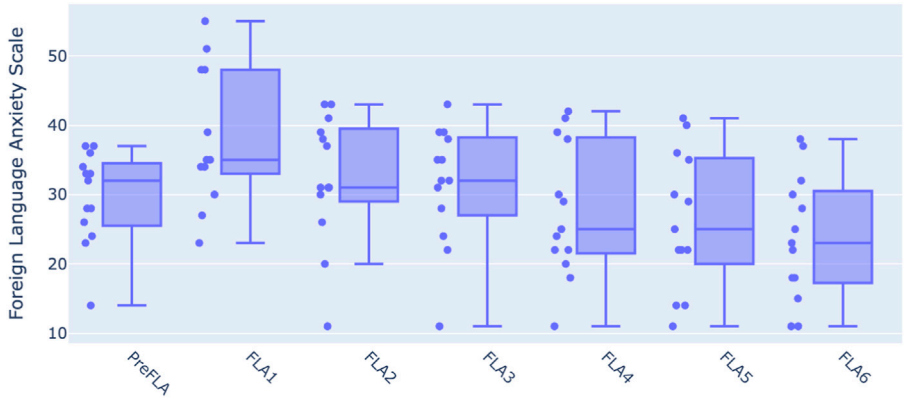


FIGURE 3
FLA scores in real-life (preFLA) and after each VR sessions (FLA1-6).

have Chinese, Korean, or Japanese as their first language and should not have lived in an English-speaking country for more than 1 year.

Thirteen East Asian participants were recruited, comprising 11 females and 2 males, aged between 23 and 29. The study received approval from the Department of Computing Ethics Committee at Goldsmiths, University of London. Participants were compensated with in gift vouchers for completing six trials, with an additional 10 voucher provided to those who participated in the post-interview.

## 3.4 Procedure

The experiment took place over 3 weeks in the Goldsmiths, University of London VR Lab, from 6th July to 21 July 2024.

Prior to the VR experience, participants were provided with detailed project information outlining potential risks. They signed an informed consent form, which assured data security, anonymity, and the right to withdraw at any point. Participants then completed a pre-questionnaire that gathered demographic information, language background, previous VR experience, FLA levels and personality traits.

Participants were required to complete two blocks, each consisting of three short presentations, totaling six sessions. Each block lasted approximately 45 min.

The presentation topics were flexible, allowing participants to choose from four low-stakes options: 1. Favorite food 2. Favorite movie or actor 3. Favorite music or singer 4. Favorite sports. Participants were informed several days prior to the experiment about the requirement to prepare two-minute presentations. For those who had not prepared in advance, an additional 10 min was allocated before each presentation to organize their thoughts.

The VR experience was developed with Unity 3D and was delivered using a Meta Quest 2 headset.

At the start of the experiment, participants entered a virtual empty room with a desk. Using hand-tracking technology, they interacted with a virtual user interface (UI) panel by pressing a black button on the desk. The first-person perspective allowed participants to customize their avatars, select the presentation environment, and choose the audience. A virtual mirror displayed their avatar's movements in real-time as they moved their head, body, and hands. In their research, Preston et al. (2015) highlighted the significance of virtual mirrors, demonstrating how viewing oneself in a mirror can influence one's perception of their body.

As shown in Figure 1, Participants could select from 6 female avatars, 6 male avatars, and 4 non-binary avatars, the latter featuring non-human forms like a purple teddy bear or a robot. They could also choose between a classroom or conference room environment, which dynamically changed based on their selection. Furthermore, participants had the option to choose the audience size (1, 4, 10, or 15 members), their attire (casual or professional), and audience behavior (positive, neutral, or negative).

Once the presentation settings were selected, participants initiated the presentation by pressing the "start" button on the desk. A timer appeared, and the virtual audience began focusing on the presenter. The background noise was reduced to ensure clear audibility for the presenter.

During the presentation, virtual humans served as the audience, exhibiting pre-programmed nonverbal behaviors such as nodding, gesturing, and leaning forward. These behaviors simulated real-life classroom dynamics but did not directly correlate with the speaker's content. Based on the selected audience attitude, the audience responded accordingly. A positive audience paid close attention, while a neutral audience's attention gradually waned, with some members performing distracted behaviors, such as looking at laptops. A negative audience showed little interest in the presentation.

The participants' virtual hands moved in sync with their physical hands, enhancing the immersive experience. After finishing their presentation, participants pressed the "end" button on the desk, stopping the timer. Depending on the selected audience attitude, the audience either applauded in the positive or neutral scenario or remained unresponsive in the negative scenario.

Following each session presentation, participants completed a post-questionnaire assessing their FLA and body ownership. These questionnaires took approximately 7–8 min to complete. This process was repeated for all six presentations.

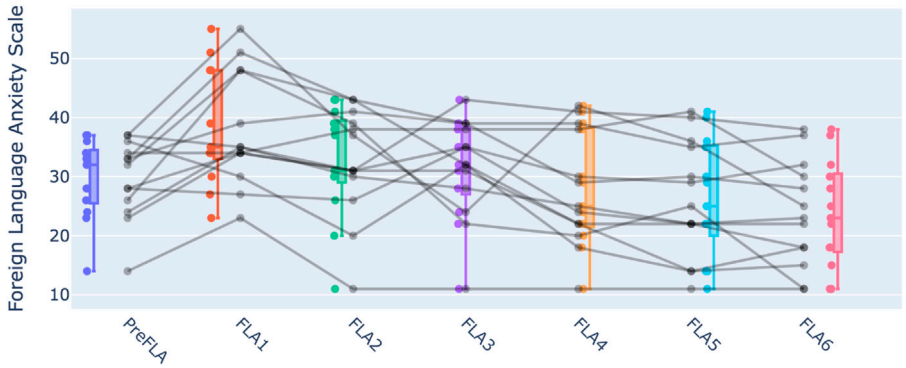


FIGURE 4
Behavioral Checklist after each of the six sessions. The trajectory of change for each individual participant is indicated by the line linking the six sessions.

After each block, participants completed a longer post-questionnaire assessing their body ownership, focus of attention and social presence. Additional feedback and thoughts were collected through 15–25 min semi-structured interviews, where participants shared their overall experience and insights.

# 4 Data collection and analysis

This study employed a mixed methods approach (see Figure 2), integrating both quantitative and qualitative data to provide a comprehensive understanding of participants' experiences and outcomes. The quantitative component included pre- and post-questionnaires to measure changes in FLA, behavioral performance evaluations based on videotaped presentations, and personality trait assessments. The qualitative component included open-ended self-evaluations and semi-structured interviews to capture participants' reflections and insights.

The quantitative data provided objective measures of FLA reduction and behavioral improvements, while the qualitative data offered deeper insights into participants' perceptions, strategies, and emotional responses. For example, reductions in FLA scores were cross-referenced with participants' descriptions of feeling more confident over time, and behavioral improvements were linked to themes such as increased familiarity with the VR environment. This integration of data ensured that the results were both statistically valid and contextually meaningful.

## 4.1 Quantitative data collection

### 4.1.1 Pre-questionnaire

Background information was collected to obtain personal information about participants. It included participants' reflections on their last in-person presentation (how they felt, what they did well, and areas for improvement), demographic information such as age, gender, frequency of VR application usage, native language, English learning experience, levels of FLA, and personality traits. The 10-item short version of the Big Five Inventory (John and Srivastava, 1999; Rammstedt and John, 2007) was included to determine whether identified traits of extroversion, agreeableness, conscientiousness, neuroticism, and openness influenced participant behaviors in the VR experience.

### 4.1.2 Foreign language anxiety

This study used the FLA classroom questionnaire developed by Kaplan-Rakowski and Gruber (2023), based on the original work of Horwitz et al. (1986). A total of 11 out of 15 items were included, all rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This questionnaire was designed to assess students' anxiety levels when delivering public presentations in English. To evaluate changes before and after each session, the study generated two versions of the core questionnaire: a pre-questionnaire, written in the present tense to measure participants' general levels of FLA, and a post-questionnaire, written in the past tense to assess FLA during the presentation.

Four items from the original 15 were excluded to avoid redundancy and ensure relevance to the study's context. Item 3 ("I tremble when I know I am going to be asked to speak English") and Item 8 ("I feel my heart beating up to my throat when I have to speak English") were similar in addressing physical symptoms of nervousness. Similarly, Item 4 ("It scares me a lot when I have to speak English without being prepared") overlapped with Item 6 ("Even if I am well-prepared for speaking in English, I am worried"), as both focused on preparation-related anxiety. Item 13 ("I feel overwhelmed by the number of rules you need to learn in English") was omitted as it pertained to general language learning rather than public speaking, while Item 15 ("I would probably feel comfortable around native English speakers") was excluded because the study's audience also included non-native speakers, making it less relevant. These omissions ensured the questionnaire was concise, focused, and tailored to the specific context of public speaking anxiety in VR.

### 4.1.3 Behavior checklist

A behavior evaluation was performed on all presentation videos collected during the experiment. A total of 78 videos (13 participants, each delivering six recorded presentations) were analyzed. To ensure impartiality, the recordings were randomized

before being assessed by an experienced English language examiner. A rubric was used to evaluate key aspects of the presentations, including speech clarity, fluency, tone, volume, use of pauses and filler words, and overall structure. Each criterion was rated on a numerical scale from 1 to 7, where 1 represented poor performance and 7 indicated excellence. This systematic approach provided an assessment of the participants' presentation skills across multiple dimensions.

#### 4.1.4 Body ownership and social presence

Virtual body ownership illusion was measured using questionnaires developed by Waltemate et al. (2018). Given the overlap between virtual body ownership and self-presence, this study treated them as a unified construct for examination. The illusion of virtual body ownership was measured using nine items grouped into five components: self-presence (1 item), spatial presence (1 item), acceptance (1 item), control (2 items), and change (4 items). Acceptance refers to accepting ownership of the virtual body, control refers to the concept of agency, and change refers to changes in one's perception of self. Participants rated statements such as, "I felt the clothing I wore in VR was the same as the clothes I wear in real life." to assess perceptual changes resulting from clothing manipulation. Statements like "During the experiment, I felt the avatar's body was my body" were presented to determine whether personalization manipulation was successful. All items were rated using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

The co-presence and social presence questionnaire was adapted to assess the participant's perception of the social presence of the virtual audience. Co-presence refers to the feeling of being physically or virtually together with others in a shared space, where individuals are aware of each other's presence and actions. Social presence extends this concept by capturing the sense of connection or interpersonal warmth between people, making interactions feel personal and engaging, even in mediated environments (Poeschl and Doering, 2015). The questionnaire consisted of four components: reaction to virtual agents (4 items), perceived virtual agent's reaction (4 items), the impression of interaction possibilities (4 items), and (co-) presence of other people (3 items). Based on a five-point Likert scale, all items were rated from 1 = strongly disagree to 5 = strongly agree.

#### 4.1.5 Focus of attention

The focus of attention questionnaire was used to assess the attention direction of participants during the presentation (Woody et al., 1997). The questionnaire was composed of 10 items, with two 5-item sub-scales: self-focus and external focus. The self-focus sub-scale measured how much individuals focused on themselves during the presentation; for example, "During the presentation, I was focusing on what I would say next." In the external focus sub-scale, individuals were assessed for their attention to the environment during a presentation; such as, "During the presentation, I was focusing on the student's appearance or clothing." A 5-point Likert scale was used for all items (1 = strongly disagree, 5 = strongly agree). A higher self-focus score indicates that participants paid more attention to themselves than to their surroundings indicating higher levels of anxiety.

### 4.2 Qualitative data collection

#### 4.2.1 Self-evaluations

In both the pre- and post-questionnaires, space was provided for participants to write longer responses with the option to write in English or their mother tongue which was later translated to English. Open-ended questions included the opportunity to describe prior experiences delivering public presentations and record anything they remembered about the trials.

#### 4.2.2 Semi-structured interviews

The semi-structured interviews were conducted via Google Meets, using the platform's captioning and transcript features to assist participants and aid the transcription process. The interviews took place after each participant had completed six presentations, allowing for reflections on their experiences. The interviewer, based in Singapore interacted with participants who were located in the UK, with each session lasting between 15 and 25 min. The semi-structured format of the interviews allowed for deeper probing into the participants' experiences, starting with questions about their prior experiences and gradually moving towards their feelings about the VR experience, their choices of settings, and their perceived benefits. Participants were also encouraged to suggest improvements, providing insights into how the VR environment could be enhanced. Once the interviews were completed, the transcriptions were checked against the interview recordings. After the transcripts were cleaned to delete irrelevant information, the recordings were destroyed as stated in the informed consent form.

### 4.3 Process of analysis

This subsection explains how the data were analyzed, starting with quantiative data and then moving to qualitative data.

#### 4.3.1 Quantitative analysis

This subsection explains how the data were analyzed. For quantitative data, we used repeated-measures ANOVA to assess changes in FLA scores over time, paired t-tests to compare performance scores, and correlation analyses to explore relationships between personality traits and outcomes.

#### 4.3.2 Qualitative analysis

For qualitative data, this study employed thematic analysis (Miles et al., 2013) within a qualitative framework to examine the impact of frequent exposure to a customizable VR public speaking application on the alleviation of FLA. We conducted thematic analysis following the three-stage process of descriptive, topic and analytic coding proposed by Richards (2015). We also triangulated qualitative findings with quantitative results to provide a comprehensive understanding of participants' experiences. After interview data had been anonymized, the initial coding was performed in a bottom-up, inductive manner, focusing on what was present in the data. We used GPT-4 for the topic coding phase of the qualitative analysis following the lead of Tai et al. (2024). The resulting codes were checked against the data and then grouped into broader themes. Only at this point were the qualitative results

compared to quantitative results and prior research, to ensure that they did not overly influence the early stages of qualitative analysis.

## 4.4 Ensuring rigor and trustworthiness

To ensure rigor and trustworthiness in our study, we implemented strategies guided by established frameworks for qualitative and mixed-methods research (Patton et al., 1983). These strategies were applied across data collection and analysis to enhance credibility, dependability, transferability (Beck and Polit, 2018), and confirmability (Lincoln and Cuba, 2012). Credibility was achieved through triangulation of data sources, including pre- and post-questionnaires, behavioral performance evaluations, and semi-structured interviews, allowing cross-validation of findings. For example, reductions in FLA were supported by both self-reported questionnaire data and observed improvements in performance scores. Member checking during interviews ensured participants' perspectives were accurately captured. Dependability was maintained through a detailed audit trail documenting research decisions, including VR application design, questionnaire development, and qualitative coding. Peer debriefing involved multiple researchers reviewing data analysis to ensure consistency and reduce bias. Transferability was addressed by providing rich descriptions of the research context, participant demographics, and experimental procedures, enabling readers to assess applicability to other contexts. Confirmability was enhanced through reflexivity, with researchers maintaining journals to document assumptions and biases. Qualitative data were systematically coded. Ethical rigor was ensured through informed consent, anonymity, and adherence to institutional ethics guidelines.

Additionally, specifically for qualitative analysis, this study reformulated existing processes to enhance reliability, dependability, transferability, and authenticity for further research. This was executed in alignment with prior research methodologies, particularly those of Miles et al. (2013) and Richards (2015). This focused on reflexive inductive approaches followed with triangulation with quantitative data and existing literature.

# 5 Results

To address the research questions and hypotheses, the results are organized into two main sections: quantitative findings and qualitative insights. The quantitative results include analyses of FLA scores, behavioural performance evaluations, and correlations with personality traits. These findings are derived from statistical analyses, including repeated-measures ANOVA and paired t-tests, to assess changes over time and individual differences. The qualitative results, drawn from self-evaluations and semi-structured interviews, provide deeper insights into participants' experiences, strategies, and perceptions of the VR environment. Together, these findings offer a comprehensive understanding of how repeated exposure to a customizable VR public speaking application impacts FLA and presentation performance.

## 5.1 Quantitative results

### 5.1.1 Foreign language anxiety questionnaire

Our primary focus was on the changes in self-reported FLA levels throughout the VR trials. Participants completed the FLA questionnaire seven times: once before the experiment (preFLA) and immediately after each VR session during their two visits to the lab (FLA1-3 after the first visit, and FLA4-6 after the second). We ran a reliability test for all FLA measurements, and found all Cronbach's alpha greater than 0.8.

As shown in Figure 3, we can see that participants exhibited higher than real-life FLA after VR session 1, but this gradually reduced as they completed the other five presentations. Normality was not rejected (Shapiro-Wilk: $p\_FLA1 = 0.326$, $p\_FLA2 = 0.183$, $p\_FLA3 = 0.300$, $p\_FLA4 = 0.444$, $p\_FLA5 = 0.518$, $p\_FLA6 = 0.658$). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated ($\chi^2(20) = 61.57$, $p = .000$). A repeated-measures ANOVA with a Greenhouse-Geisser correction determined that FLA differed statistically significantly between time points ($F(2.65, 31.79) = 7.70$, $\boldsymbol{p = 0.001}$, $\eta^2 = 0.391$). Post hoc analysis with a Bonferroni adjustment revealed that FLA1 was significantly higher than FLA4 ($\boldsymbol{p = 0.041}$), FLA5 ($\boldsymbol{p = 0.035}$), and FLA6 ($\boldsymbol{p = 0.019}$); and that FLA6 was significantly lower than FLA3 ($\boldsymbol{p = 0.004}$). No significant differences were found between preFLA and FLA1-6. Importantly, as expected, participants' final post-VR FLA score (FLA6) was significantly lower than their initial post-VR FLA score (FLA1), indicating most participants had a reduced FLA after 6 VR sessions. Overall, results from FLA data support H1.

### 5.1.2 Behavioral checklist

We videotaped participants' performance during their VR sessions and scored each session based on our behavior checklist. Here, we compared the results from each participant's last VR session (BH6) with their first session (BH1). Normality was not rejected (Shapiro-Wilk: $p\_BH1 = 0.993$; $p\_BH6 = 0.818$). A paired t-test revealed a significant ($BH1$: $Mean \pm SE$: $28.38 \pm 1.38$; $BH6$: $30.69 \pm 1.37$; $t(12) = -2.38$, $\boldsymbol{p = 0.035}$). Our results support H2.

As shown in Figure 4, although there was a slight improvement between the final performance and the first one, each participant experienced a unique progression throughout the six sessions. Seven participants showed improvements in their public presentation performance (1, 2, 4, 6, 9, 10, 12). Four participants maintained consistent scores between their first and last trials (3, 7, 8, and 13). However, participants 7, 8, and 13 showed noticeable improvements at intermediate points during the sessions. Two participants showed a slight decrease in performance between the first and last presentation (5 and 11), although participant 11 improved their performance part way through the trials.

Initially, many participants displayed frequent errors in speech clarity and fluency, marked by hesitations and filler words. Over time, as they became more comfortable with the VR setting, these issues diminished, resulting in smoother delivery and fewer disruptions. For instance, Participant 1, who initially needed to "pause between key points" showed progress, evolving into a more engaging and easy-to-follow presentation by the final sessions. Participant 12 exemplified consistent improvement, particularly in fluency and pace, reflecting growing confidence. Similarly, Participant 4 started with a lot of "hesitation and self-correction",

but by the end delivered a "bright, engaging and interesting" presentation. However, not all participants showed significant progress; Participant 7, for instance, struggled with projecting their voice using an appropriate volume.

### 5.1.3 Individual differences

We were interested in individual differences in FLA reduction: is VR more effective for certain personality types? Here, we constructed a new variable ($deltaFLA = FLA1 - FLA6$) and ran a correlation analysis with all five personality traits. We found a negative correlation between deltaFLA and extroversion ($R = -0.64, \boldsymbol{p = 0.02}$). This indicated a greater improvement for participants who were more introverted. Similarly, we constructed a new variable to capture participant performance improvements ($deltaBH = BH6 - BH1$) and conducted correlation analyses between deltaBH and participants' personality traits. However, no significant correlation was found. Overall, our result partially supports H3.

### 5.1.4 Body ownership, social presence, focus of attention

We conducted paired t-tests for social presence and focus of attention for each participant, comparing their responses after the third VR presentation to those after the sixth. No statistically significant differences were found for Social Presence ($SP3$: $Mean \pm SE$: $45.85 \pm 4.20$; $SP6$: $42.15 \pm 2.89$; $t(12) = 1.49$, $p = 0.163$), or for Focus of attention ($FA3$: $Mean \pm SE$: $2.92 \pm 0.95$; $FA6$: $2.85 \pm .99$; $t(12) = 0.52$, $p = 0.959$).

For body ownership, we conducted a repeated ANOVA test for the result after each session. Again, no statistically significant difference was found between the six sessions ($F(5, 60) = 0.827$, $p = 0.535, \eta^2 = 0.064$).

The quantitative results support the study's hypotheses by demonstrating significant reductions in FLA and improvements in presentation performance over six VR sessions. Specifically, the significant decrease in FLA scores from the first to the final session (FLA1 to FLA6) aligns with H1, which posited that repeated VR exposure would reduce participants' self-reported anxiety levels. Similarly, the improvement in behavioral performance scores from the first to the last session supports H2, indicating that participants' presentation skills improved with practice. The correlation analysis further highlights individual differences, with introverted participants showing greater reductions in FLA, partially supporting H3. These findings suggest that the VR environment provides a safe and effective space for reducing anxiety and enhancing public speaking skills.

## 5.2 Qualitative data findings

The qualitative data, comprising self-evaluations and semi-structured interviews, was thematically analyzed to explore participants' experiences and perceptions of the VR public speaking environment. Following the framework proposed by Richards (2015), the data was coded and organized into recurring themes, such as pre-VR public speaking anxiety, perceptions of the VR environment, customization and adaptation strategies, and behavioral and emotional improvements over time. These themes were linked to the quantitative findings and hypotheses. These thematic insights complement the quantitative data by providing a deeper understanding of participants' behavioral changes and personal strategies for overcoming anxiety in VR.

### 5.2.1 Pre-VR experiences and public speaking anxiety

Open-ended responses from participants before the VR experience expressed feelings of nervousness and stress regarding public speaking, particularly when presenting in a non-native language. For example, Participant 1 described feeling "very nervous," and Participant 5 noted how nerves impacted their ability to comprehend questions due to a "language barrier." Many participants voiced the desire to improve their vocabulary and grammar for future presentations to overcome these challenges. These anxieties were compounded by the differing approaches to preparation. Participants like Participant 9 and Participant 10 highlighted the importance of extensive preparation, often writing and practicing their speeches multiple times. In contrast, others, like Participant 4, admitted to preparing less for presentations they perceived as less significant. Some participants also relied on tools and techniques, such as using presentation slides for memory support (Participant 13) or practicing aloud to better retain information. These findings align with the quantitative data, where initial FLA scores (FLA1) were significantly higher than later scores (FLA4, FLA5, FLA6), supporting H1 that repeated VR exposure reduces FLA.

### 5.2.2 Perceptions of the VR environment

After their VR practice, participants' perceptions of the virtual environment were mixed. Many found VR helpful in reducing anxiety and offering a controlled space for practice, yet the artificiality of the avatars and lack of genuine audience interaction detracted from the immersive experience. Participant 11 remarked, "the characters do not blink," while Participant 5 noted that "the audience's reactions seemed soulless," which made it difficult for them to engage as they would in a real-world setting. As a result, some participants, like Participant 7, described the experience as "fake and uninteresting," leading to a sense of disconnection.

Despite these drawbacks, the semi-structured interviews revealed that the VR setting offered a safe, repeatable, and non-judgmental environment for public speaking practice. Participant 3 remarked, "I kind of feel less nervous because I am quite conscious that those people are not real," illustrating how the artificiality of the audience made it easier to practice without the fear of real-time judgment. The repeated practice within this environment also helped participants build confidence over time. Participant 6 noted feeling "more confident" by the end of the sessions, and Participant 12, who initially experienced nervousness, reported feeling "better and better" with each successive practice. This is reflected in the behavioral checklist data, where participants showed improvements in fluency and clarity over six sessions, supporting H2.

### 5.2.3 Avatar selection and identity experimentation

Participants' choice of avatars often reflected their desire to experiment with identity or enhance their confidence in the virtual

setting. For instance, Participant 7 mentioned, "At first I choose an avatar which looks like me because the first time I feel a little bit nervous, so I just want to find something which I'm familiar [with]." This suggests that initially choosing a familiar avatar helped them manage anxiety by providing a sense of comfort and familiarity. As they became more accustomed to the VR environment, some participants opted for more adventurous choices. Participant 10 expressed, "I like that feeling like doing the presentation it's a very formal situation, but I'm a bear . . .[I] look ridiculous." These choices highlight the role of personality traits in shaping participants' experiences, aligning with H3, which found a negative correlation between introversion and FLA reduction.

### 5.2.4 Customisation and adaptation strategies

Some participants had a strong reaction to the choice of location. Participant 7 expressed a distinct preference for the classroom environment over the conference room, "At first I chose the classroom and the second time I wanted to choose a work environment, but I just feel nervous because I'm not familiar with the working environment. So I also chose to stay [in the] classroom." This decision reflects an adaptation strategy that participants employed to manage their anxiety by selecting an environment that felt more familiar and less intimidating.

The ability to control audience size and feedback also influenced anxiety reduction. Participant 4 noted the impact of audience size on their comfort level, explaining, "In the smaller one, I feel more casual." They elaborated on how a smaller audience allowed them to feel as though they were presenting to a friend, which made the experience more manageable and less daunting. Participant 9 also tried different audience behaviours, initially choosing neutral but later opting for positive feedback, saying, "In my first presentation I chose neutral. . .but I was very nervous and shocked by their reaction. . .after the first one, I always choose positive." These strategies allowed participants to gradually acclimate to public speaking, contributing to reduced FLA and improved performance, as seen in both qualitative feedback and quantitative improvements in behavioral scores.

### 5.2.5 Challenges and suggestions for improvement

However, some participants found that the presence of real people in the room during testing heightened their anxiety, suggesting that real-world elements influenced the presentation experience. For example, participant 13 noted, "there are some people in a real life. They are [with] me in the room. So this makes me feel a little bit nervous. In the second [week] I asked them, "Could you please go outside the room? Let me stay alone", and then I just feel relaxed." Additionally, there was a desire for more dynamic and realistic settings, such as grander venues or more interactive audience members, to enhance the authenticity of the practice. Participant 4 explained, "I just want more options. More options for more larger experience, like I speak [in front of] a lot of people." Although some participants encountered challenges with the artificiality of the VR environment, the opportunity for many to repeat the experience within a controlled practice environment appeared valuable in building public speaking skills and reducing anxiety. These insights highlight the need for more dynamic and realistic VR settings to better simulate real-world public speaking scenarios.

### 5.2.6 Personality traits and their influence on behaviors and performance

Analysis of the qualitative data, encompassing performance evaluations, semi-structured interviews, and personality traits, indicates a correlation between introversion and improvement in VR presentation skills. Participants who scored lower on extroversion initially reported higher levels of anxiety, which diminished with repeated VR exposure. Participant 9 expressed, "I was really nervous because I did not expect this. I did not expect it to be that realistic." However, with practice, the participant found that "after a few rounds it is getting better and better." Participant 6 noted, "At first I felt a bit nervous and stressful . . . but I think it's a good way to practice my presentation," highlighting how the VR experience facilitated a gradual increase in confidence and comfort. Similarly, Participant 5 remarked, "After two [or three] times it [felt] better," indicating that familiarity with the VR environment led to a reduction in anxiety.

## 6 Discussion

The desensitization effect observed in this study suggests that repeated exposure to a controlled VR environment can effectively reduce FLA by allowing participants to practice public speaking without the immediate pressure of a live audience. This finding aligns with prior research by Melchor-Couto (2017) and Takac et al. (2019), who demonstrated that repeated VR sessions reduce speaking anxiety over time. Similarly, Gruber and Kaplan-Rakowski (2020) found that repeated VR exposure enhances the plausibility and presence of the virtual environment, which may contribute to the observed reduction in anxiety. In our study, this reduction in anxiety was particularly notable among participants with introverted tendencies, who often experience higher baseline anxiety in social or performance situations. This supports the findings of Effiong (2016), who highlighted the role of individual differences, such as personality traits, in shaping anxiety levels in language learning contexts.

The flexibility of the VR setting to allow repeated practice helped these individuals to gradually build confidence over multiple sessions, contributing to a notable decrease in FLA scores from the first to the last session. Our findings revealed a significant negative correlation between FLA reduction (deltaFLA) and extroversion ($R = -0.64$, $p = 0.02$), indicating that introverted participants tended to benefit more from the repeated VR practice than their more extroverted counterparts, who had lower initial anxiety levels. This aligns with the broader literature on personality traits, such as John and Srivastava (1999), which suggests that introverts may experience greater anxiety in social situations but also stand to gain more from controlled, low-pressure environments like VR.

## 6.1 Customization and reduced anxiety

A unique aspect of the VR experience that contributed to anxiety reduction was the ability for participants to customize aspects of their virtual environment, including avatars, audience composition, and presentation location. This personalization allowed participants

to gradually acclimate to public speaking by starting with less intimidating scenarios and progressively increasing the level of challenge. This finding aligns with Pertaub et al. (2002) and Qu et al. (2015), who demonstrated that virtual audience behavior significantly impacts anxiety and self-efficacy. In our study, many participants actively used customization to manage their anxiety, such as selecting smaller audiences or positive feedback, which mirrors findings by Qu et al. (2015) that positive audience reactions can enhance self-efficacy and reduce anxiety.

For some, this meant presenting to a smaller audience or in a more casual setting before moving to larger, professional settings. This flexibility likely enhanced the effectiveness of VR as a practice tool by enabling participants to control their exposure to anxiety-inducing stimuli, thus helping them to build confidence at their own pace. This corroborates the principles of systematic desensitization Safir et al. (2012), where gradual exposure to anxiety-provoking situations reduces fear over time.

## 6.2 Behavioral improvements in presentation skills

Most participants showed improvements in presentation skills, as observed through a reduction in disfluencies such as hesitations and filler words, indicating increased comfort and reduced anxiety over time. This finding supports Chollet et al. (2015), who found that practicing with virtual audiences improves public speaking skills, including reducing the occurrence of pause fillers and increasing confidence. Similarly, Bouchard et al. (2014) demonstrated that virtual audiences can alleviate stress and improve performance in public speaking scenarios.

Overall, behavioral scores improved from the first to the last session, reflecting growing confidence in a virtual setting that simulates real-world public speaking scenarios. The gradual reduction in disfluencies suggests that VR practice has the potential to support skill development by providing a safe space to practice and refine presentation techniques. The standardized environment of VR allowed participants to focus on enhancing their delivery without the unpredictability of a live audience, which aligns with findings by Gruber and Kaplan-Rakowski (2020) that VR provides a controlled and repeatable environment conducive to skill development.

## 6.3 Mixed perceptions of VR as a practice tool

While VR proved beneficial in reducing anxiety and providing a low-stakes environment for skill practice, participants had mixed perceptions about its authenticity. Some felt that the artificiality of VR avatars and the limited responsiveness of the virtual audience diminished their sense of immersion. This finding aligns with Oh et al. (2018), who emphasized the importance of behavioral realism in virtual environments for creating a sense of social presence. Participants in our study noted that the lack of lifelike feedback from avatars and audience members was a barrier to fully engaging in the experience, highlighting a potential limitation of VR as a public speaking tool.

To improve its effectiveness, VR technology could benefit from integrating more realistic avatars and audience reactions. Waltemate et al. (2018) found that avatar personalization increases immersion and presence, suggesting that more dynamic and interactive avatars could enhance the user experience. Additionally, the inclusion of immediate feedback mechanisms and the ability to see presentation notes or slides may enhance the overall sense of immersion and provide a more realistic environment for users to practice public speaking.

## 6.4 Limitations of the research

This study highlights the potential of VR for reducing FLA and improving public speaking skills, yet several limitations must be addressed. Firstly, the small sample size of 13 East Asian participants, all studying at an English-speaking university, limits the generalizability of the findings to other cultural or linguistic groups. Additionally, the artificial nature of the VR environment, including the unrealistic behavior of avatars, such as lack of blinking or dynamic reactions, detracted from the immersive experience for some participants. These limitations suggest the need for more realistic audience behaviors and advanced VR features to better replicate real-world presentation settings.

Another limitation is the short duration of the study, which involved two blocks with six presentations in total. While participants demonstrated improvements in FLA and presentation skills, it remains unclear whether these benefits would be sustained over time. Furthermore, participants were unable to use real-world tools such as slides or notes, which could have made the experience feel more authentic. The absence of a control group also limits the ability to determine whether the observed improvements were specific to the VR intervention or could have been achieved through alternative methods.

In addition there is an inevitable subjectivity in both qualitative research and questionnaire data. It is very important to capture this type of subjective data as foreign language anxiety is a subjective experience, and objective measures would be a proxy for this experience. However, qualitative analysis replies on the researchers interpretation. This is why it is important to triangulate the data. In future research it would be valuable to add other sources of data, such as physiological data, to this triangulation.

## 6.5 Implications and future research

These findings underscore the potential of VR as an anxiety-reducing tool, particularly for introverted individuals and those with high FLA. However, the limitations in VR realism and participant engagement indicate that VR-based public speaking training may be best supplemented with real-life practice and feedback. This aligns with Bouchard et al. (2014), who suggested that while VR can reduce anxiety, it may not fully replicate the nuances of real-world interactions.

Nonetheless, for non-native speakers, providing language support tools in VR, such as live captions or vocabulary suggestions, may further reduce FLA and improve performance.

Future studies could explore the use of more realistic VR avatars and advanced audience simulation to enhance immersion and provide a more effective practice environment. Integrating personality assessments into VR training modules could also help tailor feedback and exposure levels, maximizing the benefits for diverse learners. Furthermore, exploring the long-term effects of VR practice on FLA and public speaking performance could provide further insight into its efficacy as a training tool.

## 7 Conclusion

In conclusion, this study highlights the potential of VR as a tool for reducing FLA and improving public speaking skills, particularly for individuals with introverted tendencies and high anxiety. Over multiple VR sessions, participants demonstrated a significant decrease in FLA and showed behavioral improvements in presentation delivery, including fewer disfluencies and increased confidence. However, the artificiality of VR avatars and limited audience interaction posed challenges for immersion, leading some participants to feel disconnected from the experience. These findings suggest that while VR can be an effective supplement for public speaking practice, especially in controlled environments, its limitations underscore the need for enhanced realism and adaptive features to better support non-native speakers and those with high FLA. Future developments in VR technology should focus on creating more lifelike avatars and responsive audience behaviors to provide a more authentic and engaging practice environment.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by Ethics Committee, Department of Computing, Goldsmiths. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

SP: Conceptualization, Formal Analysis, Methodology, Writing–original draft, Writing–review and editing, Data curation, Investigation, Software, Visualization. DC: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing–original draft, Writing–review and editing. ZC: Data curation, Formal Analysis, Writing–original draft. MG: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Supervision, Writing–original draft, Writing–review and editing. XP: Data curation, Formal Analysis, Writing–original draft, Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing–review and editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

## Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. Generative AI was used during our proof reading.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2025.1519409/full#supplementary-material

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