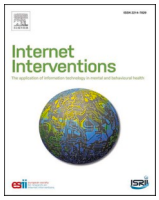
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One-session versus three-session virtual reality exposure therapy for public speaking anxiety: a randomized controlled trial

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ABSTRACT

VR technology has been a useful tool in exposure therapy for working with public speaking anxiety. The common approach to treating public speaking anxiety is a single prolonged VR exposure session, but there is still a lack of consensus on whether dividing the same amount of exposure into several shorter sessions would jeopardize its efficacy. This study aims to compare the efficacy of a single extended session versus the same intervention divided into three shorter sessions of VR-based exposure intervention for public speaking anxiety.

Using block randomization, 37 students (mean age 22.4, 70.3% female) were randomized in a two-armed parallel group randomized controlled superiority trial, with 18 participants allocated to the one-session and 19 to the three-session group. No blinding was used in this trial. The intervention involved 9 speaking tasks that were administered in a single session or divided into 3 equal parts. Public Speaking Anxiety Scale, Liebowitz Social Anxiety Scale and Brief Fear of Negative Evaluation scale were used as outcome measures pre- and post-exposure. Additionally, convenience, duration, fatigue, adaptability, and intensity of the intervention were evaluated.

Results indicate a significant reduction in the level of public speaking anxiety ($\eta_p^2 = 0.588$) and social anxiety ($\eta_p^2 = 0.169$) in both groups, but no statistically significant group differences or time-by-group interactions were detected (for public speaking anxiety interaction difference was −3.37; 95% CI [−10.02, 3.29]. Participants reported the single three-hour session to be more tiring and longer compared to the same amount of exposure split into 3 sessions, but did not indicate any difference in terms of convenience, adaptability, or intensity. Across the full program, one participant reported mild negative effects; harms were not systematically assessed. Our study findings provide preliminary evidence supporting the feasibility of different scheduling formats. However, the trial was underpowered and had no untreated control condition, so adequately powered studies in larger and more diverse samples are needed to compare the formats.

The trial was registered at ClinicalTrials.gov, No NCT06214039.

1. Introduction

It is rather common for people to feel some discomfort with speaking in front of an audience, but in severe cases, public speaking anxiety (PSA) can significantly interfere with important everyday functioning in various social and work spheres (Stein et al., 1996). For young adults starting their careers and seeking employability, public speaking anxiety can especially be a significant hurdle to their academic paths, as

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universities often require and assess performance of public speaking tasks (Bodie, 2010). Severe cases of public speaking anxiety can be categorized as distinct subtype of social anxiety disorder (SAD) (American Psychiatric Association, 2013), however pronounced public speaking anxiety can be experienced without other SAD features (Blöte et al., 2009; Pull, 2012), and the lifetime prevalence of significant fear of public speaking has been found in 21.2–24.8% of the general population (Knappe et al., 2011; Ruscio et al., 2008), higher than SAD in the same sample (6.6–12.1%) (Knappe et al., 2011; Ruscio et al., 2008).

While SAD involves a more general fear of being observed, judged or humiliated in social situations and subsequent avoidance of these contexts (WHO, 2024), public speaking anxiety involves physiological arousal, negative thoughts, and avoidance behaviors specifically in public speaking scenarios (Bodie, 2010). Similar to social anxiety disorder, PSA is suggested to arise from a biased negative self-image related to social performance (Pull, 2012). Individuals with higher PSA tend to experience increased anxiety associated with self-imposed high standards in social situations, and overestimate negative outcomes, feel emotionally out of control, and view their social skills as inadequate (Hirsch et al., 2006; Vîslă et al., 2013). Individuals with PSA are also thought to shift their focus to their internal states and worries during speaking and have heightened fear of physiological symptoms (Rapee and Abbott, 2007; Bodie, 2010), which might also contribute to a self-feeding loop of anxiety and negative self-perception during speaking tasks. Often, PSA is linked to maladaptive coping strategies such as avoidance and rumination (Hofmann, 2007) and can interfere with public speaking performance (King and Finn, 2017), which might negatively affect psychosocial functioning. Considering the prevalence and the impact public speaking anxiety has on the individual, interventions aiming to reduce PSA are especially relevant.

Exposure is one of the most common methods in public speaking anxiety treatment (Ebrahimi et al., 2019), and has been found to be an effective treatment not only for public speaking anxiety but also for wider-ranging issues, like social anxiety disorder (Ebrahimi et al., 2019; Morina et al., 2023; Reeves et al., 2022). Exposure involves structured and planned confrontation with feared stimuli, aiming to reduce the anxiety response (Craske et al., 2014; Rodebaugh et al., 2004). Variations in exposure therapy may include differences in session structure, length, and frequency. In the context of public speaking anxiety, exposure tasks typically involve delivering speeches or presentations to an audience (Banakou et al., 2024; Reeves et al., 2021). Exposure therapy for PSA often can include additional treatment elements like psychoeducation on the public speaking anxiety mechanisms (Reeves et al., 2022), cognitive therapy methods of working with negative beliefs and cognitions by confronting them (Ebrahimi et al., 2019; Reeves et al., 2022) as they are believed to also be one of the key mechanisms in public speaking anxiety (Bodie, 2010; Pull, 2012). However, creating an environment suitable for PSA targeting exposure may not be an easy task.

Virtual reality (VR) technology is gaining popularity in exposure therapy research due to its growing accessibility and potential to facilitate a variety of exposure-based interventions (Reeves et al., 2022). VR offers a controlled, safe environment for exposure tasks, addressing ethical and logistical challenges within regular therapy sessions (Rothbaum and Rothbaum, 2025). Furthermore, an expert consensus (Ma et al., 2021) identifies this adaptability and the capacity for precise control over exposure stimuli as key strengths that distinguish VR from traditional therapeutic modalities. In the context of public speaking anxiety treatment, VR can allow individuals with PSA to give public speaking tasks in front of virtual audiences in a controlled fashion (Reeves et al., 2021; Lindner et al., 2021), i. e., more standardized treatment delivery that is difficult to achieve in in vivo settings. The obvious question is whether exposure to public speaking in front of a virtual audience has the same treatment effects as exposure to public speaking in front of a real audience. While some debate remains about its effectiveness compared to in vivo exposure (Carl et al., 2019; Scheveneels et al., 2025), meta-analyses have reported that VR exposure can be equally effective as face-to-face treatment for social anxiety, including public speaking anxiety (Reeves et al., 2022; Tan et al., 2025), though in vivo exposure may have a slight advantage (Reeves et al., 2022).

One key question in exposure therapy research is how to structure sessions for maximum effectiveness while minimizing time and effort. Öst (1989) introduced one-session treatment (OST) – a single, extended 3-hour exposure session – primarily for specific phobias, arguing that a single prolonged exposure session can be an optimal and efficient treatment. Historically, research on the optimal number and timing of exposure sessions has yielded mixed results (Craske et al., 2008). Different explanations of exposure mechanisms suggest a different set of optimal conditions for implementation. According to the emotional processing model (Foa and Kozak, 1986; Foa and McNally, 1996), exposure works by modifying existing fear associations. This approach emphasizes the need for habituation, which requires longer continuous exposure. In contrast, the inhibitory learning model, proposing that new associations are created competing with the old ones, argues that variability and expectancy violation, as well as learned tolerance to some level of anxiety, are more critical than session length, favoring repeated exposures across different contexts, to ensure that new associations are more robust (Craske et al., 2008; Craske et al., 2014). Supporting this view, some studies have found that multiple sessions reduce fear renewal more effectively than a one-session treatment (Tsao and Craske, 2000; Urcelay et al., 2009). However, a meta-analysis by Odgers et al. (2022) found that one-session in vivo exposure was as effective as multi-session treatments for specific phobias – though most included studies focused on animal phobias, for which OST may be particularly effective.

It is considered that one of the key advantages of OST is its efficiency: it saves time, reduces costs, conserves resources (Odgers et al., 2022), and can help minimize participants' dropout in research settings. That said, in traditional therapy, a three-hour session may be impractical due to scheduling constraints and the intensity of such a session for both therapist and client. Furthermore, practitioners may not be trained to perform OST or simply not accustomed to such a format. Splitting the same exposure time across multiple shorter sessions could offer a more feasible alternative in clinical settings, such as outpatient care. However, as mentioned previously, OST efficiency and effectiveness rely on the need to achieve habituation during prolonged exposure (Öst, 2012). It remains unclear whether OST effectiveness is ensured only through one prolonged session or whether the same amount of exposure divided into a series of shorter sessions could have its own benefits, offering more variability as suggested by Craske et al. (2008). What is more, exposure conducted using VR technology adds another layer of complications and questions when deciding on how to divide exposure tasks. Engaging in VR tasks for a longer time could affect how real the VR environment is perceived, and prolonged VR use is associated with an increased risk of cybersickness (Melo et al., 2018), both of which could affect exposure flow and effectiveness. Therefore, it remains unclear how the efficacy of VR-based exposure for public speaking anxiety would be affected by conducting the exposure in several shorter one-hour sessions compared to one prolonged three-hour session and whether one exposure task schedule would be more effective over another.

1.1. Aims

The aim of this study was to compare the efficacy of two delivery formats of VR-based exposure intervention for public speaking anxiety – a single extended session versus the same intervention divided into three shorter sessions.

2. Material and method

2.1. Study design

The study design was a superiority two-armed parallel group randomized controlled trial. Due to smaller than planned final number of participants, this trial is now treated as a pilot study. The intervention consisted of face-to-face VR-based exposure session(s), followed by a supplementary four-week online program, both adapted from Lindner et al. (2019). There was no patient or public involvement in the design, conduct, and reporting of the trial. The trial was approved by the Committee on Research Ethics in Psychology at Vilnius University: November 13, 2023, No. 21 / (1.13 E) 250000-KT-166 Vilnius. All participants gave their informed consent prior to engaging in any study activities. The trial was registered at ClinicalTrials.gov NCT06214039; https://clinicaltrials.gov/study/NCT06214039. For more information on the study design, see the study protocol (Gegieckaitė et al., 2026).

2.2. Participants/recruitment and procedure

2.2.1. Inclusion criteria

Apart from the technical criteria, such as willingness to participate in the whole intervention program, good command of the Lithuanian language, and computer / Internet access, participants were included in the study if they were a) young adults (age ranging between 18 and 30 years); b) currently studying; c) reporting a significant level of public speaking anxiety during initial screening (scoring 60 or above on the Public Speaking Anxiety Scale).

2.2.2. Exclusion criteria

Participants were excluded from the study in case of serious specific medical conditions rendering participation in this intervention ineffective or unsafe (i.e., history of seizures or epilepsy, extreme seasickness reactions, lack of stereoscopic vision, adverse reactions to virtual reality experiences) as well as for mental health aspects that could interfere with participation in the program (i.e., moderately severe depressive symptoms, suicidal ideation, currently undergoing treatment for public speaking anxiety or other mental health issues, changes in psychoactive medication over the last 3 months).

2.2.3. Recruitment and assessment

The information about the study was shared using student email conferences and social media posts by the administration of higher education institutions, as well as student organizations of said institutions. Paper posters were put up in the common areas of higher education institutions. Research team representatives participated in various informational events at the higher education institutions and presented in person the opportunity to participate in the study. Recruitment started in January 2024 and ended in December 2025.

Participants meeting eligibility criteria ($n = 37$) were randomized according to a random allocation sequence either to the one-session intervention group ($n = 18$) or to the three-session intervention group ($n = 19$). Participants were assigned to groups continuously as they were recruited. Individual randomization with an equal allocation ratio was used. Moreover, in order to ensure an equal ratio under rolling recruitment conditions, blocked randomization was applied, i.e. randomized allocation lists were prepared in advance with 3 batches of 20 allocations and 3 batches of 10 allocations. A random sequence list was generated using an online random number service (www.random.org), and the team member responsible for participant selection was blind to the sequence (i.e., had no access to the randomization list) and received the group allocation information from a team member not involved in the eligibility assessment process only after the participant was deemed eligible. No stratification was applied. Three of the randomized participants (1 from one-session and 2 from three-session intervention group) did not attend the treatment appointment(s) and did not respond to further contact attempts. Two participants (one from each intervention group) did not complete the post-intervention assessment after repeated reminders. In total, 17 participants in each group received the full VR protocol. In the one-session group, 16 started the online program, whereas in the three-session group 13 did so. A flowchart of study participants is presented in Fig. 1.

No blinding was used in this study. Due to the nature of the intervention, neither participants nor therapists can be fully blinded. Participants were told that they would be asked to participate in up to three sessions depending on the group, however, they were not told which number of exposure sessions was expected to be superior. Primary and secondary outcome assessments were performed privately online, which reduced the therapist's effect on these responses.

2.3. Intervention protocol

The intervention consisted of one or three face-to-face VR exposure sessions. The procedures and tasks used during the VR exposure were adapted for this study from Lindner et al. (2019) and will be described in more detail below. After completion of the VR exposure part, participants from both groups were provided the opportunity to participate in four weeks of a supplementary self-guided online program developed by Lindner et al. (2019) that aimed to facilitate the transition from virtual to real-life experience by providing educational materials and assignments encouraging study participants to plan and carry out public speaking in vivo exposure tasks. The efficacy of this self-guided online program was evaluated in previous studies (Lindner et al., 2019, 2021).

The publicly available software VirtualSpeech version 5.29 was used for VR-based exposure tasks. We used a commercially available VR Meta Quest 2 headset. Trained clinical psychologists and master's-level psychology students were therapists in the study. Supervision was provided by the developer of the VR exposure treatment protocol. There was no formal assessment of fidelity; however, therapists' fidelity to the protocol during exposure sessions was discussed during regular therapists' supervision meetings.

2.3.1. Face-to-face VR-based exposure

During VR exposure, participants were first presented with psychoeducation followed by 9 short (1–3 min) speaking tasks while using a VR headset to virtually stand before audiences of different sizes. Tasks varied in difficulty and included counting backward, naming words starting with the same letter, talking about themselves, about their interests, about their achievements, or about their fear of public speaking, and preparing and giving a speech on a selected controversial topic like migration, euthanasia, abortion, etc. All speaking tasks were audio-recorded. As in Lindner et al. (2019, 2021), before each task participants reported their level of distress, negative beliefs / expectations about each task, and the probability of those expectations coming true. After each task, participants once again rated the level of distress, the highest level of distress during the task, perceived quality of their performance, and the level of presence in the VR environment. Afterwards, participants listened to the audio recording of their performance while imagining being part of the audience, and evaluated the quality of the presentation as well as how much their negative expectations were confirmed.

2.3.2. One session vs. three sessions

All participants were randomized into two intervention groups, either consisting of a single three-hour-long VR exposure session or three one-hour sessions over the course of two weeks. Both groups completed the exact same VR exposure tasks in the same order and with the same virtual audiences, as well as subsequent review of recordings and assessments. The one-session group had to perform all nine VR exposure speaking tasks over the course of 3 h, whereas the three-session group received tasks 1–3 in the first session, tasks 4–6 in the second session, and tasks 7–9 in the third and final session.

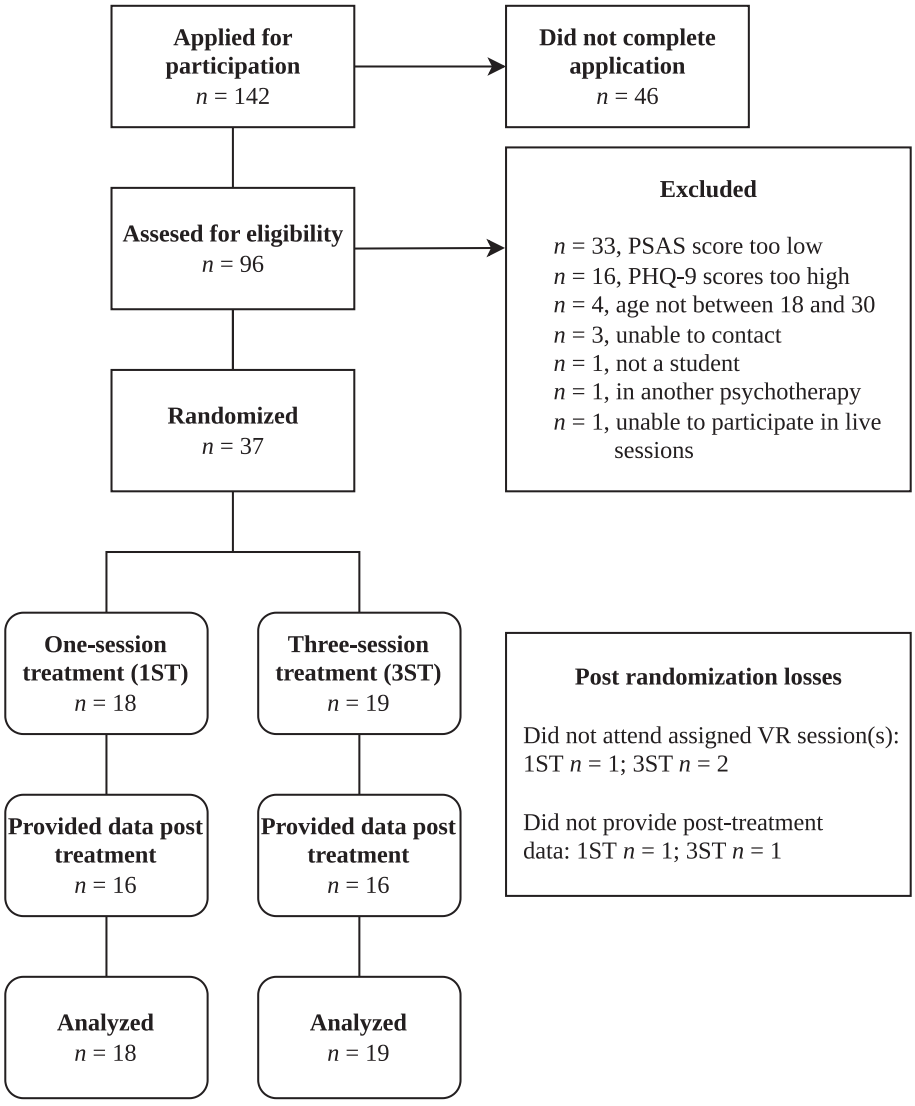


Fig. 1. CONSORT flow diagram of study participants.

No earlier than one week after the last VR exposure session, participants were invited to complete a post-exposure assessment, which was used in this study to compare the efficacy of different VR-based exposure delivery formats, and after that they were prompted to start the supplementary self-guided online program.

2.4. Measures

2.4.1. Primary treatment outcome measure

Public Speaking Anxiety Scale (PSAS; Bartholomay and Houlihan, 2016) was used as a primary outcome measure pre-intervention and 1-week post-intervention. The scale consists of 17 self-report statements measured on a Likert-type scale ranging from 1 “not at all” to 5 “extremely”. PSAS measures cognitive, behavioral, and physiological components of public speaking anxiety, with a higher total score of the scale indicating higher levels of anxiety during public speaking. Scores range from 17 to 85. The Lithuanian version of PSAS has good psychometric properties (Arcimavičiūtė et al., 2024).

2.4.2. Secondary outcome measures

The level of social anxiety was assessed with a self-report version of the Liebowitz Social Anxiety Scale (LSAS-SR; Liebowitz, 2003; Rytwinski et al., 2009). LSAS-SR consists of 24 items describing different social situations: 11 items addressing social interaction situations and 13 items addressing public performance situations. Each item is rated twice using 4-point Likert scales, one for the intensity of anxiety ranging from 0 “none” to 3 “severe” and the other one for the frequency of avoidance of the situation ranging from 0 “never” to 3 “usually”. The higher total score indicates more severe symptoms of social anxiety. Scores range from 0 to 144. Lithuanian version of the LSAS-SR has excellent internal consistency (Cronbach's $\alpha = 0.96$) and a factor structure consistent with the original version (Zamalijeva et al., 2026).

Assessment of apprehension regarding the possibility of receiving negative evaluations was performed using the Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983). The BFNE consists of 12 items, which are rated on a 5-point Likert-type scale, which in the Lithuanian version were coded from 0 “not at all” to 4 “extremely”, describing presence or absence of fear or worry about being negatively regarded by others. A total score is calculated for all items and individuals who score higher exhibit a heightened fear of negative evaluation. Scores range from 0 to 48. Reported psychometric properties of BFNE show good internal consistency and adequate construct validity (Zamalijeva et al., 2024).

2.4.3. In-session measures

In addition to primary and secondary outcome measures, a series of

single-item assessments rated on a scale from 0 to 100 were conducted during the VR exposure session before and after each speaking task. Subjective units of distress (SUD), from 0 "no distress" to 100 "extremely high distress", were rated three times: 1) right after the announcement of the speaking task that needed to be performed, 2) after the speaking task was completed, and 3) evaluating the greatest distress experienced during the task. Participants were asked to report their negative expectations (EXP) about the task, first by providing a qualitative description of what is going to go wrong during the task, then by rating the chances of this happening from 0 "definitely not going to happen" to 100 "definitely going to happen" and after the completion of the task and review of the audio recording to rate how much the expectation was fulfilled, from 0 "not true at all" to 100 "completely came true". Moreover, for each task, participants rated the quality (QUAL) of their performance from 0 "completely failed" to 100 "completely succeeded" right after the task as well as after reviewing the audio recording.

The overall sense of presence during the treatment session was measured with the Igroup Presence Questionnaire (IPQ) (Schubert, 2003). This questionnaire consists of 14 items measuring three main aspects, including spatial presence, involvement, and experienced realism. Each item is rated on a 7-point Likert scale, and the score is calculated by summing the ratings for each item. Assessments were performed at the end of the session in the one-session condition or at the end of each session in the three-session condition. A greater total score of the scale indicated a more expressed sense of presence.

2.4.4. Other measures

At the end of the face-to-face VR exposure session (series), participants were asked to provide feedback based on their experience about several characteristics of their face-to-face VR exposure session(s) format. Using a seven-point semantic differential scale, coded from 0 to 6, participants were asked to evaluate different aspects of their therapy session(s): convenience (0 – "inconvenient" vs. 6 – "convenient"), duration (0 – "long" vs. 6 – "short"), fatigue (0 – "tiring" vs. 6 – "not tiring"), adaptability (0 – "difficult to adapt to" vs. 6 – "easy to adapt to"), and intensity (0 – "not intense" vs. 6 – "intense"). Each score was used as a separate dimension.

Patient Health Questionnaire-9 (PHQ-9) was used during screening as an exclusion criterion. PHQ-9 consists of 9 items and rate the frequency of symptoms on a scale from 0 "not at all" to 3 "nearly every day". The total score of 15 and above indicates a risk of severe depression (Kroenke et al., 2001). The risk of suicidal ideation was measured by PHQ-9 item 9, which included thoughts about being dead or hurting oneself, and discussed on the phone during eligibility assessment. The Lithuanian version of PHQ-9 has been validated in young adult sample and showed good psychometric properties (Pranckeviciene et al., 2022).

This intervention was considered low-risk and was not expected to cause any harm to the participants; thus, no systematic assessment of adverse effects was planned. However, if participants experienced significant distress and felt uncomfortable to continue, exposure tasks would have been suspended. Moreover, during online intervention, participants were instructed to contact the research staff if they experienced significant deterioration of their condition. After the four-week online program, participants were asked to indicate whether they experienced any adverse effects or uncomfortable experiences during the course of the program. In case of a positive answer, they were asked to specify their negative experiences and to rate whether these experiences were mild, moderate, or severe.

2.5. Data management and statistical analysis

Statistical data analysis was performed using IBM SPSS Statistics version 29.0. Primary and secondary outcome as well as participant experiences analyses were performed as intention-to-treat (ITT) because it preserves the benefits of randomization. Participants who completed the post-treatment assessment ($n = 32$) and those who did not ($n = 5$) did not differ significantly on baseline characteristics, including baseline PSAS, LSAS, BFNE, PHQ-9 scores, as well as age, gender and assigned treatment group. Although such comparisons cannot establish the missing-data mechanism, it was assumed that the data were missing at random, and missing data were managed using the expectation-maximization imputation method for ITT analysis. Change in primary and secondary outcome measures as well as other potential differences between both intervention groups were evaluated using Repeated Measures ANOVA, p values are unadjusted. Initial power analysis was performed using the G* Power program for Repeated Measures ANOVA between factors effects with 2 groups × 3-time measurements (pre-treatment, one week post last exposure session, and at the end of the online intervention period or equivalent time). This analysis suggested that with a significance level of 0.05 achieving 80% power to detect a medium effect (Cohen f = 0.25) with an estimated correlation between repeated factors of 0.5, a total sample of 86 is needed. All comparisons were performed between baseline assessments prior to the face-to-face VR exposure session(s) (pre-intervention) and one week after the VR-based exposure session(s) (post-intervention). No interim analyses or stopping rules were used. Effect size was assessed using partial eta-squared, where values reaching 0.01 are considered small, 0.06 - medium, 0.14 - large (Richardson, 2011), and Cohen's *d,* where the value of 0.20 is classified as small, 0.50 - medium, and above 0.80 - large (Sullivan and Feinn, 2012). Normality of distribution of the outcome variables was assessed based on skewness and kurtosis, with values between −2 and 2 that were acceptable to consider a normal distribution (Gravetter and Wallnau, 2014).

2.6. Deviations from protocol

Despite extensive efforts, recruitment failed to reach the target sample of 86 participants with equal split between groups as planned in the study protocol (Gegieckaitė et al., 2026). Over the course of the data collection period, 37 subjects have fulfilled the eligibility criteria and were randomized. Moreover, the study protocol planned for several post-intervention assessments, including a supplementary four-week online program and 3- and 12-month follow-up. However, due to further substantial attrition of participants, the analysis of the follow-up results and additionally planned statistical analysis strategies, including regression analysis, were not feasible, and the study is now limited only to assessment of immediate effects of intervention. Thus, this study will only be viewed as a pilot, and the results are considered preliminary. The missing data imputation method for the intention-to-treat was switched from multiple imputations to expectation-maximization (EM) estimation because RM-ANOVA is unable to run multiple imputed datasets with available software. The power analysis was adapted for RM-ANOVA within-between interaction with 2 groups × 2-time measure (pre- and post-exposure) and suggested that at least 34 participants were needed for the analysis. In addition, a linear mixed-effects model (LMM) analysis was performed using all available observed data, without imputation, with participants analyzed as randomized to evaluate the changes in primary and secondary outcomes as a sensitivity analysis. Originally in the study protocol, a per-protocol analysis was planned for sensitivity analysis. However, LMM makes use of all available repeated-measures data and is considered a more appropriate method for handling incomplete longitudinal datasets than analyses restricted to protocol completers.

Additional analyses, not pre-specified in the study protocol, were performed to gain additional information about the processes and changes during the treatment sessions and subjective participant experience in one-session and three-session groups. The *t*-test was used to compare the sense of presence and the highest level of distress experienced during VR exposure tasks. Pearson's correlations were calculated to evaluate the association between the sense of presence and the highest level of distress. RM-ANOVA was used to assess possible changes associated with the levels of distress, negative expectations, and quality

of performance on the tasks during VR exposure and between intervention groups. Also, the *t*-test was used to compare subjective participant experience regarding the convenience, duration, fatigue, adaptability, and intensity of intervention delivery format in one-session and three-session groups.

3. Results

The data of 37 participants were included in this analysis. The average age was 22.38 ($SD = 3.04$), more than two-thirds of all participants were female, just one-fifth were from rural areas, and almost half reported being single. Comparison of sociodemographic characteristics between the one-session and three-session intervention groups did not show any significant differences. Participants from different intervention groups also did not differ in regard to their public speaking anxiety and fear of negative evaluation scores at baseline, although the three-session group did report significantly higher social anxiety scores, $t(35) = -2.13$, $p = .040$. Detailed participant descriptions are presented in Table 1.

Fig. 2 shows means and standard deviations of pre- and post-exposure assessments in one-session and three-session groups. Results of Repeated Measures ANOVA revealed a significant reduction in public speaking anxiety levels from baseline to post-treatment with a large effect size ($F(1, 35) = 49.98$, $p < .001$, $\eta_p^2 = 0.588$). Notably, no significant differences between the one-session and three-session groups ($F(1, 35) = 0.35$, $p = .558$) or interaction effects between time and intervention groups ($F(1,35) = 1.05$, $p = .312$) were found. Regarding secondary outcomes, comparisons of social anxiety levels showed a notable reduction over time ($F(1, 35) = 7.12$, $p = .011$, $\eta_p^2 = 0.169$) but no group differences ($F(1, 35) = 2.49$, $p = .124$) or interaction effects ($F(1, 35) = 3.00$, $p = .092$). However, fear of negative evaluation scores did not reduce significantly over time ($F(1,35) = 3.44$, $p = .072$) or between groups ($F(1, 35) = 0.62$, $p = .437$). No significant interaction was found ($F(1, 35) = 1.59$, $p = .216$). Detailed results of Repeated Measures ANOVA are presented in Supplement 1.

As a sensitivity analysis to assess the robustness of the primary findings, linear mixed-effects models (LMMs) were conducted to examine changes in PSAS, LSAS, and BFNE scores over time and between intervention groups, and are presented in Table 2. For PSAS, a significant main effect of time was observed ($F(1, 30.04) = 38.77$, $p < .001$), indicating a reduction in public speaking anxiety from pre- to post-intervention. Similarly, a significant main effect of time was found for LSAS ($F(1, 30.33) = 9.06$, $p = .005$). For BFNE, the effect of time did not reach statistical significance ($F(1, 31.69) = 3.92$, $p = .057$). No significant main effects of intervention group were observed for any outcome, and none of the Group × Time interactions were significant (PSAS: $p = .254$; LSAS: $p = .237$; BFNE: $p = .374$), indicating that the magnitude of improvement did not differ significantly between intervention groups. Estimated marginal means showed reductions in PSAS scores (−9.40 and − 13.72 points), LSAS scores (−4.43 and − 10.36 points), and BFNE scores (−1.32 and − 3.53 points) across the two intervention groups. These results coincide with the RM-ANOVA results.

Analysis of in-session measures was performed to provide additional insight into the processes underlying possible changes during exposure session and possible differences between the intervention groups. Results indicate that there were no significant differences in the sense of presence between one-session and three-session intervention groups on any of the 9 tasks and the overall sense of presence measured by IPQ (see Supplement 2). There were significant differences in the greatest level of distress (SUD) between intervention groups on 4 out of 9 exposure tasks (see Supplement 4) that showed higher distress levels in the three-session group. Correlational analysis indicates that the sense of presence during the task and the overall IPQ score were only significantly associated with the first task (see Supplement 3).

Using Repeated Measures ANOVA, the changes in subjective levels of distress (SUD) before and after the task, negative expectations (EXP) before and after the task, as well as the evaluation of the quality of performance (QUAL) right after the task and after listening to the audio recording were compared. Results show that the level of distress significantly reduced after 8 out of 9 tasks, observed SUD scores were significantly higher in the three-session group in 5 tasks, but there was no significant time and group interaction, indicating the change in SUD levels was similar in both groups (see Supplement 5). Analysis of negative expectations during exposure sessions showed that participants were likely to expect more negative outcomes than they actually experienced on 6 out of 9 tasks, the level of negative expectations and them being confirmed was significantly greater on the first two tasks in the three-session group, and there was one significant time and group interaction on one task, indicating that the difference in expected and confirmed negative outcomes was greater for the three-session group (see Supplement 6). Concerning the assessment of the quality of performance, results indicate that participants evaluated their performance significantly better after they had a chance to listen to its recording on 3 out of 9 tasks, on three tasks, participants from the one-session group were significantly more likely to report better performance quality, but only on one task significant time and group interaction was observed,

Table 1
Sociodemographic characteristics and levels of main outcome measures at baseline.

		Whole sample		1 session intervention group		3 sessions intervention group		Comparison	
		N	%	N	%	N	%	Chi-square (df)	*p*
Gender	Female	26	70.3	14	77.8	12	63.2	1.528 (2)	0.466
	Male	10	27.0	4	22.2	6	31.6		
	Other	1	2.7	0	0	1	5.3		
Partnership status	Cohabitating partner	12	32.4	3	16.7	9	47.4	4.484 (2)	0.106
	Living separately	7	18.9	5	27.8	2	10.5		
	Single	18	48.6	10	55.6	8	42.1		
Area of residence	Large city	16	43.2	7	38.9	9	47.4	2.653 (2)	0.265
	Town	14	37.8	9	50.0	5	26.3		
	Rural	7	18.9	2	11.1	5	26.3		
Education level	Bachelor's degree student	28	75.7	13	72.2	15	78.9	0.227 (1)	0.634
	Master's degree student	9	24.3	5	27.8	4	21.1		
Previous VR experience	Yes	15	40.5	6	33.3	9	47.4	0.755 (1)	0.385
	No	22	59.5	12	66.7	10	52.6		
		M	SD	M	SD	M	SD	*t* (df)	*p*
Age		22.38	3.04	22.33	2.99	22.42	3.17	−0.087 (35)	0.932
PSAS (screening; t_0)		68.70	5.18	68.50	4.79	68.89	5.66	−0.228 (35)	0.821
LSAS (screening; t_0)		71.03	20.81	63.89	22.64	77.79	16.80	−2.129 (35)	0.040
BFNE (screening; t_0)		34.68	8.26	33.00	9.71	36.26	6.48	−1.208 (35)	0.235

Note. PSAS – Public Speaking Anxiety Scale score; LSAS – Liebowitz Social Anxiety Scale score; BFNE – Brief Fear of Negative Evaluation scale score.

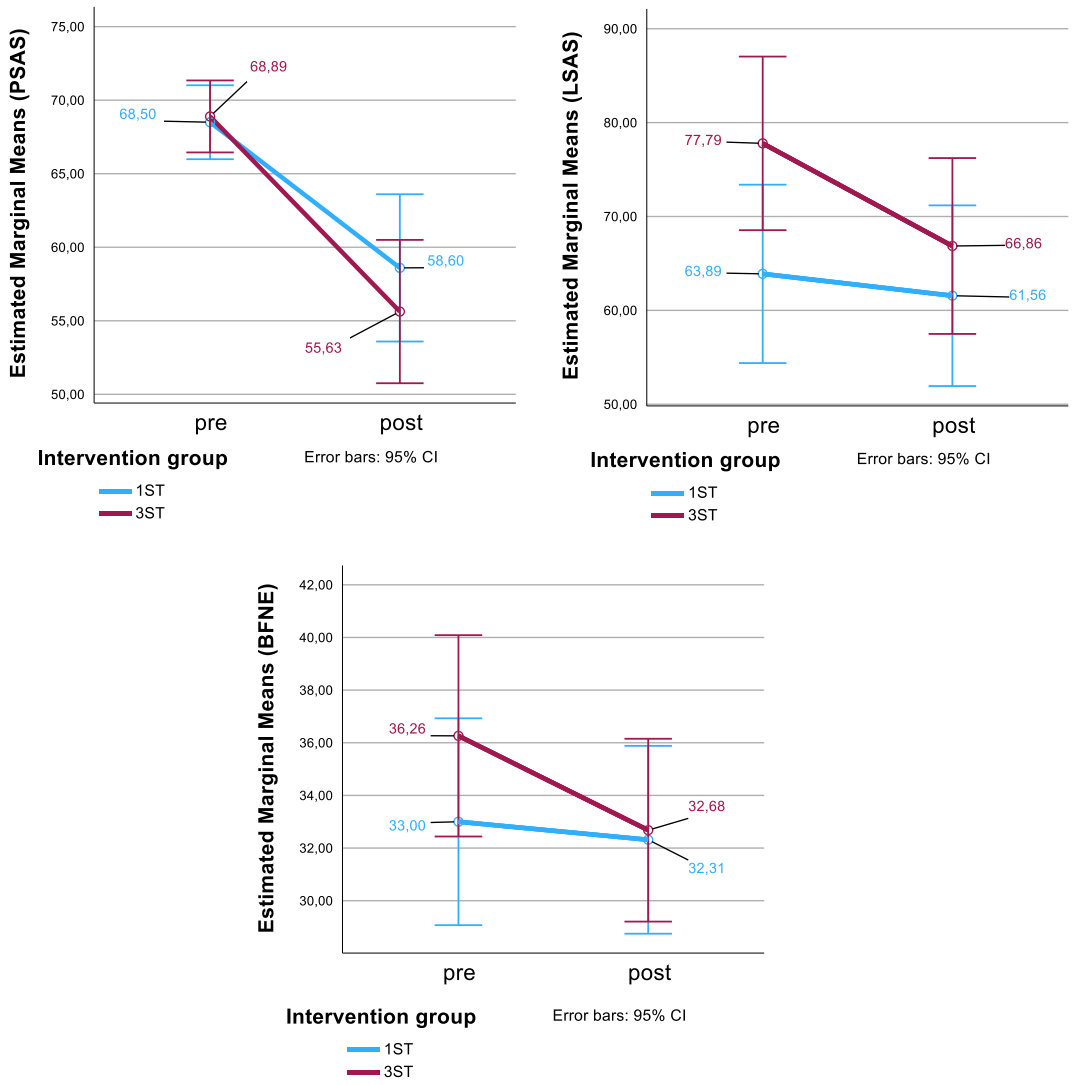


Fig. 2. Pre- and post-exposure assessment comparisons of primary and secondary outcomes
Note. 1ST – one-session treatment; 3ST – three-session treatment. PSAS – Public Speaking Anxiety Scale score; LSAS – Liebowitz Social Anxiety Scale score; BFNE – Brief Fear of Negative Evaluation scale score.

Table 2
Linear mixed model results and estimated marginal means by outcome and group.

Outcome	Group	Screening (t_0) M	Post-exposure (t_2) M	Change	Time Effect F(df1, df2)	p	Group × Time F(df1, df2)	p
PSAS	1ST	68.50	59.10	−9.40	38.77 (1, 30.04)	< 0.001	1.35 (1, 30.04)	0.254
	3ST	68.90	55.18	−13.72				
LSAS	1ST	63.89	59.46	−4.43	9.06 (1, 30.33)	0.005	1.46 (1, 30.33)	0.237
	3ST	77.79	67.43	−10.36				
BFNE	1ST	33.00	31.68	−1.32	3.92 (1, 31.69)	0.057	0.81 (1, 31.69)	0.374
	3ST	36.26	32.74	−3.53				

Note. 1ST – one-session treatment; 3ST – three-session treatment.

showing that change in QUAL was greater in the one-session group (see Supplement 7). It is also important to note that differences in scores of in-session measurements that show higher levels of distress, greater levels of negative expectations, and poorer perceived performance quality in the three-session group also coincide with significantly higher levels of social anxiety measured by LSAS in this intervention group.

Individuals who participated in one three-hour-long session intervention group found it to be significantly more tiring ($t(27.58) = -3.71$, Cohen's $d = 1.24$, $p = .001$), compared to the ones who participated in 3 separate sessions with the same number of tasks. Subjects who participated in 3 one-hour-long sessions on average reported the duration of the intervention to be significantly on the shorter side ($t(35) = -4.63$, Cohen's $d = 1.52$, $p < .001$), compared to the ones who had one three-hour-long session. Other subjective assessments regarding subjects' experience during different VR-based exposure delivery formats, including the level of convenience, intensity, and ease of adaptation, did not differ between both groups. The results of these comparisons are presented in Fig. 3.

Finally, concerning harms and adverse events, there were no cases when exposure tasks had to be suspended due to adverse effects

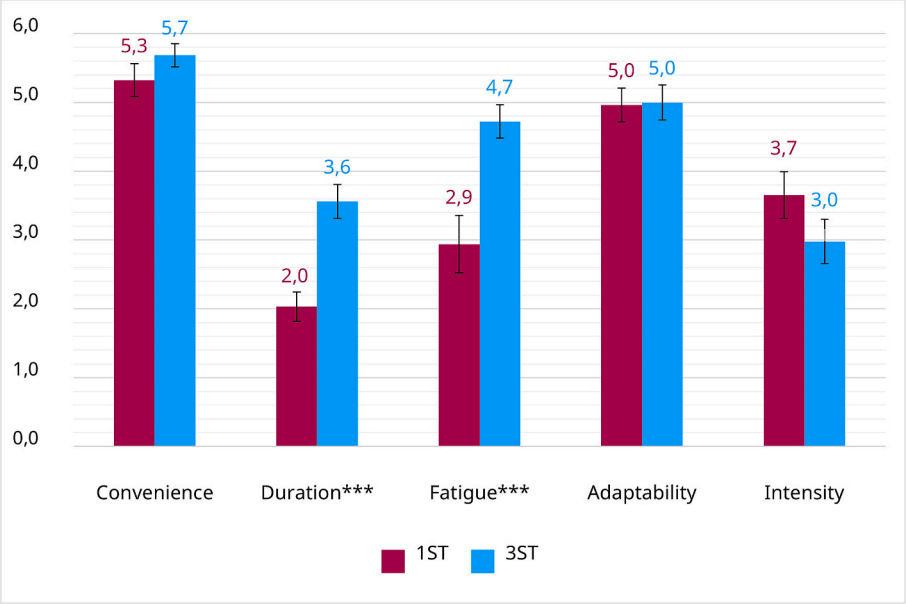


Fig. 3. Comparison of subjective participant experience in one-session and three-session groups.
Note. *** $p < .001$, graph presents measurement means and standard errors of the means. 1ST – one-session treatment; 3ST – three-session treatment. Higher scores indicate greater convenience, shorter duration, less fatigue, greater adaptability, and higher intensity.

experienced by the participants. After the four-week online program participants were asked to indicate whether they had experienced any discomfort during the program. 20 participants provided the information regarding adverse effects: 12 from one-session group and 8 from three-session group. One participant from the one-session group reported negative effects experienced during the course of the whole program, which the person also reported to be of mild severity.

4. Discussion

The current study set out to compare the efficacy of a VR-based exposure intervention for public speaking anxiety across two different delivery formats: a single extended session in contrast to the same intervention divided into three shorter sessions, and to test whether one had superiority over the other. In both instances, levels of public speaking anxiety, social anxiety, and fear of negative evaluation were evaluated one week after receiving VR-based exposure. We did not find the superiority of one condition over the other as no significant difference in primary and secondary outcomes was found between the one three-hour long session format and the three one-hour sessions format. In-session measures of the sense of presence, levels of experienced distress, negative expectations, or quality of performance during the exposure also showed some group differences in level, in line with the higher baseline social anxiety in the three-session group, but no consistent group difference in change. Reductions in public speaking anxiety and social anxiety were observed following VR-based exposure delivered in either format. Despite this decline in overall anxiety, the reduction in fear of negative evaluation was not statistically significant.

First of all, looking at the overall effects, both intervention groups showed a significant reduction in the level of public speaking anxiety. Previous studies have reported that virtual reality can create environments suitable for exposure therapy and can be effectively used for symptom reduction while treating public speaking anxiety (e.g., Lindner et al., 2019; Lindner et al., 2021; Reeves et al., 2021; Stupar-Rutenfrans et al., 2017), and these results have also been corroborated by a meta-analysis (Reeves et al., 2022). Here again, results of this study also indicated a very large effect size when comparing the primary outcome – public speaking anxiety levels – before and after intervention. However, this finding should be interpreted with caution. Results yielded in small study samples might have a tendency to produce extreme effect size estimates (Morris, 2020). As a result, the very large reduction of public speaking anxiety in the relatively small-scale study may be an overestimation. Without an untreated comparison group, part of the reduction may reflect natural change or repeated assessment. Selection on high screening PSAS scores may also contribute to regression to the mean if screening served as the pre-treatment assessment. Additionally, these results represent the immediate, short-term effect, which is likely to be unaffected by real-life public speaking experience, making it impossible to make any assumptions regarding possible long-term effects.

The main objective of this study was to compare two modes of VR exposure delivery formats. We raised the question of whether different approaches to dividing exposure tasks would affect efficacy, with one condition showing superiority in its efficacy. We considered that different theoretical arguments could support the superiority of each of the conditions. One prolonged session of exposure would be supported by the habituation idea, as the OST was based on emphasizing the need for prolonged exposure (Öst, 2012). Alternatively, authors of the inhibitory learning model (Craske et al., 2008) suggested that variability of the exposure and expectancy violations in different scenarios would help with the robustness of new learned associations and emphasize that habituation is not essential. In this case, three sessions of the exposure task would introduce more variability. Exposure would happen on three different days, with some of the conditions differing – time of the day and week, mood, doing the exposure session for the first time, or coming in for the repeated sessions, and so on. What is more, adding a VR element to treatment not only introduces additional benefits, but can possibly also lead to disadvantages for sessions, as it is not clear how the sense of presence might change with time and how cybersickness or fatigue might affect the exposure experience. We found no significant differences in treatment outcomes between the conditions, neither showing superiority and clear advantages in reducing public speaking anxiety. Our reported pattern was similar to a recent meta-analysis by Odgers et al. (2022), which found that one-session in vivo exposure was as effective as multi-session treatments for specific phobias. Previous studies in the field also found mixed results on the optimal number and timing of exposure sessions (Craske et al., 2008). This might suggest that the exposure schedule might not be the essential effectiveness

mechanism. Both conditions included essential and established exposure therapy's and CBT elements for anxiety disorders and public speaking anxiety - exposure tasks, psychoeducation, and working with expectancy violations (Kaczkurkin and Foa, 2015; McWilliam et al., 2025). In fact, Lindner et al. (2019) point out this intervention's emphasis on working with catastrophic beliefs through exposure and other possible additional mechanisms, like targeting self-attention and biased recall by using audio feedback. Most likely, these core elements of the intervention might have been the essential content in explaining the reduction of speaking anxiety in both conditions, and the fact that neither condition showed superiority. However, our study design does not allow us to pinpoint the mechanisms or specific elements that might explain the observed improvements in both conditions. Also, while we theorized that each condition's superiority could be supported by different arguments from two theories, our study design and results do not allow us to claim that two conditions represent different mechanisms of habituation or variability. On the one hand, even in one-hour sessions, habituation from repeated exposure might have been achieved; on the other hand, in both conditions, different tasks included giving speeches to different audience sizes and classes that are important for inhibition, therefore, both conditions might have included enough of the habituation or variability of exposure tasks to significantly reduce public speaking anxiety. However, we did not detect a statistically significant difference in outcomes between the schedules. Finally, the finding that it was perceived as significantly more tiring suggests that offering a multi-session alternative could improve the intervention's 'Usability', a key component of the TEQUILA framework (Löchner et al., 2025) for responsible digital mental health implementation, by accommodating individual differences in fatigue and treatment preferences. Providing patients with a choice of treatment format may further enhance engagement, satisfaction, and treatment retention, as evidence suggests that accommodating patient preferences is associated with improved treatment completion, reduced dropout, and better treatment outcomes (Johnson et al., 2025; Lindhiem et al., 2014). From an implementation perspective, shorter session delivery may also facilitate adherence, increase scheduling flexibility, reduce the burden associated with prolonged exposure sessions, and enhance integration into routine clinical services. Conversely, a one-session format may remain advantageous in contexts where rapid treatment completion is needed or where opportunities for repeated attendance are limited. These considerations suggest that the optimal delivery format may depend not only on efficacy but also on practical and contextual factors. Furthermore, individual patient characteristics, such as social anxiety severity, tolerance for cognitive fatigue, treatment preferences, and prior experience with VR-based interventions, may influence which format is most acceptable and beneficial. Future research should investigate potential moderators of treatment response and acceptability to identify for whom each delivery format is most appropriate. However, our sample size limited the power to detect between-group differences, and therefore potentially important differences in effectiveness or acceptability cannot be ruled out.

The secondary outcome measures revealed a more complex pattern of treatment effects, as fear of negative evaluation did not show a statistically significant reduction over time. The results could suggest that while the intervention may have targeted behavioral and physiological manifestations of social anxiety, it may have been less effective in addressing deeper cognitive structures related to fears of social evaluation. This is contrary to the study which relied on 360 videos, real-life recordings displaying naturally varying facial expressions that could potentially be perceived as judgment or other types of negative evaluation (Reeves et al., 2021). On the one hand, this could result from the fact that it may be rather challenging for the participant to believe that artificially looking people from an artificially generated environment might actually judge them, as compared to in vivo exposure or real-life 360 video. This lack of perceived realism may have reduced the sense of presence, which experts identify as a critical component for triggering the emotional engagement necessary for modifying core fears in VR (Ma et al., 2021). On the other hand, these contradictory findings may also indicate that fear of negative evaluation represents a core cognitive feature of public speaking anxiety, influencing individuals' tendency to adjust their behavior to avoid unfavorable judgments from others. This pattern can be understood through the hierarchical organization of cognitions in anxiety disorders (David et al., 2009; Vîslă et al., 2013). Fear of negative evaluation may represent a core irrational belief that operates at a more fundamental level than the situation-specific automatic thoughts typically addressed through exposure therapy. While repeated virtual reality exposure may have modified response expectancies and automatic thoughts related to public speaking performance itself, these core evaluative schemas about social judgment appear to be more resistant to change through exposure alone (Vîslă et al., 2013). Irrational beliefs function as evaluative schemas that bias perception and generate situation-specific cognitions, thus, reductions in speech-related anxiety may reflect changes in surface-level automatic thoughts and learned response expectancies rather than fundamental shifts in underlying beliefs about negative evaluation. This could suggest that targeting these deeper cognitive structures may require explicit cognitive restructuring techniques in addition to exposure-based interventions. However, both the limited realism of computer-generated audience and the underlying cognitive structures are plausible explanations, which the present data cannot test, hence future studies could include process measures to test these negative evaluation related assumptions.

4.1. Strengths and limitations

The main strength of this research is that it addresses an understudied but practical topic of comparing the efficacy of different delivery formats of VR-based exposure intervention, and these preliminary results may inform clinical practice and intervention planning. Another strength is the comprehensive assessments, which not only included psychometric scales related to public speaking anxiety, social anxiety, and fear of negative evaluation, but also took participants' subjective assessment of the intervention delivery format into account. Lastly, our study demonstrated that commercially available software could be used to provide public speaking environments for exposure, which increases accessibility of this type of intervention for practitioners.

Despite these advantages, this study could not avoid limitations restraining the generalizability of results. One of the main limitations is the small sample size. Though not uncommon in RCTs, a sample of 37 participants may be associated with inflated effect size and other methodological artifacts. Thus, further investigation is needed to confirm the results obtained. Another limitation is the higher baseline LSAS score in the three-session group, which may have influenced the comparison of changes in social anxiety. Furthermore, the majority of the participants in this sample were female. With previous studies showing some differences in the way VR environments are perceived among different genders (Felnhofer et al., 2012), it is important to aim for more balanced samples in terms of gender. Notably, all primary and secondary outcome assessments were based on self-report; thus, the results might have been affected by self-report and expectancy bias. Additionally, both groups included active treatments, without a control group. Even though the effectiveness of VR-based exposure treatment for public speaking anxiety has been demonstrated before (Reeves et al., 2022), it is likely that results and conclusions would have been more accurate and comprehensive if the control group was included – although recent guidelines suggest that comparative efficacy trials between active interventions provide superior comparison strength compared to waitlist controls (Goldberg et al., 2023).

4.2. Future directions

It is important to note that in this study, targeting public speaking anxiety, the level of fear of negative evaluation did not show a

statistically significant reduction after VR exposure treatment. Although it may not have been the primary target, the fear of being negatively seen by others plays a significant role in both social anxiety and public speaking anxiety. Therefore, future research could integrate explicit cognitive restructuring tasks targeting core irrational beliefs or manipulate the environments used for VR exposure to identify the ones that are most associated with greater perceived realism and are more judgment-provoking. Additionally, studies could look into deeper belief systems associated with the fear of negative evaluation and clarify whether these might require more prolonged treatment to achieve significant change.

Our study tested the superiority hypothesis of scheduling exposure into one prolonged or three smaller sessions. While we did not detect superiority of either condition in reducing public speaking anxiety, this question should be further explored in larger and more diverse samples, ideally in adequately powered trials designed to test equivalence or non-inferiority with a prespecified margin. Further application of different intervention delivery formats should be tested in future research. VR-based exposure OST has been reported to be effective when working with public speaking anxiety (Reeves et al., 2022), however, not all benefit equally from these interventions. A one-size-fits-all approach is convenient but may not be optimal when seeking further efficacy increase, thus, future studies should investigate which delivery formats may possibly be more beneficial for which population.

4.3. Conclusion

Results of the randomized controlled trial showed a substantial reduction in public speaking anxiety and social anxiety levels after VR exposure treatment in both intervention groups, and no statistically significant between-group difference in change was detected. Equivalence was not tested. Participants' subjective evaluation did not indicate any pronounced negativity towards either of the two approaches, i.e., 1 three-hour session and 3 one-hour sessions were assessed to be similar in convenience, intensity, and adaptability. Our pilot study findings provide preliminary evidence supporting the feasibility of different scheduling formats. However, the trial was underpowered and had no untreated control condition, so adequately powered studies in larger and more diverse samples are needed to compare the formats.

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Declaration of competing interest

The authors do not have any competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.invent.2026.101024.

Data availability

Data will be shared according to FAIR principles, following the publication of trial results, participant-level data without identifying information, i.e., anonymized dataset and codebook, will be made available to all research institution-affiliated researchers. Upon a reasonable request, an anonymized dataset and codebook can be made available to other interested parties. Other intervention-related materials, including task instructions and record forms, will be made available upon request.

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