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Virtual reality acceptance and commitment therapy intervention for social and public speaking anxiety: A randomized controlled trial

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ABSTRACT

Virtual reality (VR) offers new and flexible ways to provide psychological interventions. The aim of this study was to develop and investigate the effectiveness of a VR intervention based on acceptance and commitment therapy (ACT) for social and public speaking anxiety. ACT is a process-based approach that aims to (a) increase individuals' abilities to handle difficult emotional and cognitive experiences and (b) develop the motivation required for change to occur. In this study, a sample of university students with social interaction or communication anxiety ($N = 76$; age $M = 24.95$, $SD = 6.50$, 69.7% females) was blindly randomized into a total of 2 h of VR ACT training (VRACT; $n = 37$) or a waiting list control (WLC; $n = 39$) group. The VRACT group was gradually exposed to social situations using a VR head-mounted display (HMD) and received audio-recorded ACT-based instructions aimed at increasing psychological flexibility. The outcome measurements included self-reported social and communication anxiety, well-being, psychological processes, and behavioral measures. At the final feedback meeting held one week after attending three VR sessions, we observed a significant decrease in social and communication anxiety ($d = 0.55$–0.61) and a significant improvement in psychological flexibility ($d = 0.61$), with moderate effect sizes. These findings contribute to advancing knowledge of how ACT can be efficaciously delivered using VR to improve mental health outcomes for university students with social anxiety.

1. Introduction

Digital technology has become a fundamental part of daily life (Valmaggia et al., 2016). Virtual reality (VR), which refers to a total, immersive human–digital interaction experience (Xiong et al., 2021), has been used since the 1990s in health care (Riva & Wiederhold, 2015), surgery (Khor et al., 2016), and rehabilitation (Rose et al., 2018). To obtain immersion, individuals are often introduced to digital environments, avatars, or stimuli. One way to achieve this is by using stereoscopic head-mounted displays that create a depth illusion to a flat image by adding screen disparity (Ling et al., 2012; Wann et al., 1995), or cave automatic virtual environments (CAVE) where projectors display images on the walls of a cube-shaped walkable room to create a suspension of disbelief (Cruz-Neira et al., 1992; Gromer et al., 2018). Even though this technology is not as recent as one might presume, VR tools have witnessed increased use in recent decades, including in psychology research (Schuemie et al., 2001; Wilson & Soranzo, 2015). New technologies influence the way in which care is delivered, and VR in psychological interventions is now a reality (Valmaggia et al., 2016). One form of VR psychological training is virtual reality exposure training (VRET), which has mostly been used in the treatment of anxiety-related disorders (Carl et al., 2019; Powers & Emmelkamp, 2008). Exposure-based techniques are frequently used in behavioral therapies for difficulties related to anxiety disorders (Kaczkurkin & Foa, 2015).

Anxiety disorders represent the most prevalent and earliest forms of mental disorders (Kessler et al., 2005; Mohr & Schneider, 2013) and affect up to one-third of the US population during their lifetime (Bandelow & Michaelis, 2015). Social anxiety disorder (SAD), a highly prevalent anxiety disorder, affects 12% of the US population during their lifetime (Ebrahimi et al., 2019). A common SAD symptom is being acutely fearful of social situations in which someone feels that they are likely to be negatively evaluated (Leichsenring & Leweke, 2017; Stein & Stein, 2008). The most common subtype of SAD is public speaking anxiety or speech anxiety (Furmark et al., 2000), that is, a fear of speaking in front of people that can lead to considerable distress (Pull, 2012). Physical symptoms such as tremors, blushing, sweating, or avoiding social situations may be associated with these fears (Leichsenring & Leweke, 2017; Spence & Rapee, 2016). Public speaking

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anxiety is a disabling fear, with early onset occurring during adolescence (Ebrahimi et al., 2019), which can lead to long-term negative consequences if left untreated. In a survey conducted in the USA, 61% of students reported having a fear of speaking in front of a group (Dwyer & Davidson, 2012). In another study conducted in Brazil, 64% of college students reported a fear of public speaking (Ferreira Marinho et al., 2015). In Finland, one-third of students reported experiencing substantial stress, primarily as a result of performing in public, and had sought support as a result (Kunttu et al., 2017). The aim of the current research, therefore, is to help students find the best tools aimed at decreasing distress caused by public speaking (Bodie, 2010).

Psychological exposure intervention for these issues generally occurs in an imaginary or in-vivo (in real life) experience where in-vivo exposure presents the possibility to directly challenge the fearful situation (Otte, 2011). Both therapists and patients might find it challenging to conduct and engage in exposure exercises, especially when the exposure takes place in a real-life context outside of the therapy room (Miloff et al., 2016). The fearful situation can be difficult to confront in real life, for example, because an audience can generate extreme anxiety, and creating and managing the feared situation can be complicated. VRET serves as an intermediary (Krijn et al., 2004) that allows the creation of personalized phobic stimuli (Miloff et al., 2016) and makes it possible to control the intensity and repeatability of the fearful situation, making it a viable alternative to imagined or in-vivo exposure (Gebara et al., 2016). Therefore, VR can represent a feasible substitute for standard exposure techniques (Klinger et al., 2005). Previous studies (Anderson et al., 2013; Kampmann, Emmelkamp, & Morina, 2016) involving several sessions of exposure in virtual social interactions have shown that VRET is more effective than control groups in handling social anxiety symptoms, that it might have an effect comparable to that of active interventions (Kampmann, Emmelkamp, & Morina, 2016; Lim et al., 2022), and that it can produce long-lasting benefits (Anderson et al., 2017). Although the evidence regarding VRET is preliminary due to a small number of studies (Kampmann, Emmelkamp, & Morina, 2016), research has recently shown that it may be an effective intervention for social and public speaking anxiety (Emmelkamp et al., 2020; Lim et al., 2022; Maples-Keller et al., 2017; Morina et al., 2021; Nazligul et al., 2017; Sarpourian et al., 2022; Stupar-Rutenfrans et al., 2017; Takac et al., 2019).

Standard interventions for the treatment of anxiety focus on controlling negative thoughts in exchange for more adaptive ones (Kaczkurkin & Foa, 2015). Nevertheless, modern process-based approaches, such as acceptance and commitment therapy (ACT), tend to emphasize the risk of counterproductive outcomes when attempts are made to control dysfunctional experiences (Hayes, 2004; Kahl et al., 2012). In the ACT field, a great deal of research has focused on anxiety, where people are taught to relate with anxiety freely and without defense (Hayes et al., 2006) for the purpose of enhancing willingness, acceptance skills and psychological flexibility more broadly, the ability to fully contact the present moment, and, based on the context, adapting one's behavior to chosen values (Hayes et al., 2006). ACT arguably exemplifies process-based therapy (Hofmann & Hayes, 2019), where a limited set of evidence-based processes fitted to the needs of an individual, and a set of practices deployed for the purpose of altering processes of change, shape a practical model, ultimately leading to an intervention method for a desirable treatment outcome (Hayes, 2019). In ACT, psychological flexibility is the main psychological process of change and is often fostered using skills training, experiential exercises, metaphors, and exposure (Ong et al., 2020). Since psychological flexibility is strongly associated with social and public speaking anxiety (Gorinelli et al., 2022; Webb et al., 2016; Werner et al., 2012), previous studies have proposed acceptance-based interventions as alternatives to traditional solutions (Glassman et al., 2016). Even though studies on ACT and its efficacy are rapidly increasing (e.g., A-Tjak et al., 2015; Gloster et al., 2020), there is a dearth of research combining VR and process-based interventions. A pilot ACT study on public speaking anxiety (Yuen et al., 2019) sought to investigate video conferencing versus VR exposure intervention for homework. However, because of the expensive cost of VR equipment, the content delivery was made using webpages on a remote computer screen and not a VR HMD. The substantial cost of VR research is a considerable limitation and possible reason for its scarcity. Nevertheless, this type of technology has developed rapidly in the last few years, and it is now generally affordable to invest in a VR headset.

Using an experimental clinical design, we sought to investigate whether exposure to a VR process-based ACT intervention could improve social anxiety, communication anxiety, and psychological flexibility outcomes among university students. The research design was developed based on our earlier experience of brief public speaking anxiety interventions (Gallego et al., 2020). Specifically, we were interested in observing whether a brief, three-session VR process-based ACT intervention (VRACT) would impact participants' social and public speaking anxiety compared to the no-intervention condition (i.e., the waiting list control [WLC] group). We hypothesized that the VRACT intervention would a) decrease social interaction and communication anxiety and b) increase the communication skills and psychological flexibility of university students. To the best of our knowledge, there are no published studies examining ACT delivery in tackling students' social and public speaking anxiety through exposure using a VR headset device. Furthermore, VR research mostly involves computer-simulated scenarios rather than 3D immersive recordings of real-world experiences. Overall, the study expands our expertise of brief process-based anxiety interventions through the use of VR.

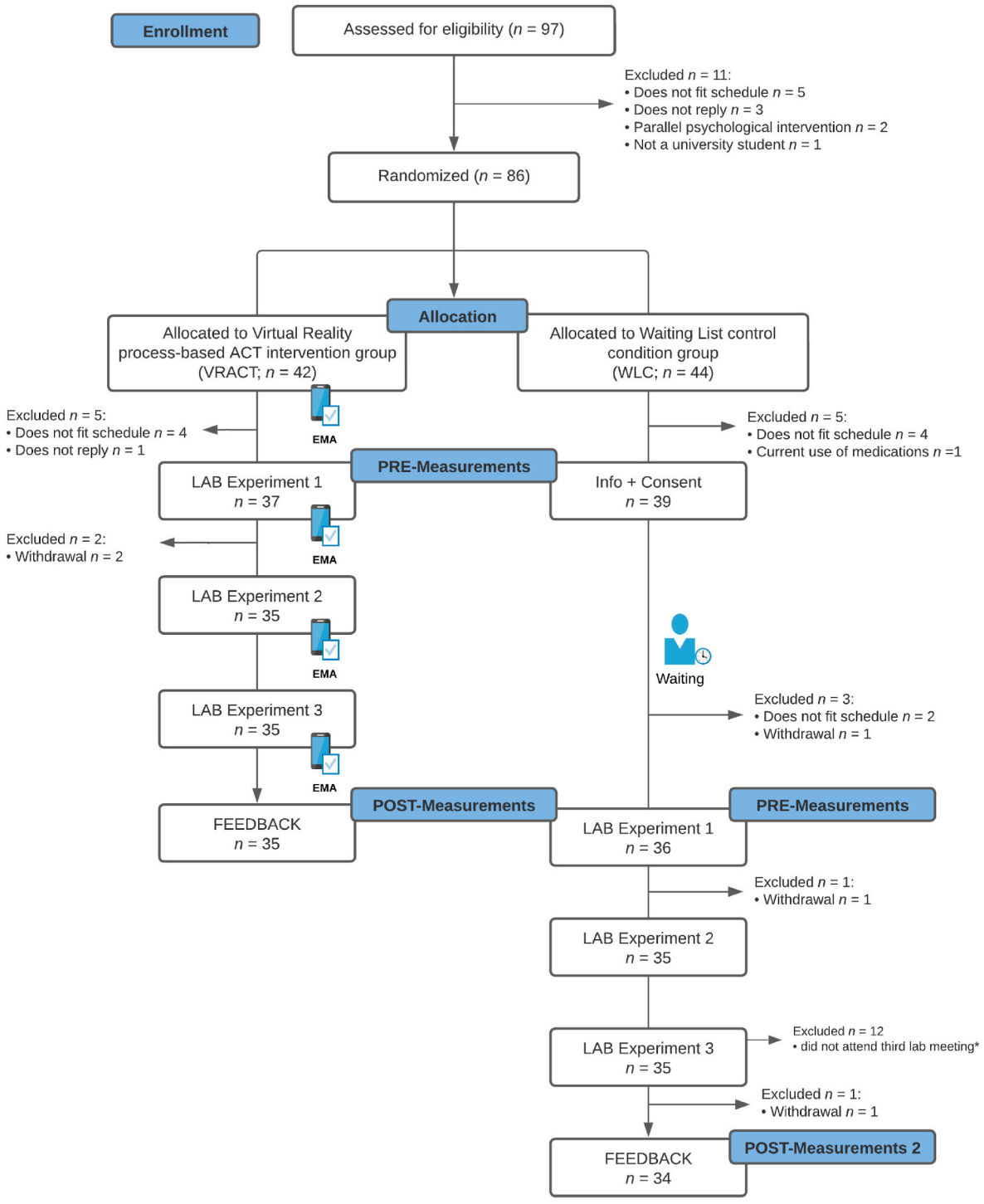
2. Method

2.1. Design

The study was conducted between the autumn of 2019 and the spring of 2020 and during the autumn of 2021. The students in the experimental intervention condition received a free VRACT for social interaction and communication anxiety, while those in the WLC group were placed on a waiting list for the duration of three weeks before they were offered the opportunity to join the VRACT intervention. Both groups were measured before the start of the intervention, after the time spent on the waiting list, or after the intervention (during a post-measurement feedback session) and mid-study during each lab meeting. In addition, electrodermal and electrocardiogram activity was recorded during the sessions, and during the three weeks of active intervention, the intervention group filled in a brief ecological momentary assessment (EMA) survey through a mobile phone app. However, in the current study, neither the EMA nor the physiological data were reported. Thus, the focus of the current study was to use self-reported anxiety and psychological flexibility measures as well as a behavioral avoidance measure to compare the efficacy of the brief three-session VRACT with that of the WLC group. The study was granted ethical approval by the University Ethical Committee on March 29, 2019. The study design is presented in Fig. 1.

2.2. Participants

The participants ($N = 97$) were recruited from various faculties of the University of Jyväskylä through newsletters and poster advertisements placed around campus. According to the advertisement, student volunteers were being recruited for a study investigating perceived insecurity and anxiety while performing in social situations. Students contacted the research team by email or telephone to express their interest in the study. Potential participants were sent a screening Webropol survey link containing more detailed information about the research, a section for the collection of preliminary personal information, and information regarding the inclusion criteria: 1) no current intervention for performance anxiety and 2) no holidays during the intervention period. Those



Note. *The participants were unable to attend the third face-to-face lab meeting due to the spread of COVID-19 and the immediate lockdown measures implemented by the university.

Fig. 1. *Design of the Study*. *Note.* *The participants were unable to attend the third face-to-face lab meeting due to the spread of COVID-19 and the immediate lockdown measures implemented by the university.

who met the inclusion criteria received an email with instructions on scheduling an initial study session using the online scheduling tool Doodle. Students ($n = 21$) taking psychogenic medications, participating in concurrent psychological treatments, who failed to respond to the email, or had difficulty participating in the intervention due to their schedule were excluded, resulting in a final sample of 76 participants (age $M = 24.95$, $SD = 6.50$; Fig. 1). The researchers were blinded to the randomization group assignment, which was performed by an individual outside of the research group using the randomization tool on the random.org website. The final sample was predominantly female ($n = 53$; 70%). No significant differences in the demographic variables were found between the two groups (VRACT, $n = 37$; WLC, $n = 39$) at pre-

measurement (Table 1). Both groups participated in the pre-measurement held in the Department of Psychology, University of Jyväskylä, and filled in questionnaires on a tablet provided by the researcher.

2.3. The virtual reality intervention

The VRACT intervention was composed of three face-to-face sessions (i.e., once weekly for three weeks) in a lab within the Department of Psychology, totaling almost 2 h or approximately 110 min. During the fourth week, there was a final face-to-face meeting for the purpose of gathering feedback and post-measurements. The participants in the WLC group waited for three weeks, after which they were offered the same VRACT intervention.

In the lab, the participants sat in a chair in front of a camera and a table, with physiological equipment devices close by (electrodermal and electrocardiogram activity recorded by BrainVision QuickAm), and access to a pen, a tablet with questionnaires, and a VR device. The researcher and assistant managed the situation with two separate computers: The VR environments and audio sources were controlled by the main computer, while the physiological measurements were performed by the second computer. At the initial lab meeting, the participants completed informed consent forms, background information, and self-reported questionnaires on a tablet and were fitted with physiological measurements. The researcher then measured the interpupillary distance (IPD) of the participants, adjusted their lens distance, and familiarized them with the VR headset.

The VR intervention included five environment scenarios (baseline, neutral scene, one person, three people, and lecture hall; Table 2) recorded in real-world contexts. One VR session included these five scenarios, and the VRACT training lasted a total of 20–25 min (per session). The session was repeated three times during the study. Thus, the VRACT training lasted a total of 68 min over the course of three weeks, while the VR social exposure accounted for 42 min of the total time (repeating the scenarios of one person, three people, and a lecture hall three times). During the VR exposure, the participants listened to an ACT-based audio exercise (Table 2).

VR arguably offers several advantages in terms of time efficiency, safety, and immersion. For various practical reasons, it can be challenging to expose a person to in-vivo situations. The VR training in the current study used gradual in-vivo exposure, giving the sense of being in a fearful context that triggers anxiety. Parallel with the exposure, the participants were introduced to psychological flexibility training (via headphones), allowing them to practice their skills in a safe and controlled environment. The exercises were based on our earlier studies (Gallego, 2021) aimed at identifying psychological flexibility processes associated with public speaking anxiety, and studies investigating the impact of one session ACT-based exposure. Based on these previous observations, the manual included especially openness to experiences exercises, behavioral awareness exercises, and both hierarchical and distinction -based exercises. The audio exercise included a description of the ACT model ("The aim is not to alter or remove unpleasant thoughts, but instead, the aim is to alter the effect of the emotions and thoughts"). Further, it instructed the participants to be present, noticing ("You are able to notice that you have thoughts and emotions when you are with other people"), and have an accepting attitude toward thoughts and emotions ("When you notice thoughts and emotions, be open to what you experience"). The audio recording instructed the participants to pay attention to the impact and influence of their thoughts ("Observe the influence that these thoughts have on you") and pointed out that they can choose their actions ("You are able to choose what you do independent of your thoughts and emotions"). The audio instructions also applied distinction ("You are different from your thoughts") and hierarchical frames ("Your thoughts and emotions are part of you"). In the ACT-based audio recording, approximately 6000 words were presented during the three VR sessions (2000 words per session).

The participants were then instructed about the behavioral task (BAT), where they had to speak in front of an audience in VR for 10 min about themselves and their strengths and weaknesses. This type of task has been used before and has shown good suitability within our experimental environment (Gallego et al., 2020, 2022). More detailed information about the BAT and the reported times of the VR scenarios can be found in Table 2. As a measurement of avoidance, distress tolerance was measured using the amount of time spent in the behavioral task (time of talking). The procedure was repeated three times, once weekly for three weeks. Finally, the participants were asked to fill in the post-assessment questionnaires during the fourth week.

Table 1
Participant characteristics.

Baseline Characteristics	All	VRACT	WLC
	$N = 76$	$n = 37$	$n = 39$
Age *M* (*SD*)	24.95 (6.50)	24.03 (4.35)	25.82 (8.00)
Gender			
Female	53 (69.7%)	26 (70.3%)	27 (69.2%)
Male	23 (30.3%)	11 (29.7%)	12 (30.8%)
Year of Study (*SD*)	2.81 (3.04)	2.41 (2.49)	3.19 (3.48)
Faculty Education			
Humanities and Social Sciences	22 (28.9%)	13 (35.1%)	9 (23.1%)
Information Technology	16 (21.1%)	7 (18.9%)	9 (23.1%)
Education and Psychology	15 (19.7%)	5 (13.5%)	10 (25.6%)
Mathematics and Science	11 (14.5%)	5 (13.5%)	6 (15.4%)
Sport and Health Sciences	9 (11.8%)	6 (16.2%)	3 (7.7%)
Business and Economics	3 (3.9%)	1 (2.7%)	2 (5.1%)
VR Experience			
Yes	26 (34.2%)	13 (35.1%)	13 (33.3%)
No	50 (65.8%)	24 (64.9%)	26 (66.7%)
Mindfulness/ACT Familiarity			
Mindfulness	14 (18.4%)	6 (16.2%),	8 (20.5%),
ACT	8 (10.5%)	5 (13.5%)	3 (7.7%)
No Familiarity	54 (71.1%)	26 (70.3%)	28 (71.8%)
Social Anxiety*			
Minimal	30 (39.5%)	15 (40.5%)	15 (38.5%)
Social Anxiety	46 (60.5%)	22 (59.5%)	24 (61.5%)
Communication Apprehension**			
Low	0 (0%)	0 (0%)	0 (0%)
Average	23 (30.3%)	9 (24.3%)	14 (35.9%)
High	53 (69.7%)	28 (75.7%)	25 (64.1%)

Note. *Social interaction anxiety scores according to the SIAS: cut-off score 34. **Communication apprehension scores according to the PRCA-24: 24–50 low; 51–80 average; 81–120 high.

2.4. Technical equipment

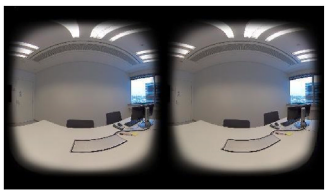
For the virtual intervention, the HTC Vive PRO Virtual Reality HMD was used. It has a resolution of 2880 × 1600 (615 PPI), with a 90 Hz refresh rate, a 110-degree field of view, built-in spatial audio, and an integrated microphone that allows for easy immersion. It is a tethered VR headset connected to a computer. The VR environment scenes were created by the research team around the university campus with the Insta360 Pro 2 professional VR camera, which has six fisheye lenses and can record professional 180 and 360 3D videos at 7680 × 7680 (8 K) @30 fps. The insta360 Pro 2 takes two 8 K videos simultaneously, with built-in stabilization, and combines them to create an immersive experience. The videos recorded in this experiment were edited and combined using the Insta360 stitcher software to create a 3D 180-degree format with a resolution of 7680 × 3840. During the sessions, the videos were displayed inside the headset using the SteamVR platform and the Virtual Desktop media player.

2.5. Measures

2.5.1. Primary outcome measures

The Social Interaction Anxiety Scale (SIAS; Mattick & Clarke,

Table 2
Structure and content of the VR process-based ACT intervention (VRACT): Scenes and examples of themes across the lab sessions.

Environment Scenes	Themes
1 - Baseline 	Time = session 1: 3.00 m; session 2: 3.48 m; session 3: 3.10 m **Instructions, aim, and importance of the exercise, place the focus on breathing and the present moment** *Purpose*: "The purpose of these exercises is to teach a new perspective on thoughts and feelings." […] "In order to achieve this, we need to learn certain skills to deal with these thoughts and feelings." […] "Note that this exercise will teach you the principles and general methods that you can use and practice later on as well." *Noticing*: "Just as you can notice when breathing is taking place or what you can feel on your shoulders, you can also notice what thoughts and feelings you have and how you choose to treat them." This scene did not include social interaction.
2 - Neutral Scene 	Time = session 1: 4.10 m; session 2: 5.27 m; session 3: 5.30 m **Thoughts and feelings as passing clouds, breathing is part of you—sky metaphor** *Metaphor*: "Like the clouds in the sky, your breathing comes and goes. Similarly, your thoughts and feelings can come and go. You can notice what thoughts and feelings you have here and now in the same way you can notice and observe the clouds in the sky." *Framing*: "Note that clouds are different from the sky; clouds move along the sky. In the same way, you can notice that your thoughts are different from you and that your thoughts come and go in you." This scene did not include social interactions.
3 - One person  	Time = session 1: 5.05 m; session 2: 5.11 m; session 3: 6.20 m **Thoughts and feelings in individual social interaction** *Acceptance*: "Look at the person in front of you. You might notice feelings of anxiety, unsure of yourself." […] "Just notice thoughts and emotions. Practice being open and accepting" […] With unpleasant feelings, you can still look at another person." This scenario comprised two versions to counterbalance the gender difference.
4 - Three people  	Time = session 1: 4.05 m; session 2: 3.45 m; session 3: 4.25 m **Thoughts and feelings in group social interaction** *Noticing*: "See those people in front of you …." […] "What thoughts and feelings do you notice right now …" *Defusion and acceptance*: "You are not your thoughts, but you have thoughts. Note that we can distinguish two things here: you and your thoughts in this situation, at this moment. In another situation, you may have other thoughts." […] "Thoughts and emotions come and go." […] "be open, accepting what you experience …" This scenario comprised two versions to counterbalance the gender difference.
5 - Lecture hall 	Time = session 1: 5.09 m; session 2: 4.09 m; session 3: 4.45 m **Thoughts and feelings in front of an audience** *Noticing and accepting:* "You are in front of a group of people. Imagine that you have to say something or hold a presentation." […] "Notice what thoughts and feelings you experience right now, and be open …." […] "View your thoughts and feelings as you look at the clouds in the sky" […] "You can continue looking at the listeners with all the feelings and thoughts you have in this moment." *Choosing value-based actions*: "Now, look at the people sitting. You can choose to look at them." […] "You are able to look at them independent of what you are feeling or thinking." […] "Every single choice and action take you towards a greater goal or destination." […] "Practice these skills over the next week."
6 - Behavioral Task (BAT) - Lecture hall 	**Instructions (1 min), 3-min baseline + 10-min speech** The participants were instructed to prepare a 10-min speech about their strengths and weaknesses. They had a baseline of 3 min in the empty room to think about the topic. Afterward, a virtual audience, recorded from a university lecture, appeared, and they had to start their speech. They could stop at any time; however, the instructions contained a specific framing to increase motivational factors and encourage the students to speak for as long as possible ("Remember, just engaging in the process of the task is the most important part of your participation"; Eswara Murthy et al., 2019, p. 36).

1998) measures anxiety related to initiating and maintaining social interaction. It comprises a 20-item scale (e.g., "I have difficulty talking with other people") whose cutoff score for clinical social anxiety is 34 (Brown et al., 1997). Each item is rated on a Likert scale ranging from 0 (not at all characteristic or true of me) to 4 (extremely characteristic or true of me). The total score varies from 0 to 80, with a higher score reflecting higher levels of social anxiety interaction. It is internally consistent, with alpha ranging from 0.88 to 0.93, and has a good discriminant validity (Mattick & Clarke, 1998). In the current study, Cronbach's alpha was excellent, 0.92.

The **Personal Report of Communication Apprehension** (PRCA-24; McCroskey, 1982) was used in four contexts—speaking in public, speaking in small groups, speaking in meetings, and interpersonal encounters—to investigate anxiety and fear associated with communicating with other people. The PRCA-24 is a 24-item scale (e.g., "I get nervous when I have to participate in a meeting") where higher scores are indicative of greater levels of communication anxiety (CA) in social situations. It uses a Likert-type scale with a 5-point response format (1 = strongly disagree, 5 = strongly agree). Among the four contexts, scores range from 6 to 30, leading to a total score of 24–120. Total scores below

51 indicate very low CA, scores between 51 and 80 moderate CA, and scores above 80 high CA. McCroskey (1978, 1984) and McCroskey et al. (1985) reported that the PRCA-24 has construct, predictive and content validity as well as high internal consistency, with alpha ranging from 0.93 to 0.95. We found Cronbach's alpha of .92 for the total score and 0.77, 0.90, 0.89, and 0.74 for the public, small group, meeting, and interpersonal encounters, respectively.

2.5.2. Secondary outcome measures

Psychological, emotional, and social well-being were measured using the short form of the **Mental Health Continuum** (MHC-SF; Keyes, 2009). The MHC-SF comprises 14 items (e.g., "How often did you feel that you had warm and trusting relationships with others") measured on a Likert scale ranging from a low of 0 (never) to a high of 5 (every day). The total score ranges from 0 to 70, with higher scores indicating a higher level of well-being. The MHC-SF has previously demonstrated excellent internal consistency (Cronbach's $\alpha > 0.80$; Keyes, 2009). In this study, it showed good internal consistency (Cronbach's $\alpha = 0.87$).

The Perceived Stress Scale (PSS; Cohen et al., 1983; Cohen & Williamson, 1988) was used to measure stress. It consists of 10 items measured on a 5-point Likert scale (0 = never, 4 = very often) and assesses how stressful people perceive their lives in the last month. A total score from 0 to 13 indicates low, 14–26 moderate, and 27–40 high levels of stress. The PSS-10's internal consistency has ranged from 0.74 to 0.91 in previous studies (Lee, 2012) and was reported as $\alpha = 0.82$ in the current study.

Visual Analog Scales (VAS). In this study, the students answered the following four questions: "How uncomfortable do you feel about giving a speech?" "How stressful do you feel about giving a speech?" "How nervous does speaking make you?" "How willing are you to give a speech?" They were instructed to indicate how they felt by selecting a number ranging from 0 (not uncomfortable at all) to 10 (extremely uncomfortable). According to Boonstra et al. (2014), a score $\leq$3.8 indicates mild, 3.9–5.7 moderate, and $\geq$5.8 severe symptoms.

2.5.3. Process measures

The Comprehensive Assessment of ACT Processes (CompACT; Francis et al., 2016) measures psychological flexibility through the subscales openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), and valued action (CompACT-VA). The CompACT is a 23-item questionnaire (e.g., "I can keep going with something when it's important to me") with a 7-point Likert scale ranging from 0 (strongly disagree) to 6 (strongly agree), with higher scores representing greater psychological flexibility. The total score ranges between 0 and 138, with the CompACT-OE ranging from 0 to 60, the CompACT-BA from 0 to 30, and the CompACT-VA between 0 and 48. In this study, the CompACT showed good internal consistency (Cronbach's $\alpha = 0.86$) for the total score, with 0.79 for the CompACT-OE, 0.64 for the CompACT-BA, and 0.84 for the CompACT-VA subscales.

The Self Compassion Scale – Short Form (SCS-SF; Raes et al., 2011) was used to measure self-compassion. It is a self-reported 12-item questionnaire (e.g., "I'm disapproving and judgmental about my own flaws and inadequacies") measured on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always), with higher total scores indicating greater self-compassion. The SCS-SF has shown an almost perfect correlation with the long-form SCS ($\alpha > 0.86$; Raes et al., 2011). In this study, we observed good internal consistency, with Cronbach's α of 0.85 for the total score.

The subjective fear of being negatively evaluated by others in social situations was assessed with the **Fear of Negative Evaluation Scale-Brief Form** (BFNE; Leary, 1983), which is a 12-item instrument measured on a 5-point Likert scale. Good psychometric properties (Weeks et al., 2005) and excellent internal consistency have been recorded for the BFNE (Kampmann, Emmelkamp, & Morina, 2016). In this study, we observed Cronbach's $\alpha = 0.91$.

2.6. Statistical analysis

All statistical analyses were performed using Mplus (version 8; Muthén & Muthén, 2017) and IBM SPSS Statistics 26. The pre-measurement baseline differences between the VRACT and WLC groups were investigated using *t*-test and chi-square analyses. Additionally, differences in distress tolerance between sessions one and three were tested using paired sample *t*-test. The impact of the intervention (the interaction effect indicated by the Wald test) was analyzed using structural equal modelling (SEM) and latent change scores with the full information maximum likelihood (FIML) estimation method. All the available information was used in the analyses, and missing data were assumed to be missing at random. Thus, all randomized participants who completed the pre-measurements were included in the analyses. Effect sizes (ESs) were reported using Cohen's *d*. The corrected between-group ES was calculated by dividing the mean difference in change between the intervention and control groups by the mean standard deviation of the pre-measurements. The within-group ES indicated the magnitude of change from pre-to post-measurement in each group and was calculated by dividing the mean difference in the change between the pre- and post-measurements by the mean standard deviation of the measurements. A within- and between-group ES of 0.20 was considered small, 0.50 moderate, and above 0.80 large (Cohen & Williamson, 1988).

The clinically significant change was calculated on the primary outcome measures using the Jacobson-Truax method (Jacobson & Truax, 1991), which involves two stages for evaluating the recovery of individuals (Lambert & Ogles, 2009; McGlinchey et al., 2002). In the initial stage, the reliable change index (RCI) is calculated to determine if the change in participants' scores is not merely a result of measurement unreliability. Next, a cut-off score was determined to indicate a point that each participant with social interaction or communication anxiety must cross to shift from a dysfunctional to a functional distribution, for SIAS and PRCA-24 respectively. A weighted midpoint between the means of a functional and dysfunctional population (Cut-off C), was calculated for SIAS using the functional normative data ($M = 19.7$; $SD = 12.55$) described in Heimberg et al. (1992) and the non-functional data at pre-measurement from this study ($M = 49.26$; $SD = 8.25$) by including participants with a SIAS score of at least 34 indicating social anxiety (see also Table 1). Regarding PRCA-24, a functional normative sample from external sources was not available. For this reason, a point of two standard deviation beyond the range of the mean at premeasurement (Cutoff A, Jacobson & Truax, 1991) was determined for PRCA-24 using the non-functional pre-measurement sample of this study ($M = 96.87$; $SD = 8.86$). Based on these two steps, the Jacobson-Truax method classifies individuals into four categories: recovered (individual has passed both the Cutoff and the RCI criteria), improved (has passed RCI criteria but not the Cutoff), unchanged (has passed neither criteria), or deteriorated (has passed the RCI criteria in a worsening direction).

3. Results

All the participants reported at least mild communication anxiety (PRCA-24 > 51). Exactly 60.5% of them were categorized as having social interaction anxiety, and 69.7% had high levels of communication anxiety (SIAS $\geq$ 34; PRCA-24 > 80).

3.1. Intervention effects: intervention group vs. waiting list group

Two participants in the VRACT group and three participants in the WLC group did not complete the post-measurements. Thus, the dropout rates were 5.41% and 7.69%, respectively. There was a significant interaction effect (Table 3) in nearly all the outcome measures, with the VRACT intervention group showing larger changes compared to the WLC group on the primary outcome measures of social interaction anxiety (SIAS) and communication anxiety (PRCA-24, total). The

Table 3
Mean Scores, Standard Deviations at Pre- and Post-measurements, Pre–Post Change (Wald Test with p-values) between the Intervention and Waiting List Control Groups, and Within-group (d_w) and Between-group (d_b) Cohen's d Effect Sizes.

		PRE $n = 76$ *M* (*SD*)	POST $n = 71$ *M* (*SD*)	Pre–Post Change Wald Test $df = 1$, p value	d_w	d_b
SIAS						−0.55
	VRACT	38.27 (14.07)	31.72 (14.27)	32.86	0.46	
	WLC	39.69 (15.62)	41.31 (16.21)	$p < .001$	−0.10	
PRCA-24						−0.61
	VRACT	89.60 (11.87)	81.89 (16.04)	19.97	0.55	
	WLC	88.97 (15.99)	89.91 (16.35)	$p < .001$	−0.06	
PRCA-24-GD						−0.50
	VRACT	22.65 (4.58)	20.02 (4.55)	8.35	0.58	
	WLC	21.80 (5.97)	21.85 (5.68)	$p = .004$	−0.01	
PRCA-24-M						−0.37
	VRACT	23.19 (4.65)	21.87 (5.15)	6.12	0.27	
	WLC	22.87 (5.02)	23.33 (5.15)	$p = .013$	−0.09	
PRCA-24-IC						−0.26
	VRACT	18.95 (3.97)	17.75 (5.14)	2.39	0.26	
	WLC	19.00 (4.81)	18.93 (5.55)	$p = .122$	0.01	
PRCA-24-PS						−0.68
	VRACT	24.81 (3.51)	22.53 (3.95)	13.04	0.61	
	WLC	25.31 (4.35)	25.72 (3.52)	$p < .001$	−0.11	
PSS						−0.36
	VRACT	17.49 (5.38)	15.44 (5.14)	5.29	0.39	
	WLC	18.31 (5.95)	18.28 (4.91)	$p = .021$	0.01	
MHC-SF						0.37
	VRACT	50.19 (9.12)	53.24 (7.78)	6.48	−0.36	
	WLC	48.82 (10.33)	48.23 (10.64)	$p = .011$	0.06	
VAS – Uncomfortable						−1.17
	VRACT	8.16 (1.48)	6.47 (1.93)	25.91	0.98	
	WLC	8.41 (1.33)	8.37 (1.33)	$p < .001$	0.03	
VAS – Stressful						−1.56
	VRACT	8.57 (1.20)	6.88 (2.14)	42.43	0.97	
	WLC	8.49 (1.32)	8.76 (1.17)	$p < .001$	−0.22	
VAS – Nervous						−1.40
	VRACT	8.51 (1.22)	6.52 (2.17)	29.56	1.13	
	WLC	8.41 (1.60)	8.41 (1.43)	$p < .001$	−0.00	
VAS – Willingness						0.13
	VRACT	3.22 (2.47)	3.85 (2.75)	0.50	−0.24	
	WLC	2.67 (2.39)	2.99 (2.13)	$p = .479$	−0.14	

Note. Social interaction anxiety (SIAS), communication apprehension (PRCA-24), general discussion (PRCA-24-GD), meetings (PRCA-24-M), interpersonal communication (PRCA-24-IC), public speaking anxiety (PRCA-24-PS), perceived stress (PSS), well-being (MHC).
VAS – Uncomfortable: How uncomfortable do you feel about giving a speech? VAS – Stressful: How stressful do you feel about giving a speech? VAS – Nervous: How nervous does speaking make you? VAS – Willingness: How willing are you to give a speech?.

between-group ESs were moderate ($d > 0.50 < 0.80$, respectively). The investigation of the subscales of the PRCA-24 revealed a moderate between-group ES in general discussion (PRCA-24-GD) and public speaking (PRCA-24-PS) and a small between-group ES ($d > 0.20$) in meetings (PRCA-24-M) and interpersonal communication (PRCA-24-IC, with a non-significant effect). Among the secondary outcomes, the VRACT group showed a large decrease in perceived speaking anxiety (VAS), a small decrease in stress (PSS), and a small increase in well-being (MHC-SF) compared to the WLC group. The secondary outcome measures showed a large between-group ES ($d > 0.80$) for the VAS scales related to uncomfortableness, stressfulness, and nervousness about speaking and a small between-group ES for MHC-SF and PSS in favor of the VRACT group, but no significant changes were reported for the VAS scale in relation to willingness to make a speech (Table 3).

In the VRACT group, a large within-group ES ($d > 0.80$) was reported for the VAS scales related to nervousness, uncomfortableness, and stressfulness. A moderate within-group ES ($d > 0.50$) was observed for communication anxiety (PRCA-24, total) and its subscales of general discussion and public speaking anxiety, while close to moderate within-group ESs were recorded for social interaction anxiety (SIAS). The within-group ESs were small ($d > 0.20$) in all the other measurements. The within-group ESs were mostly very small or small for the WLC group and ranged from .00 to .22.

Regarding the process measurements, there was a significant interaction effect (Table 4) for psychological flexibility (CompACT), self-compassion (SCS-SF), and fear of being negatively evaluated (BFNE), which favored the intervention group. The between-group ESs for the process measures were moderate for psychological flexibility (CompACT) and small for self-compassion (SCS-SF) and fear of being negatively evaluated (BFNE), which favored the intervention group. For the psychological flexibility subscales, the between-group ESs showed a moderate difference for openness to experiences (CompACT-OE) and behavioral awareness (CompACT-BA) and a small difference for valued action (CompACT-VA).

For the intervention group, the within-group ESs were moderate for psychological flexibility (CompACT) and close to moderate for its subscale openness to experiences (CompACT-OE). For the remaining measures, the within-group ESs were small. In the WLC group, the within-group ESs were very small, ranging from 0.01 to 0.12.

Finally, we examined clinically significant changes (Jacobson & Truax, 1991) for the VRACT intervention group on the primary outcome measures (SIAS & PRCA-24) at post-assessment using four categories: 1) recovered, 2) improved, 3) unchanged, 4) deteriorated. After excluding dropouts and participants below the Cutoff score and examining the intervention group at post-measurement in social interaction anxiety (SIAS; $n = 20$), we discovered that 20% (4) were recovered, 5% (1) improved, 75% (15) unchanged, while no participants deteriorated. Similarly, after excluding dropouts and participants below the Cutoff value and investigating the VRACT group at post-measurement in communication anxiety (PRCA-24; $n = 28$), we observed that 25% (7)

Table 4
Process Measurements: Mean Scores, Standard Deviations at Pre- and Post-measurements, Pre–Post Change (Wald Test with p-values) between the Intervention and Waiting List Control Groups, and Within-group (d_w) and Between-group (d_b) Cohen's d Effect Sizes.

		PRE $n = 76$ *M* (*SD*)	POST $n = 71$ *M* (*SD*)	Pre–Post Change Wald Test $df = 1$, p value	d_w	d_b
CompACT						.61
	VRACT	84.78 (16.09)	94.99 (16.56)	13.14	−0.63	
	WLC	81.56 (17.18)	81.67 (21.63)	$p < .001$	−0.01	
CompACT-OE						0.54
	VRACT	31.35 (10.00)	36.36 (10.58)	10.81	−0.49	
	WLC	30.05 (9.73)	29.68 (12.02)	$p = .001$	0.03	
CompACT-BA						0.53
	VRACT	18.14 (4.61)	20.37 (7.09)	6.63	−0.37	
	WLC	17.59 (5.75)	17.05 (6.82)	$p = .010$	0.09	
CompACT-VA						0.28
	VRACT	35.30 (6.96)	38.19 (5.76)	4.29	−0.45	
	WLC	33.92 (7.22)	34.84 (7.67)	$p = .038$	−0.12	
SCS						0.28
	VRACT	3.12 (0.56)	3.31 (0.63)	4.15	−0.33	
	WLC	3.06 (0.72)	3.08 (0.75)	$p = .042$	−0.02	
BFNE						−0.27
	VRACT	41.68 (9.94)	37.64 (10.04)	7.92	0.39	
	WLC	40.77 (10.20)	39.54 (11.26)	$p = .005$	0.11	

Note. Psychological flexibility (CompACT), openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), valued action (CompACT-VA), self-compassion (SCS), fear of negative evaluation (BFNE).

were recovered, 14.3% (4) improved, 57.1% (16) unchanged and 3.6% (1) deteriorated.

3.2. Intervention effects: waiting list control group after intervention

Among the participants in the WLC group, three did not complete the post-measurements during the WLC period, while two others withdrew from the study after taking part in the intervention (no post-measurement 2). There was a significant within-group change (Table 5, pre–post–post2 change, Wald test) in all three main measurements, showing a significant decrease in social anxiety (SIAS) and communication anxiety (PRCA-24) and a significant increase in psychological flexibility (CompACT) when the intervention was offered after the waiting period (Table 5, post–post2 change). The within-group ESs were small ($d = 0.22$–0.45) for all measures.

Clinical significance (Jacobson & Truax, 1991) was also calculated for the WLC group at post-2 measurement where we observed the following: SIAS, 18.2% (4) were recovered, 4.5% (1) improved, and PRCA-24, 12% (3) were recovered, 24% (6) improved. No participants deteriorated in both SIAS and PRCA-24.

3.3. Avoidance & distress tolerance

Time was assessed when the participants decided to stop the behavioral task (BAT) during the 10-min presentation. Over time, avoidance behavior decreased: During the first session, 21.05% of the participants decided to stop the task before the 10-min mark, while 10.53% decided to stop the BAT during the third lab session ($n = 57$). Furthermore, distress tolerance was measured using the amount of time used in the BAT. The participants engaged in the BAT for an average of 8.49 min during the first lab meeting but maintained their engagement for an average of 9.38 min during the third lab meeting, indicating an improvement in distress tolerance over time ($n = 57$; $t(56) = -3.204$, $p = .002$). There was a significant change in both the VRACT ($n = 35$; $t(34) = -2.289$, $p = .028$) and WLC groups once the intervention was offered ($n = 22$; $t(21) = -2.212$, $p = .038$, respectively).

4. Discussion

This study compared the 2-h VRACT intervention for social and public speaking anxiety with the WLC group. The findings supported our hypothesis by showing that after attending the three VR sessions, the participants in the intervention group recorded significantly decreased self-reported social interaction and public speaking anxiety, fear of negative evaluation, and stress and significantly increased well-being, psychological flexibility, and self-compassion. Furthermore, the participants in the experimental group reported that giving a speech was less stressful and that they felt significantly less nervous and more comfortable compared to those in the WLC group. The intervention also demonstrated encouraging results on clinically significant change with 23%–39% of participants either recovered or improved in the primary outcome measurements at post-assessment, reflecting changes in initiating and maintaining social interaction, and anxiety associated with communicating with others, respectively. Parallel measures in the no-treatment comparison group showed no changes in anxiety, psychological flexibility, or self-compassion. Further, our behavioral

Table 5
Mean Scores, Standard Deviations, Wald Test of the Changes, and Within-group Effect Sizes (Cohen's d) after the Waiting Period (Pre–Post) and the Intervention (Post–Post2).

	PRE $n = 39$ *M* (*SD*)	POST $n = 36$ *M* (*SD*)	Pre-Post Change p value, d value	POST 2 $n = 34$ *M* (*SD*)	Post-Post2 Change p value, d value	Pre–Post–Post2 Change Wald Test $df = 2$, p value
SIAS	39.69 (15.62)	41.31 (16.21)	$p = .066$ $d = -0.10$	37.01 (16.72)	$p = .003$ $d = 0.26$	12.48 $p = .002$
PRCA-24	88.97 (15.99)	89.91 (16.35)	$p = .386$ $d = -0.06$	82.41 (16.70)	$p < .001$ $d = 0.45$	18.41 $p < .001$
CompACT	81.56 (17.18)	81.67 (21.63)	$p = .960$ $d = -0.05$	91.03 (21.02)	$p < .001$ $d = -0.44$	33.65 $p < .001$

Note. Social interaction anxiety (SIAS), communication apprehension (PRCA-24), psychological flexibility (CompACT).

measure—the speech task—also supported the hypothesis by showing an increase in communication skills. These results—that increased psychological flexibility and self-compassion were accompanied by decreased anxiety—are consistent with those of previous study reports that psychological flexibility and self-compassion are negatively associated with social and public speaking anxiety (Gorinelli et al., 2022; Webb et al., 2016; Werner et al., 2012). While ACT has proven to be effective in previous studies (Gloster et al., 2020), the amount of research on VR-based ACT remains limited. To our knowledge, this is the first study to deploy VR-based exposure to social anxiety combined with instructions of mindful noticing, acceptance, defusion, and the self as an observer in the service of valued living (see Hayes, 2019).

The intervention had a significant positive effect on social anxiety, which is consistent with earlier study reports that VR is an effective treatment for such conditions (Anderson et al., 2013; Kampmann, Emmelkamp, & Morina, 2016). In terms of efficacy, the effect sizes of this study were in line with Kampmann, Emmelkamp, & Morina, 2016 ($d_w = 0.55$) or lower (Anderson et al., 2013, $d_b = 1.19$) than other VR treatments for social or public speaking anxiety symptoms (Carl et al., 2019). The different delivery modalities employed in each study may have contributed to these varying outcomes. In our study, all participants received an identical intervention, and the VR process was "automated" in that no in-person therapeutic assistance was provided during or between VR sessions. In contrast, in other studies (e.g., Anderson et al., 2013; Klinger et al., 2005), cognitive behavioral therapy was often provided by a therapist within VR exposure environments or between sessions. Moreover, while many studies have used computer-simulated scenarios, this study employed 180-degree recorded videos. Although these two types of scenarios are similarly immersive (Nason et al., 2020), recorded videos are more accessible and have shown promising results for treating social or public speaking anxiety (Reeves et al., 2021; Zainal et al., 2021). Finally, regarding user engagement, the dropout rate in this study was lower compared to other studies (e.g., 25% in Kampmann, Emmelkamp, & Morina, 2016), possibly suggesting that the intervention content or the total number of sessions played a significant role.

Previous research using VR in conjunction with traditional methods has shown a reduction in social or public speaking anxiety after a substantial number of sessions (e.g., 8 sessions in Anderson et al., 2013, p. 10 sessions in Kampmann, Emmelkamp, & Morina, 2016, p. 12 sessions in Klinger et al., 2005), suggesting that nine to ten VR-based sessions could provide an effective treatment for SAD (Jeong et al., 2021). However, there are indications that even shorter sessions could be effective in treating social anxiety (Jeong et al., 2021). In fact, there has been an increase in studies showing VR intervention efficacy with fewer sessions (Reeves et al., 2021). In our study, after just three sessions and less than 2 h of VR "automated" intervention, both anxiety and psychological flexibility skills were positively affected. Further, the positive impact of the VR-based training was repeatedly demonstrated when the WLC group was offered the VR intervention.

There are, however, a few notable limitations. First, we used several self-reports, which are arguably not reflective of actual behavior. A previous study by Gallego et al. (2022) showed that participants' self-reports of their public speaking anxiety were in correspondence with their actual behavior. In a behavioral task in the current study, we also observed that self-reported decreases in social anxiety were accompanied by longer speeches. Nevertheless, we cannot exclude that the observed positive changes are due to the exposure effect. Thus, the current study shows how an ACT exposure-based training in VR could be provided. Second, during the intervention, the intervention group filled in a brief EMA survey through a mobile phone app. Thus, the observed changes in social anxiety and psychological flexibility could be because of the EMA or the combined effect of the EMA and the VR training. We investigated this possibility by offering the WLC group the VR training without the EMA after the waiting period and observed similar changes, confirming our conclusions of the VR training. The third limitation concerns the generalizability of the results. The study participants were recruited from a student population and, thus, may not represent a clinical population. Further, the predominantly female and relatively small sample size raise some concerns about generalizability. Despite the sample being non-clinical, about 60% of the participants were categorized as having social interaction anxiety and high levels of communication anxiety. Finally, while the VRACT proved to be effective in the short-term, the sustainability of the results over a longer period of time is unclear due to the lack of follow-up. However, other studies using VR for social or public speaking anxiety have reported sustained results at three- or six-month follow-up evaluations (Kampmann, Emmelkamp, & Morina, 2016; Zainal et al., 2021). Although VR provided several study advantages, it also presented a few usability issues. A limited number of individuals encountered headset fit discomfort, mild headache, or distress from the fearful stimuli. During the study, however, we adjusted the headset fit whenever discomfort occurred and took notice of the participants' reactions after experiencing VR, often for the first time. At the end of the study, the students provided feedback indicating that the intervention was well received. Moreover, we used 180-degree video recordings from real-world experiences, which are less interactive than computer-generated scenarios but provide high fidelity in terms of the people and objects within the VR environment. The headset was disinfected after each session, which prevented any infections or skin irritations. Furthermore, participants did not experience any severe events, such as seizures, or have any strong adverse complaints.

Nevertheless, future research is needed to confirm these findings. Further studies could consider exclusion criteria that are based on health checks (e.g., epilepsy and recurrent migraines), ensure the usage of comfortable headsets, recruit participants from clinical populations with social or public speaking anxiety, or conduct follow-up studies to assess the long-term effect of VR interventions.

The current findings could also have clinical implications. VR interventions can be used as tools in conjunction with the therapeutical path when clients are ready to face their fears in an immersive but safe and controlled environment. Moreover, these types of VR interventions could also be used as part of teaching practices, for example, when training students in public speaking skills. A VR headset with a built-in intervention could be made available for students who want to practice their skills in a similar manner as in our study. In fact, our intervention alone was able to demonstrate significant changes in social and public speaking anxiety, even without additional face-to-face help from a therapist or specialist. Furthermore, the VR training resulted in improvements in the participants' psychological flexibility skills, which could have an impact on their lives beyond social and public speaking. However, this needs to be shown in further studies. Overall, the current study provides a valuable contribution by showing how VR can be used not only as an exposure technique but also as an effective tool for implementing and successfully delivering ACT to improve mental health outcomes among university students with social anxiety.

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Declaration of competing interest

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