Virtual Reality Training for Public Speaking: The Role of Mindfulness and Self-Efficacy in Reducing Anxiety

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Abstract

Public speaking anxiety (PSA) is a common social anxiety that can hinder presentation quality and negatively affect personal, educational, and career outcomes. It is especially prevalent in higher education and workplace settings. This study examined the connection between a mindfulness training intervention and public speaking anxiety (PSA), and mediating role of self-efficacy in this relationship. This was researched in the context of a virtual reality (VR) training environment. The research builds on existing studies that show mindfulness can be associated with anxiety and improve self-efficacy, which in turn could result in a lower PSA. Participants in an experimental group who received a mindfulness training, and a control group repeatedly gave a 3-minute presentation, of which two were given in VR. Using questionnaires and physiological measurements of heart rate and electrodermal activity (EDA), PSA, mindfulness and self-efficacy were measured. Participants reported a decrease in PSA over time, and an increase of self-efficacy over time. This was reflected by the EDA measurements. No effect of the mindfulness training was found. A higher self-efficacy correlated with a lower PSA score. There was no mediation effect of self-efficacy in the relationship between mindfulness and PSA.

Keywords: Public speaking anxiety, self-efficacy, mindfulness, virtual reality.

Contents

Introduction

In higher education and workplace environments, public speaking is a fundamental and recurring task (Macey et al., 2023). However, there are many people who experience public speaking anxiety (PSA) (Harris et al., 2002). PSA is a prevalent social anxiety that can lower presentation quality and seriously impact people's prospects in personal development, educational success, career choice, and job performance (Wang et al., 2020). Thus, addressing PSA is essential to support individuals' professional and personal growth.

Practicing public speaking can reduce PSA (Chollet et al., 2015). However, due to increasing numbers of students and a shortage of time and resources, there is a lack of opportunities to practice in higher education curricula (Kollöffel & Heuvel, 2020; Kroczek & Mühlberger, 2023). A solution is using virtual reality (VR) training in public speaking, which enables repeated safe and private practicing in front of a larger audience without the need for other individuals (Vafadar, 2013). VR applications consist of computer-generated simulated environments replicating real-world or imaginary environments with which users can interact (Abbas et al., 2023). These VR applications enable users to build, practice and strengthen their public speaking skills, resulting in lower PSA (Chollet et al., 2015).

Next to Chollet et al. (2015), several researchers have shown that VR is a promising tool to reduce PSA (Lim et al., 2023; Vanni et al., 2013). This effectiveness is often indicated by a reduction in participants' PSA from pre- to post-tests in individual VR practice sessions (Lim et al., 2023; Vanni et al., 2013). Furthermore, research has demonstrated that practicing public speaking in a VR environment not only reduces PSA but can also enhance one's self-efficacy (Frisby et al., 2020), which can improve achievement and performance (Bandura, 1997).

Another way of reducing PSA is the use of biofeedback or mindfulness training (McKinney & Gatchel, 1982; Murali et al., 2021; Pribyl et al., 2001). Mindfulness, or relaxation, is a state of consciousness characterized by open and receptive awareness, enhancing focus and promoting mental clarity (Brown & Ryan, 2003). There are several mindfulness techniques. Focused-attention mediation, one of these techniques, helps improve mental control by training the mind to stay focused on one thing and block out distractions (Chan et al., 2017). Furthermore, mindfulness-based interventions can positively help handle (mental) issues such as depression, anxiety, and eating disorders (Kumar et al., 2017). Thus, since mindfulness influences anxieties, looking into the use of mindfulness techniques for training programs for PSA can be valuable.

Next to being related to a reduced PSA, practicing meditation or self-desensitization to experience a state of mindfulness also is related to an increased self-esteem (Kirsch & Henry, 1979; Kumar et al., 2017). More specifically, Sharma and Kumra (2022) researched self-efficacy and its relation to mindfulness and anxiety and reported a significant positive relationship between mindfulness and self-efficacy, and a significant negative relationship between self-efficacy and anxiety. However, this was not studied in the context of PSA specifically. Lucchetti et al. (2003) did study the relationship between self-efficacy and PSA and demonstrated a negative correlation between self-efficacy and PSA. On the other hand, they found that self-efficacy can also be negatively influenced when faced with a threatening situation. They did not include mindfulness in this research. As higher self-efficacy is linked to lower PSA levels, exploring whether creating a less threatening presentation situation through mindfulness enhances this self-efficacy towards presenting. Research in this relationship may shed light on the potential for self-efficacy to act as a mediator in the relationship between mindfulness and PSA.

These relations between mindfulness, self-efficacy, and PSA have not yet been studied in an experimental and VR setting. In this study, an experimental setting is created using VR as a tool since VR offers experimental control over the environment in which presentations are practiced. It allows participants to all practice in the exact same virtual environment under similar conditions, in contrast to presenting in real life. A VR environment that accurately replicates physiological states that are experienced in real-life public speaking, is an accurate rehearsal tool. It enables the application of what is practiced to real-life situations (Owens & Beidel, 2015). So, this study aims to expand the theory by investigating the influence of mindfulness on PSA when practicing public speaking in an experimental VR context, with self-efficacy serving as a potential mediator in this relationship. The insights of this research will contribute to the evidence-based development of public speaking training and mindfulness interventions.

Theoretical Framework

Possessing good public speaking skills like having a convincing and confident tone of voice, posture, use of hands and, thereby, the ability to deliver compelling presentations can significantly contribute to educational achievement, career development, and social developments in interpersonal connections, conflict resolution and negotiation (Carnegie & Esenwein, 2017; Chollet et al., 2015; Wang et al., 2020). However, there are many people who experience public speaking anxiety (PSA), limiting the development of these skills (Harris et al., 2002; Wang et al., 2020).

Public Speaking Anxiety

Public speaking anxiety (PSA) is often mentioned as one of the most common social anxieties that affects individuals of all ages, genders, and socioeconomic backgrounds (Lee et al., 2002; Wang et al., 2020), posing challenges to developing public speaking skills and confidence (Wang et al., 2020). Physical stress symptoms of PSA that individuals may encounter include heart palpitations, a quivering voice, increased blood pressure, sweating, abdominal discomfort, diarrhea, muscle tension and confusion (Harris et al., 2002; Lee et al., 2002).

Next to physical symptoms, PSA also has cognitive impacts. Individuals can encounter stress, frustration, and compromised speech performance, leading to underachievement and avoidance of public speaking situations (Harris et al., 2002; Wang et al., 2020). Uncontrollable anxiety makes it hard for public speakers to be rational and logical, with speakers having trouble with their short-term memory, which may result in forgetting what they are supposed to say during a presentation (Li, 2020). Anxiety may also occur before a public speaking event, by imagining it (Harris et al., 2002; Poeschl, 2017). Despite recognizing the irrationality of their fears, individuals who experience PSA often are unable to change their attitudes towards public speaking without appropriate assistance and training

(Harris et al., 2002). This inability to overcome PSA without support highlights the importance of interventions to help individuals manage their fear of public speaking effectively.

Anxiety can be distinguished into two forms: trait anxiety and state anxiety. Trait anxiety is a fundamental aspect of an individual's personality and describes the inclination to feel tense in certain anxiety-inducing scenarios, such as a public speaking event. It is a personal characteristic (Wang et al., 2020). State anxiety, on the other hand, is an anxious state triggered by a specific stimulus, in this case public speaking (Poeschl, 2017). The level of state anxiety an individual experiences depends on the stressful situation and the persons' trait anxiety (Endler & Kocovski, 2001). For the purpose of this research, the focus will be on state anxiety for public speaking only.

PSA can be measured subjectively, through self-reports and interviews, and objectively, using physiological measurement devices(Lima et al., 2019; Roos et al., 2023; Wiederhold et al., 2002). Together, these measurement tools help assess the effectiveness of PSA interventions, offering insights for future research and therapy.

PSA can be reduced through frequent exposure to the feared situation, such as practicing public speaking or structured training programs (Chollet et al., 2015; Davis et al., 2017; Pertaub et al., 2002). A meta-analysis by Allen et al. (1989) found that a treatment technique such as training skills repeatedly or systematic desensitization reduced PSA. Pribyl et al. (2001) also showed that participating in public speaking skills training had a significantly decreasing effect on reported PSA scores. These forms of exposure to the situation that triggers PSA fall under cognitive behavioral therapy (CBT) (Davis et al., 2017; Poeschl, 2017).

Practicing public speaking to reduce PSA could happen in an individual setting, but this lacks the critical audience feedback from real speech environments (Frisby et al., 2020).

Audiences can offer direct and indirect feedback during and after a presentation through non-verbal behavior, influencing anxiety (MacIntyre et al., 1997). This type of audience feedback helps interpersonal skills training, such as public speaking (Chollet et al., 2015; MacIntyre et al., 1997). MacIntyre et al. (1997), for example, found that the preferred audience for a low PSA is interested, responsive and non-evaluative. An interested, responsive, and non-evaluative audience makes a supportive, less intimidating speaking environment and alleviates pressure on the speaker, ultimately reinforcing confidence and reducing anxiety. However, there is a lack of opportunities for practicing public speaking with these audiences in a higher education setting due to increasing numbers of students and a shortage of time and resources (Kollöffel & Heuvel, 2020; Kroczek & Mühlberger, 2023).

A solution to these constraints for public speaking practice is the recent technological development of virtual reality (VR) public speaking training that offers an effective alternative for public speaking practice with a real audience. It enables repeated safe and private practice in front of various audiences without the need for other individuals, and offers several feedback types (Chollet et al., 2015; Frisby et al., 2020; Vafadar, 2013). VR can serve as a practical solution for helping students overcome PSA in settings with limited resources.

Virtual Reality

Due to technological developments, public speaking can be practiced using virtual reality as a tool. Abbas et al. (2023) composed the following definition of Virtual reality (VR): "VR is a three-dimensional computer-generated simulated environment, which attempts to replicate real world or imaginary environments and interactions, thereby supporting work, education, recreation, and health." (p. 7). VR applications can generate training scenarios that are otherwise hard to realize (Poeschl, 2017). Users can carry out scenarios in VR safely, with no to minimal consequences of mistakes, and privately (Poeschl, 2017; Wang et al., 2020). VR training has a wide range of applications, including social skills training, such as job interviews, conversational skills, intercultural communication, and public speaking (Chollet et al., 2015; Harris et al., 2002). It has been used as a treatment for social anxieties, like for PSA (Botella et al., 2000; Vanni et al., 2013). Social anxieties can be treated using exposure therapy. However, in-vivo exposure therapy is not always practical or ethical, for example when situations are difficult, expensive or dangerous to recreate (Owens & Beidel, 2015). That is where virtual reality exposure therapy (VRET) offers a potential alternative. VRET provides a valuable opportunity for safe and effective practice of public speaking, offering a solution for individuals with PSA (e.g., Finn et al., 2009; Premkumar et al., 2021).

Findings of several studies suggest that training public speaking in a VR environment that elicits anxiety can be effective in reducing PSA since it can provide a virtual replica of anxiety-inducing social situations such as a classroom environment (Harris et al., 2002; Lee et al., 2002; Lim et al., 2023; Vanni et al., 2013). VR presentation environments can include classrooms, lecture rooms, offices, conference halls, meetings, streets, shops, bars and meeting rooms (Lim et al., 2023). The situations can be reconstructed with virtual audiences adjustable in size, behavior, or facial expressions, creating supportive or unsupportive environments, thereby providing feedback (Kothgassner et al., 2012; Kroczek & Mühlberger, 2023; Pertaub et al., 2002). So, with its adjustable settings, VR allows exposure to a personalized specific anxiety-inducing social situation (Powers & Emmelkamp, 2008).

An authentic performance experience is essential for adopting VR as a rehearsal tool and transferring what is learned to real-life (Frisby et al., 2020). PSA experienced in VR can be compared to PSA experienced in an actual speaking situation according to the experiment of Kothgassner et al. (2016) and the review of Vanni et al. (2013). The similarity between public speaking environments, along with the ability to simulate realistic audience behaviors, enables systematic desensitization (gradual exposure to reduce fear) and anxiety habituation (decreased anxiety response over time due to prolonged exposure) to anxiety-inducing stimuli in VR. This allows VR users to apply what they learn in a VR public speaking situation to public speaking in real life (Lim et al., 2023). Anxiety can also be induced by these environments. PSA symptoms like a higher heart rate, a higher skin conductance, and skin conductance response can be induced using VR for public speaking according to Owens and Beidel (2015). The symptoms induced in VR were similar, but the not equal to the response to an actual audience. Overall, since VR can replicate the experience of public speaking and elicit comparable anxiety responses, it is a valuable tool for exposing individuals to a public speaking situation.

Audiences in virtual reality could trigger anxiety in phobic and non-phobic people (Pertaub et al., 2002). Here too, a supportive audience could create a less intimidating speaking environment which decreases pressure on the speaker, ultimately reducing anxiety, while an unresponsive one will be stressful and anxiety provoking (MacIntyre et al., 1997). Furthermore, according to Chollet et al. (2015), the use of virtual reality reduces the fear of being judged, since the audience consists of non-conscious virtual humans and the people practicing are aware of that (Lucas et al., 2014). This understanding also increases the engagement and willingness to train with these social agents (Moreno et al., 2001), making virtual humans capable of helping anxious individuals improve their social skills and reduce anxiety (Chollet et al., 2015). Several researches support the claim that VR is capable of helping with PSA; Chollet et al. (2015) found that using interactive virtual audiences in VR presentation training improved public speaking skills. Anderson et al. (2005) let participants follow a treatment of anxiety management training and four VR presentation sessions and found that scores on PSA indicators improved significantly from pre- to post-test (d = 1.1-1.5). Additionally, the literature reviews by Vanni et al. (2013) and Lim et al. (2023) concluded that VR practice sessions significantly reduce PSA levels. Furthermore, research from Wallach et al. (2009) showed that repeated exposure to a virtual audience resulted in a reduction of PSA symptoms over time. All these results collectively highlight that VR is a valuable tool for treating public speaking anxiety and improving social skills.

Mindfulness

Next to training public speaking in VR, being in a mindful state can be helpful in reducing PSA. Mindfulness is a state of consciousness characterized by open and receptive awareness and attention (Brown & Ryan, 2003). This state enables individuals to maintain a heightened consciousness of ongoing events and experiences, enhances focus, and promotes mental clarity (Brown & Ryan, 2003; Dane, 2010). During a resting state, the parasympathetic nervous system (PNS) regulates physiological functions, resulting in a lower heart rate and enhanced attention (Bell et al., 2018). While mindfulness can be experienced as a trait in a person's everyday life, it can also be experienced as a state that occurs during and after for example meditation (Brown & Ryan, 2003; Dane, 2010). In this research, however, mindfulness will be assessed as a state.

Mindfulness-based interventions have been found to help alleviate several mental health problems like anxiety disorders, depression, and eating disorders (Baer, 2003; Hofmann et al., 2010). Mindfulness techniques such as relaxation, meditation, and self-desensitization, which is teaching a person to be relaxed and not anxious in a target situation by imagining being in that situation, have been shown to be effective in reducing PSA, as noted by Kirsch and Henry (1979). Examples of relaxation or meditation techniques for stress or anxiety relief are body scan, in which users are instructed to focus on relaxing one body part at a time (Call et al., 2014); mental labelling, in which users are instructed to label (physical) feelings and emotions (Tanay & Bernstein, 2013); focused-attention meditation, in which users direct attention to their body regions and their breathing (Chan et al., 2017); and a breath technique, were users are guided to direct their attention to their breathing and that sensation (Tanay & Bernstein, 2013). A significant direct link between mindfulness and anxiety (β = -0.31, p < 0.001) was found by Sharma and Kumra (2022) who researched this relationship by distributing questionnaires. The fact that, for example, focused-attention mediation enhances cognitive control and promotes sustained attention and suppression of irrelevant stimuli (Chan et al., 2017), also suggests mindfulness may contribute to reducing anxiety in performance situations. Kumar et al. (2017) also investigated the relationship between mindfulness and PSA using questionnaires distributed to people who had to present at least three times in the last 12 months. They found a correlation between mindfulness and PSA (r = -0.220, p < .001), but they also found that mindfulness positively correlated with self-esteem (r = 0.370, p < .001). This correlation may be attributed to the fact that methods aimed at fostering a mindful state may help reduce evaluating oneself in a negative light, control critical thoughts of anxiety, and promote a self-awareness that is "non-self-evaluative" (Rasmussen and Pidgeon, 2011, p. 13), minimizing feelings that lead to low self-esteem (Brown et al., 2007; Kumar et al., 2017). So, these research findings highlight the potential of the different mindfulness strategies to reduce PSA and enhance self-esteem.

There is more evidence linking mindfulness to beliefs about the self. Research from Bajaj et al. (2016) and Rasmussen and Pidgeon (2011) showed a relationship between mindfulness and anxiety and that self-belief played a mediating role in this association. Furthermore, the research of Kumar et al. (2017) did not only find a correlation between mindfulness and self-esteem, but a mediation analysis confirmed that self-esteem mediated the relationship between mindfulness and specifically PSA (β = - 2.146, CI = - 3.902 to 0.768). There are also studies stating that next to self-esteem, mindfulness can enhance self-efficacy in social behavior change (Bayır & Aylaz, 2021) and in academic contexts (Hanley et al., 2015). Sharma and Kumra (2022) researched the mediating role of self-efficacy in the relationship between mindfulness and PSA by distributing questionnaires. They found that there is also a significant indirect relationship through self-efficacy between mindfulness and anxiety ($p < .001$), with a β in the relationship between mindfulness and self-efficacy of 0.04 ($p < .001$) and a β in the relationship between self-efficacy and anxiety of -0.37 ($p < .001$). So, having a higher self-efficacy affects levels of anxiety (Sharma & Kumra, 2022).

Self-Efficacy

Many authors, such as Lucchetti et al. (2003) and Kang et al. (2019), use Bandura's theory (1978) to define self-efficacy as an individual's belief in their ability to succeed. Self-efficacy has a direct influence on performance and on activities one chooses to engage in. In many cases, higher self-efficacy levels in a skill lead to better performance outcomes. Additionally, self-efficacy can affect coping with and handling aversive experiences (Bandura, 1978). However, self-efficacy can also be negatively influenced when an individual is placed in a threatening situation (Lucchetti et al., 2003). According to Bandura (1978), self-efficacy expectations stem from four sources: prior performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal. Diminishing emotional arousal, for example, can minimize avoidance behavior (Bandura, 1978). Also, previous performance experiences strongly influence self-efficacy beliefs (Lucchetti et al., 2003). Both emotional arousal and performance experience can be replicated using a VR environment (Frisby et al., 2020). In this research, *self-efficacy regarding presentations* will be seen as the individuals' feelings towards delivering presentations and their confidence about giving a sufficient presentation to their own standards or opinion.

Lucchetti et al. (2003) found that self-efficacy expectations can correlate with PSA levels. Their research showed a significant inverse correlation between self-efficacy expectations and PSA scores ($r = -.39$, $r^2 = .15$, $p < .001$). This means that the higher their participants' self-efficacy expectations, the lower they scored at PSA. Individuals who expect to perform well in future presentations will experience less anxiety than those who think they will fail and thus have lower self-efficacy. Furthermore, practicing presentations helps individuals strengthen their self-efficacy beliefs and comfort in public speaking skills, which in turn influences their anxiety levels (Kang et al., 2019). This is because practicing presentations and increased self-efficacy increases the sense of being in control over a situation, which in turn lowers anxiety in these situations (Bandura, 1997; Frisby et al., 2020). Lucchetti et al. (2003) also suggested that there is a reversed relationship between the two concepts, in which levels of anxiety can affect the extent to which individuals believe they are able to handle anxiety-inducing situations such as public speaking. The findings on this reciprocal relationship between self-efficacy and anxiety levels suggest that taking into account self-efficacy while practicing public speaking may be an effective strategy for reducing PSA.

Looking at self-efficacy in combination with VR training for public speaking, the authenticity of the environment is important. As mentioned, emotional arousal and performance experience can be replicated using a VR environment. When a VR environment is authentic, replicating the public speaking environment and the accompanying feelings and emotions, self-efficacy for public speaking is potentially addressed (Frisby et al., 2020). Realistic VR thus offers the pedagogical opportunity to enhance efficacy and performance by letting the users experience the psychological states of performance anxiety (Frisby et al., 2020).

Research Questions

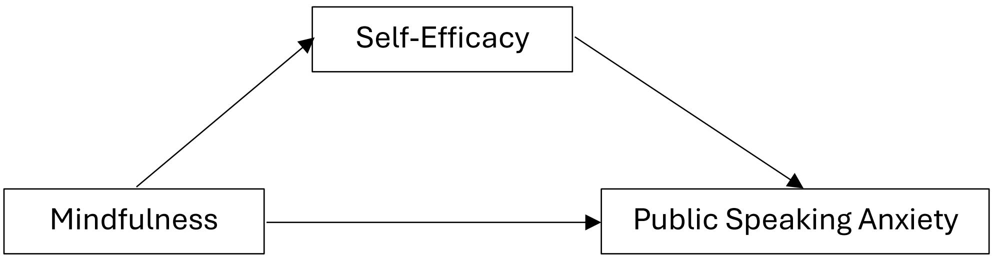
There has been research on the relationship between mindfulness and PSA. Some studies have delved into the mediating role of self-esteem on the relationship between mindfulness and anxiety (Bajaj et al., 2016; Kumar et al., 2017; Rasmussen & Pidgeon, 2011). However, this research mostly relied on non-experimental methods, without an intervention and control group, assessing the variables through questionnaires only at a single point in time, thereby looking at mindfulness and anxiety more as a trait. Considering PSA as a distinct sub-type of anxiety (Kumar et al., 2017), it is valuable to focus more specifically on this type, rather than the broad term “anxiety”. In this research PSA will be evaluated as a state anxiety. Additionally, the existing research primarily focused on the mediating role of self-esteem, not on self-efficacy. The existing literature did also not conduct research in the context of VR. So, the combination of the variables mindfulness, PSA and self-efficacy in VR remains underexplored. Therefore, this research aims to contribute to the current theoretical knowledge by answering the following research questions:

1. “To what extent does a mindfulness micro training influence public speaking anxiety when presenting in a virtual reality environment?’
2. “Does self-efficacy have a mediating role in this relationship between mindfulness and PSA?”.

The mediation model that will be investigated is visualized in Figure 1.

Figure 1

Mediation Model



Based on previous theory and research, the following hypotheses are proposed:

H1. Participants following a mindfulness training will have a bigger decrease in public speaking anxiety while presenting in a VR training environment compared to the participants in the control group, indicating a negative correlation between mindfulness and public speaking anxiety.

H2. Participants following a mindfulness training will have a bigger increase in self-efficacy in their public speaking skills compared to the participants in the control group, indicating a positive correlation between mindfulness and self-efficacy.

H3. Having a higher self-efficacy in public speaking is associated with lower levels of public speaking anxiety, indicating a negative correlation between self-efficacy and public speaking anxiety.

H4. Self-efficacy mediates the relationship between mindfulness and public speaking anxiety.

Method

Research Design

The present study used a quantitative research approach with a within-subjects and between-subjects experimental design where a public speaking VR experiment was executed. The primary objective of this experiment was to examine the effects of a single mindfulness training (independent variable) on PSA (dependent variable) while presenting in VR, using repeated measures. Additionally, the study aimed to investigate the possible mediating role of self-efficacy. The experiment had two conditions, participants were divided into an experimental condition and a control condition. This control condition was added to ensure the validity of the results.

Participants

This research was conducted with a convenience sample of students at Dutch universities, students at universities of applied sciences, or newly graduated young professionals, since this population frequently performs in public speaking engagements or will have to in their (future) careers. The participants were recruited using personal connections, flyers, and the SONA credit system. The inclusion criteria for this study were that participants had to be students or newly graduated young professionals and be able to understand English. The experiment had two conditions: the mindfulness intervention group ($N = 25$) and the control group ($N = 24$). The participants were randomly assigned to one of the two conditions in order of the experiment appointments. To ensure a relatively high power (>.80) for the study, each group consisted of 24 or 25 participants (Voorhis & Morgan, 2007). The final sample consisted of 49 participants (12 male, 37 female) with an average age of 23 ($SD = 2.79$). Participants were asked about their prior experience with VR. Of the total, 64.3% reported having used VR once or a few times, 33.3% had never used it before, and 2.4% had used it frequently. The distribution of previous VR experience did not differ significantly between the experimental and control condition.

Procedure

Preparation

This project was approved by the ethical commission of the University of Twente (240110) before data collection started. During the experiment itself, the participants were provided with an information letter and an informed consent form to sign, which made clear that they have the right to stop participating in the experiment at any time, informed them that the experiment will be anonymized, and stated there would be no other observers present. The letter also informed the participants of the possibility of experiencing nausea or headaches. Only one participant experienced this but still ended up finishing the experiment. Only the survey results and physiological measurements would be used in the study.

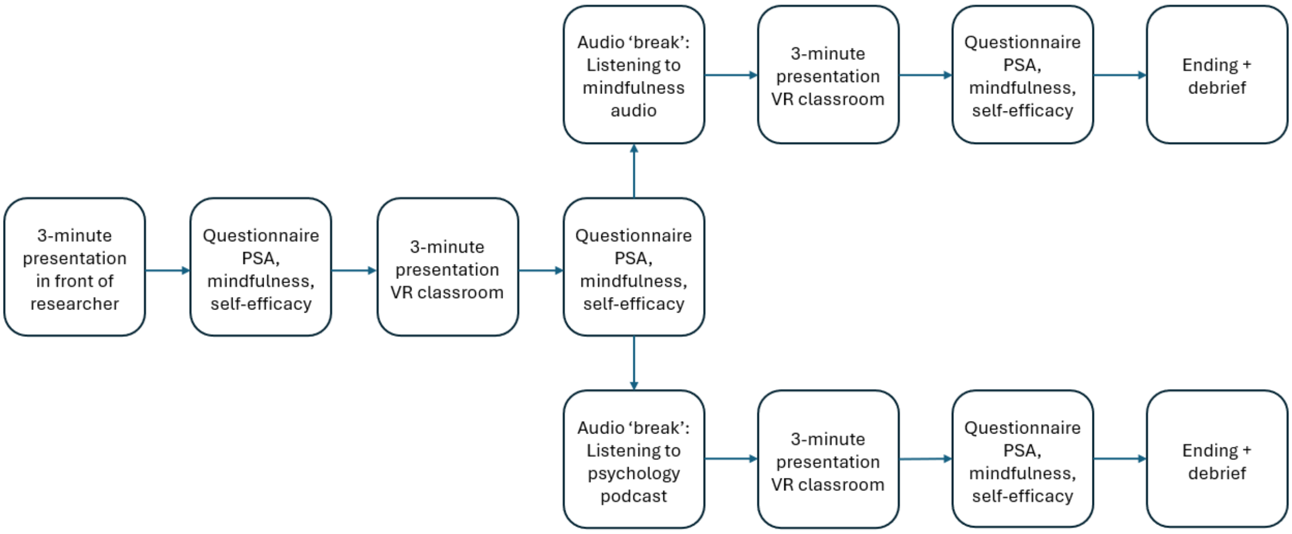
To ensure that the participants were adequately prepared for the experiment, they were asked to bring a short (PowerPoint) presentation to use to give a 3-minute presentation on an academic or work-related topic. To avoid too much preparation, which could deter potential participants it was recommended that the presentation was on a topic they had to present about before.

Experiment

The participants followed one experimental session, which included presenting three times and experiencing either the intervention or the control-group break. The experiments were performed in project rooms at university or at participants' homes. The experimental sessions took 45-60 minutes in total. Figure 2 provides an overview of what happens in one experimental session, complementing the description provided in the text below.

Figure 2

Diagram of the Experimental Session



First, to establish some baseline measurements on the physiological parameters and survey (Appendix B, C, D, E), the participants gave their short 3-minute presentation in the real-life environment in front of the researcher. At the same time, they were wearing the Embrace Plus wristband. They were wearing the wristband during the entire experiment. The starting times of the presentations were recorded for accurate data analysis afterwards. Afterwards, they filled out the baseline measurement questionnaire. Then, the participant received an explanation of the VR environment and the controls to become familiarized with the VR environment.

Next, the participants gave their 3-minute presentation in the VR environment, where they presented their slides. Subsequently, they received a post-test survey with questions about their PSA (Appendix E) and self-efficacy (Appendix D) regarding presenting, as well as the state of mindfulness they experienced during the VR presentation (Appendix C).

After that, the participants got a short break from presenting, whilst wearing the Embrace Plus wristband. The experimental group was exposed to a 13-minute-long mindfulness intervention in the form of an audio during this break. The control group did not receive this intervention; they were exposed to a 13-minute segment of an American podcast on learning and memory. This was done to have the experimental and control conditions have a break with similar conditions: listening to an audio. To ensure little interference with the listening process, noise-cancelling headphones were used when listening to the audio to reduce external noise and minimize potential distractions. Also, to make the participants feel at ease, the researcher left the room during this break.

The participants then presented their presentation for a second time in the VR environment, followed by another post-test survey that measured their PSA levels, self-efficacy, and the state of mindfulness regarding giving presentations again.

Finalizing the Experiment

After the experiment, the participants were disconnected from all equipment and debriefed about the goal of the experiment regarding the mindfulness intervention.

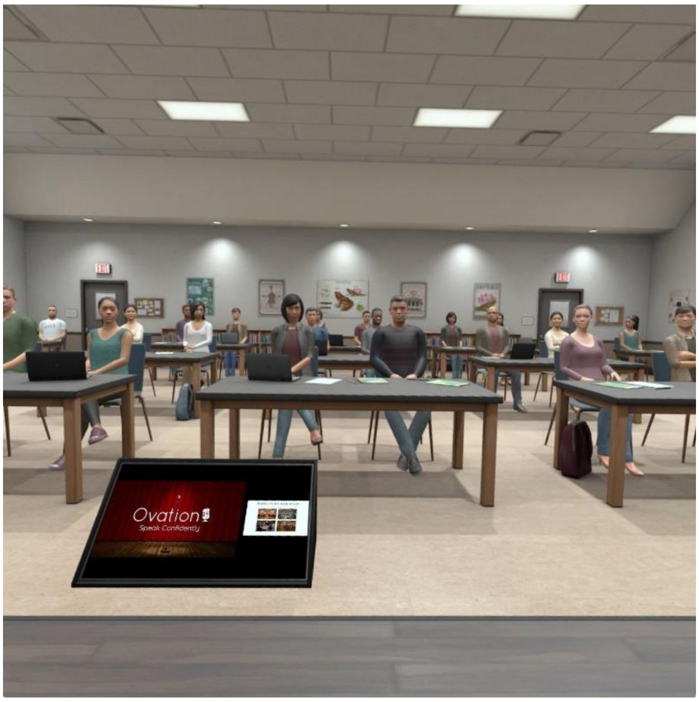
Instrumentation

Ovation

This research used Meta Quest 3 paired with the presentation software Ovation. The Meta Quest 3 consisted of a head-mounted system and two hand controllers to navigate the system. The Ovation software facilitates public speaking practice. The software offers a range of virtual rooms to practice presentations, with the opportunity to import one's own slides. This experiment used a classroom setting with an audience of 30 people, since this is a common scenario for higher education students (see Figure 3). For this experiment, the audience engagement was set to medium. Since the focus of this study is not on feedback and its effects, the feedback options that Ovation offers were turned off.

Figure 3

Exemplar of the Classroom Setting in VR



Mindfulness Intervention

For the mindfulness intervention of the experimental group, a relaxation micro-training was used. It was communicated as a 'relaxation audio' towards the participants to avoid a biased reaction towards the mindfulness intervention. The audio is a 13-minute-long body scan audio recording describing relaxation exercises, in which the listener is instructed to focus on different body parts at a time, repeat them in their heads, and relax them (see Appendix A for the script). The audio is designed and recorded by a mindfulness expert at the University of Twente (Chan, 2023) and has been used in previous research.

Physiological Measurements

To measure the participants' stress and arousal, an indicator of anxiety, physiological measurements were conducted. Some examples of physical stress or anxiety symptoms associated with PSA are increased blood pressure, heart palpitations, sweating and muscle tension (Harris et al., 2002; Lee et al., 2002). Heart rate (HR) and skin conductance, or electrodermal activity (EDA), are among the indicators that reflect these physiological responses to anxiety (Giannakakis et al., 2022). HR, the number of heartbeats per minute, increases during periods of stress or anxiety as these states activate the sympathetic nervous system (SNS). This results in the release of hormones affecting an individual's physical and emotional responses, like causing the brain to struggle to regulate cognitive tasks and disrupting rational thinking (Giannakakis et al., 2022; Li, 2020). Similarly, EDA, which is the electrodermal activity of the skin due to activation of the sweat glands, reflects changes in sympathetic nervous system activity due to stress or anxiety (Giannakakis et al., 2022; Roos et al., 2023). Wiederhold et al. (2002), for example, noticed that EDA was significantly ($p < 0.01$) higher in phobic people who experienced a for them anxiety-inducing event in comparison to non-phobic people where this event did not induce anxiety. This electrical conductivity can represent even moderate amounts of sweating that are not observable on the skin (Giannakakis et al., 2022). Wearable sensors, electrodes and biofeedback devices provide non-invasive measurements to operationalize the intensity of the physiological responses related to stress (Lima et al., 2019; Roos et al., 2023; Wiederhold et al., 2002). These devices provide quantitative data on the intensity of stress and arousal experienced during public speaking. The device used in this study was the Embrace Plus, a wristband that monitors several physiological parameters. The ones used for this experiment were HR and EDA. HR was recorded in beats per minute (BPM), and EDA was recorded in microSiemens (µS). The mean values of these parameters per minute were used in the analyses, adjusted to individual participants' baseline values. Heart rate variability (HRV) was not used in this research since the Embrace Plus wristband was not able to record that for most participants due to hand movements. The wristband was strapped tightly on the non-dominant wrist and measurements were recorded by the application Empatica Care Lab.

Self-Report Measures

By combining the physiological measurements with self-report measures, a more nuanced and multidimensional understanding of the variables can be constructed. To illustrate the physiological measurements, and to capture participants' feelings and experiences with presenting influencing their public speaking anxiety, state of mindfulness and self-efficacy, the participants had to repeatedly fill out questionnaires during the experiment. The questionnaires include adapted questions from several existing questionnaires on mindfulness, self-efficacy and PSA. During the experiment, there was a baseline measurement moment after a first real-life presentation and two other measurements, each after a VR presentation. For the baseline measurement (see Appendix B), the questionnaire consisted of some demographic questions and statements from the three scales (see Appendix C, D and E) about the baseline presentation in real life in front of the researcher. For the repeated measures, the three scales (Appendix C, D and E) were used to ask about the presentations that were just performed in VR.

Mindfulness. Five questions were asked to measure if the mindfulness intervention causes a state in which the participants experience more mindfulness. The questions originally from the Mindful Attention Awareness Scale (MAAS) by Brown and Ryan (2003), which is a trait scale, and were adjusted to a state scale to measure the short-term or current expression of mindfulness. In this subscale, the Likert scale was adjusted from 1 (not at all) to 6 (very much) to a Likert scale with scores ranging from 1 (not at all) to 5 (extremely) to make it consistent with the scoring of other subscales in the questionnaire. An example question from this subscale is: "I was finding it difficult to stay focused during giving the presentation.". Cronbach's alpha of the original MAAS was .87. Construct validity was measured using a confirmatory factor analysis (CFA), which showed a good model fit for the single-factor model (CFA = .91, RMSEA = .058) (Brown & Ryan, 2003).

Self-Efficacy. To assess the participants' self-efficacy regarding presenting, four items were constructed using the Self-Efficacy for Social Situations scale by Gaudiano and Herbert (2003) (Cronbach's alpha = .81) as an example. Each question had to be answered on a scale of 1 (not at all) to 5 (extremely). The self-efficacy questions were asked to assess how participants feel about giving presentations and how confident they are about giving a good enough presentation to their own standards. One example question is, "How confident are you that you have the basic skills to perform well when you give public speeches?".

PSA. In addition to physiological measurements, the level of PSA was measured using a set of 17 questions from the Public Speaking Anxiety Scale (PSAS) developed by Bartholomay and Houlihan (2016). The questions were adjusted to the past tense to refer to the presentation that was just given. An example question from this scale is, "I felt tense before giving the speech." Responses were measured on a Likert scale ranging from 1 "not at all" to 5 "extremely". Five of the items are reverse-coded. The reported Cronbach's alpha of the original PSAS is .94. The PSAS had good concurrent validity (r =.835–.845) when compared with other speech anxiety measures.

Data Analysis

The quantitative data collected from the self-report questionnaires and the physiological measurements were anonymized and analyzed using the software SPSS and R.

Self-Report Measures

Questionnaire responses were recorded in Qualtrics. The exported data from the three questionnaires was combined into one Excel file for data management, and imported in SPSS and R. First, Cronbach's alpha was computed per construct to ensure reliability on the merged scales. The accepted value for this research before moving on with the analysis was 0.6. A Confirmatory Factor Analysis was conducted to assess the validity of the questionnaires.

Next to the calculation of descriptive statistics, several analyses were conducted to assess the effects of PSA, mindfulness and self-efficacy. To compare the mean scores on the different variables across the repeated measures, a repeated measures ANOVA was conducted for every variable and compared to see the main effects of time, condition and a possible interaction effect. Next to the repeated measures ANOVA, a mediation analysis with regression was performed to investigate the mediating effect of self-efficacy on the relationship between mindfulness and PSA in VR. For this analysis, the variables 'PSA change' and 'SE change' were computed to reflect the changes in PSA- and SE scores from the second to the third presentation. The second and third presentation scores were used since the mindfulness training took place between these two presentations. The mediation analysis was performed using multiple regression and partial correlations. Furthermore, an ANCOVA was conducted to see if self-efficacy change is a covariate in the relationship between mindfulness and PSA.

The significance level (alpha) of these analyses was set at .05.

Physiological Measurements

The physiological measurements were analyzed with R to determine whether there were increases or decreases in physical stress indicator levels during the experiment and whether they illustrated the answers to the self-reported measures. The data used from the Embrace Plus wristband recorded data were heart rate measured in beats per minute (BPM) and skin conductance measured in electrodermal activity (EDA). The data was extracted from the program in files in which the data was aggregated per minute by the Empatica Carelab application.

First, the mean values of BPM and EDA were visualized in a plot. A linear mixed effects model (LMER) was constructed and fitted on the BPM and EDA data to analyze this data. A LMER was chosen because this model accounts for the repeated measures with multiple observations per participant across and within sessions. In addition to the fixed effects for condition (experimental vs. control), session (first, second, or third presentation), and minute (first, second, or third minute of the presentation), the model also includes random effects for participants, adjusting for individual variability and different baseline values. An ANOVA was conducted on this model to examine the main and interaction effects of condition, session, and minute on BPM and EDA over time. The main effects refer to the independent influence of the factor on BPM or EDA, allowing to determine if there are significant differences in these measures across the different conditions, sessions or minutes of the presentations. Interaction effects explore how these factors influence each other. For instance, the interaction effect of condition × session examines if the impact of mindfulness training (condition) varies across the presentation sessions. Afterwards, pairwise comparisons as part of a post-hoc analysis were executed to see the direction of the effects.

Results

Self-Report Measures

Reliability

To assess the reliability of the adjusted questionnaires designed to measure mindfulness, self-efficacy and PSA, the internal consistency for each construct across all three questionnaires after the presentation measurement points was examined using Cronbach's alpha. In almost all three measurement points, items PSA6 and PSA17 (see Appendix E) had item-total correlations lower than 0.20, indicating the item may not effectively measure the same underlying construct as the rest of the items in the scale. Furthermore, during the experiment, participants expressed confusion about the PSA17 item since it was negatively formulated. Additionally, the mean Cronbach's alpha would increase from 0.89 to 0.91 if these items were deleted. So, it was decided to delete the items PSA6 and PSA17 for the final analysis. Table 1 illustrates the eventual Cronbach's alpha values for each construct from the questionnaires after each presentation.

Table 1

Cronbach's Alpha per Construct

Construct	**Cronbach's alpha**			
	Questionnaire 1	Questionnaire 2	Questionnaire 3	Mean
Mindfulness	0.60	0.64	0.63	0.62
Self-efficacy	0.82	0.78	0.71	0.77
PSA	0.90	0.90	0.93	0.91

Note. Accepted value of Cronbach's alpha was 0.6

Construct validity

A series of Confirmatory Factor Analyses (CFA) was conducted on the baseline (B) questionnaire to evaluate whether the items from the three separate sub-scales —Mindfulness

(M), Public Speaking Anxiety (PSA) and Self-efficacy (SE) — each correspond to a single underlying factor consistent with theoretical expectations. The analyses aimed to validate the factor structure of each scale independently.

The chi-square test for the mindfulness scale ($\chi^2(5)= 10.95$, $p = .52$) and the self-efficacy scale ($\chi^2(2)= 2.37$, $p = .31$) demonstrated a good fit of the model. For the PSA scale the chi-square test ($\chi^2(90)= 210.51$, $p < .001$) indicated a suboptimal match between the hypothesized model and the observed data. The alternative fit indices comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA) are shown in Table 2. These fit indices also demonstrate a strong fit for the self-efficacy scale, whereas the values from the mindfulness and PSA scales are below acceptable thresholds.

Table 2

Fit Indices for the Sub-scales

Scale	CFI	TLI	RMSEA
Mindfulness	0.83	0.66	0.16
Self-efficacy	0.99	0.98	0.06
PSA	0.69	0.63	0.17

Note. Acceptable values were CFI ≥ 0.90, TLI ≥ 0.90, RMSEA ≤ 0.08

The standardized factor loadings for the items on each scale (Appendix C. D, E) indicate varying degrees of association with their respective factor (Table 3). An absolute value of 0.5 for the factor loadings was used as a lower limit. Most of the self-efficacy and PSA items showed high factor loadings on their respective factors, representing their constructs as single factors. Items M2_B, M4_B, PSA4_B, PSA8_B, and PSA12_B had a factor loading lower than the accepted threshold. A closer analysis of these items demonstrates that the mindfulness items loaded on one other factor, while the PSA items loaded on three other factors.

The lower factor loadings and the fit measures of the mindfulness and PSA scales suggest a few potential areas for model improvement. Overall, the model performed well. For this thesis, the model was not adjusted, and the questionnaires were used with these items representing the constructs since a pilot test before the actual use of the survey was not possible due to lack of time and participants.

Table 3

Factor Loadings of the Items on the Three Factors

Item	Self-efficacy scale	Mindfulness scale	PSA scale
SE1_B	0.86	-	-
SE2_B[a]	0.82	-	-
SE3_B[a]	0.80	-	-
SE4_B	0.76	-	-
M1_B	-	0.78	-
M2_B	-		-
M3_B	-	0.66	-
M4_B	-		-
M5_B	-	0.84	-
PSA1_B	-	-	0.84
PSA2_B	-	-	0.73

PSA3_B	-	-	0.82
PSA4_B	-	-	
PSA5_B	-	-	0.72
PSA7_B[a]	-	-	0.64
PSA8_B[a]	-	-	
PSA9_B	-	-	0.73
PSA10_B	-	-	0.63
PSA11_B	-	-	0.66
PSA12_B	-	-	
PSA13_B	-	-	0.69
PSA14_B	-	-	0.62
PSA15_B	-	-	0.72
PSA16_B	-	-	0.68

[a] Reversed items

Descriptive Statistics

The mean scores for self-efficacy (SE), mindfulness (M) and public speaking anxiety (PSA) for the three measurements (1-3), one after each presentation, and for each condition (experimental group and control group) are shown in Table 4. For SE and PSA, a higher score means a higher sense of self-efficacy towards whether the participants could perform well enough for their own standards in a presentation, and a higher sense of public speaking anxiety. For M, a lower score means a higher sense of mindfulness.

Table 4

Descriptive Statistics per Measurement

	Experimental		Control	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
SE - 1	3.20	0.68	3.11	0.89
SE - 2 (VR)	3.30	0.60	3.19	0.83
SE - 3 (VR)	3.55	0.65	3.63	0.67
M - 1	2.17	0.64	2.20	0.69
M - 2 (VR)	2.16	0.48	2.35	0.75
M - 3 (VR)	1.83	0.41	2.24	0.73
PSA – 1	2.24	0.55	2.15	0.75
PSA - 2 (VR)	2.43	0.57	2.41	0.79
PSA - 3 (VR)	1.81	0.45	1.88	0.75

Note. The theoretical minimum and maximum scores are respectively 1 and 5 for all scales.

Changes in Self-Efficacy, Mindfulness and PSA Across Time and Conditions

A repeated measures ANOVA was conducted to assess the effects of time (first, second, or third presentation, in which the second and third were VR presentations), condition (experimental vs. control), and their interaction on the feelings of mindfulness, self-efficacy, and PSA.

Mauchly's Test of Sphericity indicated that the assumption of sphericity was met for self-efficacy ($\chi^2(2) = 1.96$, $p = .376$) and PSA ($\chi^2(2) = 3.57$, $p = .168$). However, the assumption was violated for mindfulness ($\chi^2(2) = 7.99$, $p = .018$). Therefore, the Greenhouse-Geisser estimates were used to analyze mindfulness in the repeated-measures ANOVA.

For self-efficacy, there was a significant main effect of time across the three presentations ($F(2, 94) = 17.44$, $p < .001$), with a high effect size (Partial $\eta^2 = .27$), indicating that the self-efficacy scores varied across the different presentations. This is visualized in Figure 4. Pairwise comparisons revealed that the participants' self-efficacy towards being able to perform well enough in a presentation for the participants' own standards increased significantly from the first to the third presentation ($p < .001$), as well as from the second to the third presentation ($p < .001$).

In contrast, for mindfulness, there was no main effect of time across the three presentations ($F(1.73, 81.07) = 2.46$, $p = .10$). This means the participants did not score significantly differently on the mindfulness scale across the three presentations. This is visualized in Figure 5.

For PSA, there was a significant main effect of time across the three presentations ($F(2, 94) = 29.85$, $p < .001$), with a high effect size (Partial $\eta^2 = .39$), indicating that there were significant changes in PSA scores over time. Pairwise comparisons showed that the participants had significantly higher PSA scores in the second presentation compared to the first baseline presentation ($p = .01$). This is visualized in Figure 6. Furthermore, the PSA score decreased in the third presentation compared to the second ($p <.001$). The difference in PSA scores between the first baseline presentation and the third presentation was also significant ($p < .001$), with PSA scores being higher in the first baseline presentation.

Figure 4

Self-efficacy Scores over Time

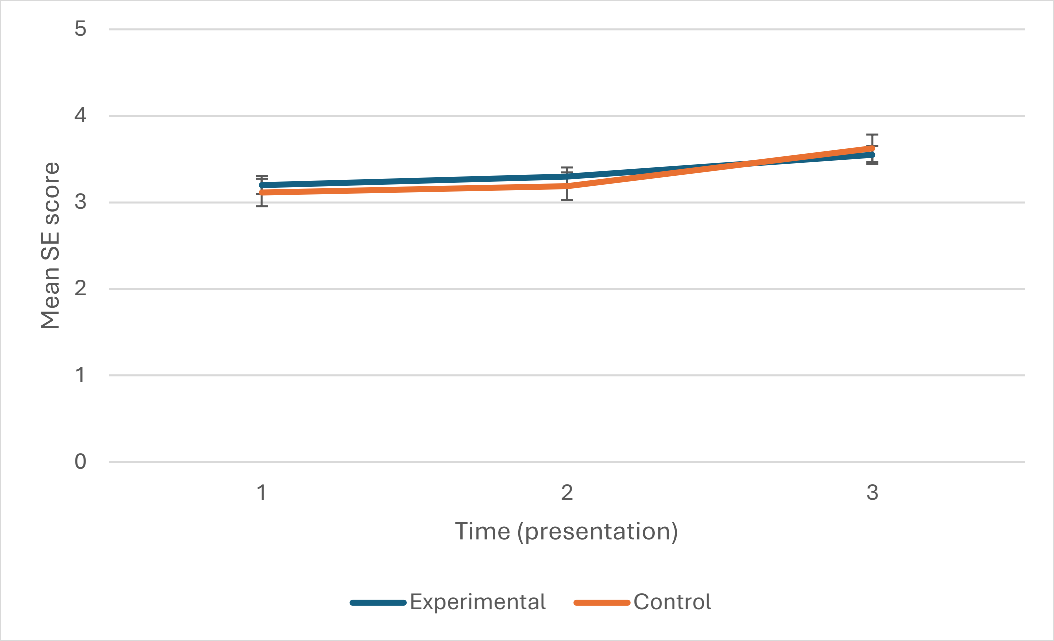


Figure 5

Mindfulness Scores over Time

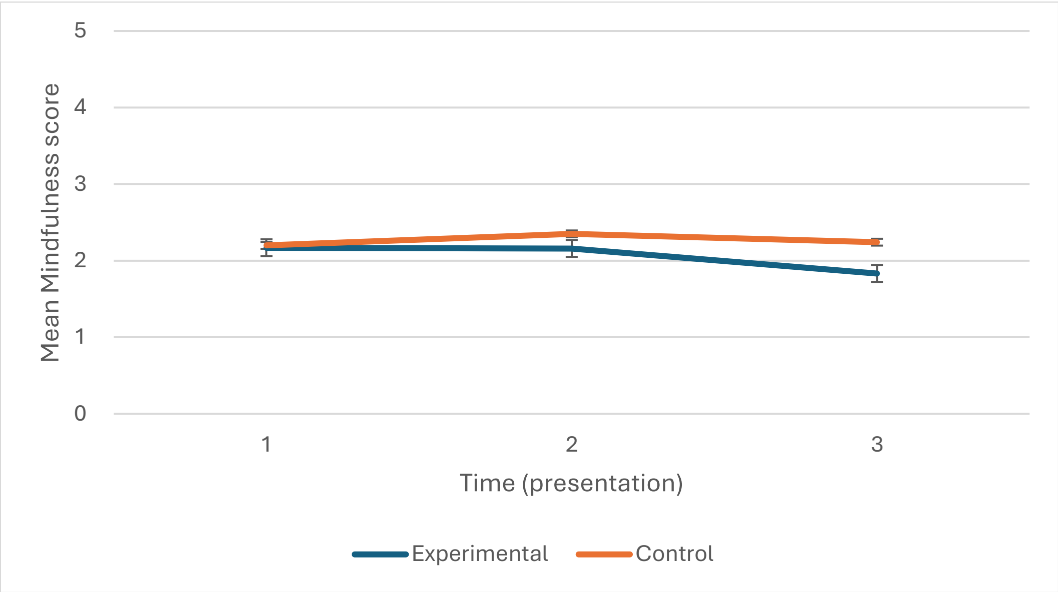
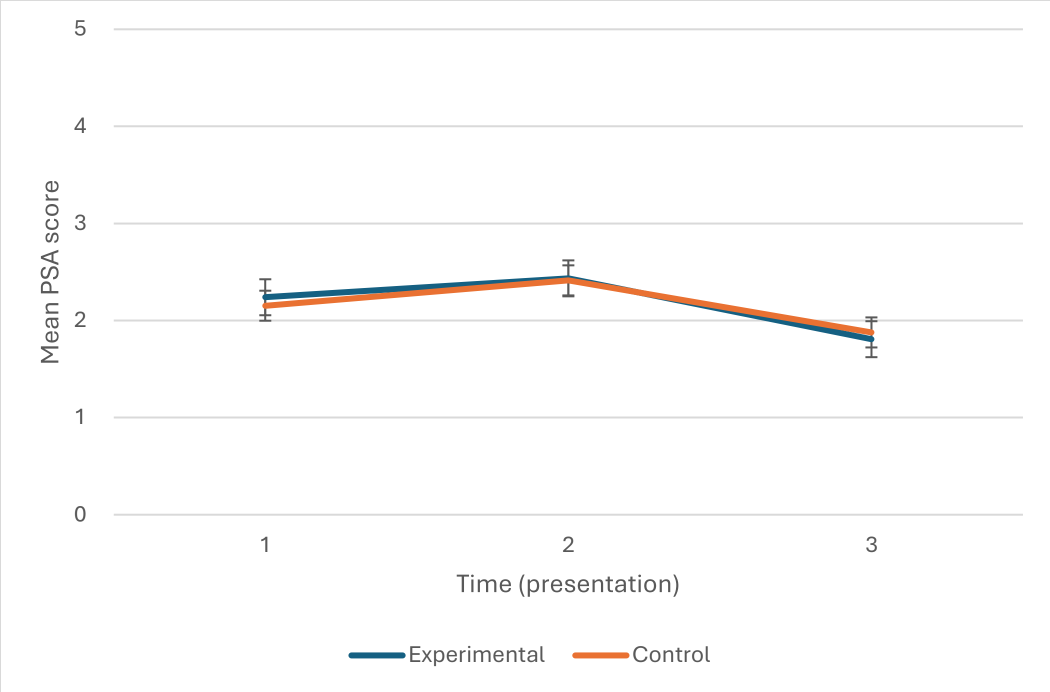


Figure 6

PSA Scores over Time



When comparing the measurements at the condition and time levels, there was no interaction effect of time and condition (time * condition) for all three variables. This indicates that the scores for each variable did not differ across the three measurement points, regardless of the condition the participants were in. This can be seen in Table 5.

Table 5

Repeated Measures ANOVA

Measure	Effect	*F*	df	*p*-value	Partial η²
Self-efficacy	Time	17.44	2	<.001	.27
	Time * Condition	0.86	2	.425	.02
Mindfulness	Time	2.46	1.73	.100	.05
	Time * Condition	1.78	1.73	.179	.04
PSA	Time	29.85	2	<.001	.39

Time * Condition	0.54	2	.585	.01

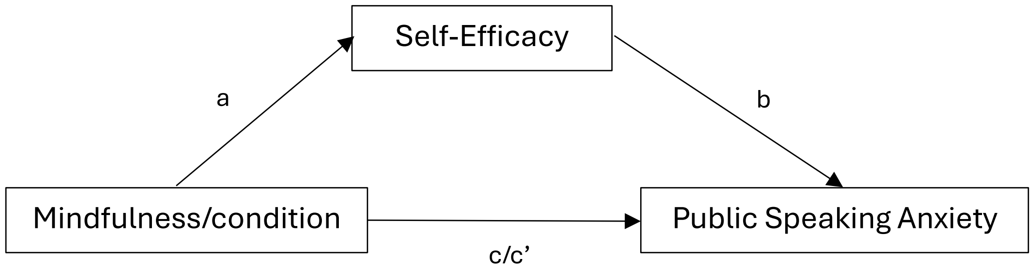
To further investigate the impact of the mindfulness intervention, a second repeated measures ANOVA was performed for mindfulness on only the second and third presentation. Given that the mindfulness training occurred between these two presentations, the differences in mindfulness scores between those two presentations were relevant to investigate. The repeated measures ANOVA revealed a significant main effect of time ($F(1, 47) = 7.41$, p = .009). However, there was again no interaction effect of time and condition (time * interaction), meaning the effect of time did not differ between the mindfulness training or the podcast condition ($F(1, 47) = 1.88$, p = .18).

Self-Efficacy as a Mediator Between Mindfulness and PSA

The variables 'PSA Change' and 'SE Change', the change in PSA—and SE-scores between the second and third presentations, were computed to assess the influence of the mindfulness training on PSA and the possibility of a mediating effect of self-efficacy on the relationship between mindfulness and PSA (Figure 7). There is a mediation if the predictor (mindfulness) has a direct effect on the dependent variable (PSA) (c); the predictor (mindfulness) has a significant effect on the mediator (self-efficacy) (a); the mediator affects the dependent variable (PSA) (b); and the direct effect 'c' is significantly reduced after controlling for the indirect effect through the mediator (c'). The scores of the second and third presentations were used since the mindfulness intervention took place between these presentations.

Figure 7

The Mediation Model



A mediation analysis was conducted using hierarchical regression with the condition (experimental vs. control) as the independent variable. The total effect (c) of condition on change in PSA without taking into account the mediator was not statistically significant (B = 0.09, p = .51), already indicating there is no mediation. The effect of condition on change in self-efficacy (a) was also not statistically significant (B = 0.19, p = .212). Looking at the effect of self-efficacy change on PSA change (b), self-efficacy change was a significant predictor (B = -0.50, p <.001). A higher self-efficacy score, correlated with a lower PSA score. However, the direct effect (c') of mindfulness on PSA change, also controlling for self-efficacy change, was again not statistically significant (B = 0.18, p = .12), meaning there was no mediating effect in this model. To further confirm the absence of mediation, a Sobel test (z = -1.21, p = 0.22) was conducted and confirmed there was no significant indirect effect of condition on PSA through self-efficacy.

Also, using partial correlations, it becomes clear that there is a small positive relationship (r_p = 0.23) between mindfulness condition and PSA when controlling for self-efficacy scores. This correlation is bigger than compared to when there is no controlling for self-efficacy (r_p = 0.10). This suggests that self-efficacy is an important factor, partially explaining the relationship between mindfulness and PSA, since without its influence, the impact of mindfulness on PSA appears slightly stronger. When controlling for condition, the correlation between self-efficacy and PSA is not much bigger (r_p = -0.56) than when not controlling (r_p = -0.52).

Role of Self-Efficacy Change as a Covariate

Next to mediation analysis, an Analysis of Covariance (ANCOVA) was also conducted to see if the self-efficacy change works as a covariate in the relationship between mindfulness and PSA change. There was no main effect of condition (experimental or control) on PSA change ($F(1) = 2.49$, $p = .12$, $\eta 2 = 0.05$). Covariate SE-change was significantly ($F(1) = 3.12$, $p < .001$, $\eta 2 = 0.30$) affecting PSA change, with a large effect size.

Physiological Measurements

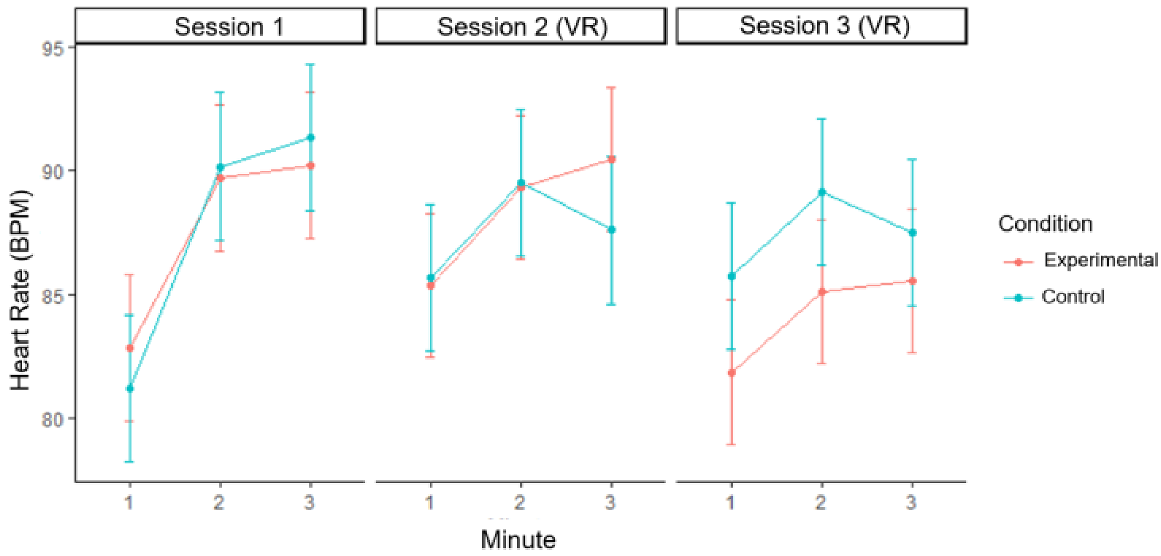
When analyzing the physiological measurements, the dependent variables were heart rate, which was recorded as BPM, and skin conductance, which was recorded as EDA. The independent variables were Condition (Experimental vs. Control), Session (first, second or third presentation, in which the second and third were VR presentations) and Minute (first, second or third minute).

Heart Rate Across Presentations

The effects of Condition, Session and Minute were assessed by conducting an ANOVA on a linear mixed-effects model. The assumptions of normality of the residuals, homogeneity of variance, linearity and normal distribution of random effects were checked and met, so the analysis could be carried out. The linear mixed-effects model was fitted to the BPM of the participants, with fixed effects for Condition, Session and Minute, and their interactions. Random intercepts for subjects were included to account for individual differences in baseline BPM levels. The BPM values were also plotted per Condition, Session and Minute, these can be seen in Figure 8.

Figure 8

BPM-Means per Minute During the Three Presentation Sessions.



The ANOVA of the LMER (Table 6) revealed a significant main effect of Minute (which minute of the presentation) on BPM ($\chi^2 = 21.61$, df = 2, $p < 0.001$). This indicates that heart rate varied significantly across the different minutes of the presentation sessions. This can also be seen in Figure 8. The other main effects (condition and session) and interaction effects (condition x session x minute) were not significant.

Table 6

Results of the ANOVA on the LMER on BPM

Effect	**Chi square**	**Df**	**Pr(>Chisq)**
Condition	0.08	1	.775
Session	3.63	2	.163
Minute	21.61	2	<.001*
Condition * session	3.06	2	.217
Condition * minute	0.36	2	.845
Session * minute	4.99	4	.288

Condition * session * minute	1.07	4	.899

* significant result

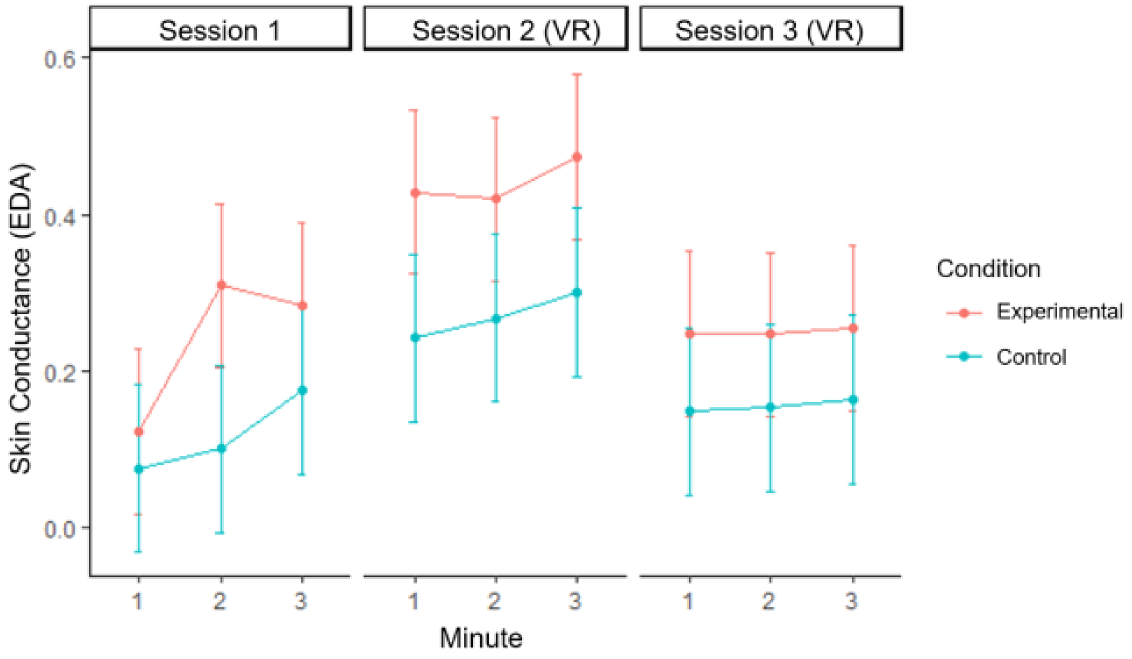
Pairwise comparisons on the BPM values per sessions were conducted as part of a post-hoc analysis using Tukey's HSD to control for multiple comparisons. The pairwise comparisons indicated that BPM levels were significantly higher in Minute 2 than in Minute 1 for every presentation ($p < .001$). In Minute 3 the BPM levels were also significantly higher than in Minute 1 ($p < .001$). Minute 2 and Minute 3 did not differ significantly from each other, suggesting a habituation to the VR environment.

Skin Conductivity Across Presentations

Similarly to the heart rate data, for the skin conductance data, a linear mixed-effects model was fitted to the EDA, with fixed effects for Condition, Session, and Minute, and their interactions. Here too, random intercepts for subjects were included to account for individual differences in baseline levels. The model's EDA values were also plotted per Condition, Session and Minute (see Figure 9).

Figure 9

EDA-Means per Minute for Each Presentation Session.



The assumptions of normality of the residuals, homogeneity of variance, linearity and normal distribution of random effects were checked. There was a minor violation for the assumption of homogeneity of variance and linearity; when plotting the residuals against the fitted values the plot deviated slightly from the requirement to have a random scatter around a horizontal line (see Appendix F). However, the other assumptions were met, so it was decided that the analysis could be further carried out. The ANOVA on the LMER (Table 7) revealed a significant main effect of Session on EDA ($\chi^2 = 23.78$, df = 2, $p < 0.001$), indicating skin conductance differed significantly across the presentation sessions. This can also be seen in Figure 9. The other main effects (Condition and Minute) and interaction effects were non-significant, meaning that the changes in EDA were consistent across both conditions and across the minutes measured.

Table 7

Results of the ANOVA on the LMER on EDA

Effect	Chi square	Df	Pr(>Chisq)
Condition	1.18	1	0.278
Session	23.78	2	0<.001*
Minute	2.68	2	0.262
Condition * session	0.96	2	0.620
Condition * minute	0.28	2	0.870
Session * minute	2.15	4	0.707
Condition * session * minute	1.12	4	0.876

* significant result

Pairwise comparisons on the EDA values per sessions were conducted as part of a post-hoc analysis using Tukey's HSD to control for multiple comparisons. The pairwise comparisons indicated that EDA was significantly higher in Session 2 than in Session 1 ($p < .001$). The EDA scores were also significantly higher in session 2 than in Session 3 ($p < .001$). Session 1 and Session 3 did not differ significantly from each other.

Discussion

Interpretation of Findings

The current study aimed to investigate the effects of a mindfulness training session on public speaking anxiety (PSA) and self-efficacy (SE) during three short presentations, two of which took place in virtual reality (VR). The study utilized self-report assessments and physiological measurements.

Public Speaking Anxiety and Presentation Exposure

The questionnaire results indicated a significant non-linear change with a high effect size in PSA across the three presentations. Relative to the first presentation, participants reported heightened anxiety during the second presentation, which was the first VR presentation. However, their anxiety decreased during the third presentation, reaching a significantly lower level than during the initial baseline presentation. This partly corresponds with conclusions made by literature reviews by Lim et al. (2023) and Vanni et al. (2013) that VR practice sessions significantly reduced PSA levels. However, the initial higher PSA scores in the first VR presentation could also be due to it being the first time doing this in VR, and the following decrease in the second presentation could be due to a habituation effect (Lim et al., 2023). If, however, there was no case of habituation effect, these results underline VR as an effective tool for addressing the challenge of growing student numbers and limited time and resources for practical training in higher education curricula. Interestingly, this pattern of decreasing PSA was consistent across both the experimental and control groups, suggesting that the mindfulness training did not directly impact the participants' anxiety levels. This result does not align with statements from research by Kirsch and Henry (1979) and Kumar et al. (2017), which respectively showed a reduction in PSA after following meditation treatments and an association between mindfulness and PSA scores. The study by Kumar et al. (2017) only indicated an association between the two variables, as they did not employ an experimental design with a mindfulness intervention and control group like the current study. Instead, they measured the mindfulness levels of participants in general using an adapted MAAS, which limits the ability to draw causal conclusions. In contrast, the current study's experimental approach allows to assess the impact of mindfulness training on PSA. The fact that no significant effect was found suggests that the length and intensity of the mindfulness training used in this experiment was not sufficient. This could be illustrated by the study of McKinney and Gatchel (1982), who used a longer, more frequent intervention—a 30-minute relaxation exercise practiced at home across six sessions—and found an anxiety reduction. Their study shows the importance of providing adequate time and engagement with mindfulness techniques in order to notice reductions in anxiety. In comparison, the mindfulness intervention in this study was shorter and less frequent, which may explain the limited effects in reducing PSA. In the context of this current research procedure, it is possible that the decreased PSA scores could be attributed to the participants practicing their presentations, becoming more accustomed to presenting after three rounds (habituation (Rothbaum et al., 2006)), adapting to the VR environment after the initial exposure, which could have slowed the decreasing effect, or benefiting from a calming activity during the break (e.g., listening to an audio such as mindfulness training or a podcast).

Mindfulness Training Effect

The questionnaires also recorded answers on a mindfulness-state scale to check the effects of the mindfulness training. For mindfulness, there was no effect across the three presentations. The results showed no significant effect on mindfulness across the three presentations. However, when considering only the last two presentations, in between which the participants followed the mindfulness training, there was a notable impact of time. There was also no main effect of condition, indicating that being in the experimental or control group did not influence the increase in participants' mindfulness level. This could likely be due to the fact that listening to a podcast in the control group could also have a calming effect on the participants. Kang and Gretzel (2012), for example, noticed that people listening to a podcast reported high mindfulness. This was however not checked with a control group. The effects of the mindfulness training could also have manifested itself in other aspects that stayed out of view because they were not the focus of this research and thus were not measured. For example, Firouz (2023) measured the effects of a mindfulness training session on the participants' perceived level of nervousness and level of control over their nervousness by conducting semi-structured interviews, which provided more insights and a deeper understanding of the participants' feelings. Conducting interviews would possibly have given more information on whether the participants experienced mindful feelings and, if not, why not.

Self-Efficacy Changes

Lastly, the surveys collected responses on the self-efficacy scale, revealing a significant increase in self-efficacy over time with a large effect size, with the highest self-efficacy reported during the final presentation. This suggests that participants grew more confident in their presentation skills over time within the VR practice setting. This aligns with Frisby et al. (2020), who observed that participants reported greater comfort as part of self-efficacy towards presentations after positive practice sessions, moving them away from anxiousness. Similarly, it supports the finding of Kang et al. (2019) who demonstrated that practicing a presentation or public speaking strengthens self-efficacy beliefs. This aligns with Bandura's (1978) theory, that states that mastery experiences are crucial for developing self-efficacy. Successful practice of skills builds confidence and reinforces the belief that individuals can handle something similar in the future.

Again, there was no notable difference in self-efficacy scores between the conditions, so we could not conclude that the mindfulness training impacted this outcome. This does not align with the evidence found that a state of mindfulness can correlate with higher self-efficacy (Hanley et al., 2015; Sharma & Kumra, 2022). Again, in these studies by Hanley et al. (2015) and Sharma and Kumra (2022), the state of mindfulness was only measured, not intentionally induced. The observed increase in self-efficacy and the decrease, as mentioned above, in PSA during the experiment align with the theoretical findings of Lucchetti et al. (2003), suggesting that higher self-efficacy in participants is associated with reduced PSA.

Physiological Changes

The analysis of the physiological measurements of heart rate and skin conductivity as indicators of anxiety revealed that heart rate remained consistent throughout the three presentation sessions. This does not reflect the changes in self-reported anxiety levels. However, skin conductivity (EDA) showed a significant main effect throughout the presentation sessions, with clear variations. These findings align with the self-reported anxiety measurements, as EDA was elevated during the second presentation and then decreased during the third, even reaching levels lower than those observed during the baseline presentation. The fact that heart rate remained consistent and EDA changed throughout the sessions was unexpected since both are reflections of activation in the sympathetic nervous system when an individual experiences anxiety (Bell et al., 2018). Notably, there were no observable condition effects for both heart rate and EDA, suggesting that the mindfulness intervention also did not influence physiological changes during the presentations, which was expected based on the fact that during a resting state, physiological functions, such as heart rate are regulated by the parasympathetic nervous system (Bell et al., 2018).

For the physiological measurements, differences within the sessions at a minute-by-minute level were also examined. In terms of EDA, there was minimal change in EDA during the presentations. The overall effect of time within the presentation was not significantly different across the minutes, suggesting that any observed differences were not notable in the results.

There was a noticeable trend in heart rate, with an increase in the second minute compared to the first, followed by stabilization or a decrease. This pattern could be explained by attributing the initial increase in heart rate (HR) to the body's response to stress or physical activity since the participants presented while standing up. The body reacts to standing up by an abrupt HR increase (Borst et al., 1982). Or it could be due to the body's reaction to having an increased oxygen demand while presenting (Al'Absi et al., 1997). Then, the heart rate could peak in the second minute and then plateau or decrease in the third minute. This could be attributed to the possibility that participants became more accustomed to the public speaking situation in the third minute of the presentation. These patterns were consistent across the control and experimental groups, as no significant difference existed between them.

The Mediating Effect of Self-Efficacy

Another aim of this study was to investigate whether self-efficacy mediated the relationship between mindfulness and PSA. This hypothesis was informed by prior research that examined these individual connections (Kirsch & Henry, 1979; Kumar et al., 2017; Sharma & Kumra, 2022). The findings of this experiment indicated that there was no evidence of mediation. While a correlation existed between self-efficacy scores and PSA scores, mindfulness training did not affect PSA, indicating that self-efficacy could not have an influence in this context. This does not align with the expectations that were set because of research from Kumar et al. (2017) and Sharma and Kumra (2022). They, however, did not use an experimental design to measure state anxiety and to induce a state of mindfulness, and Sharma and Kumra (2022) researched anxiety in general instead of PSA. An explanation for the lack of mediation could be that the mindfulness training may not have been intensive enough to impact PSA through self-efficacy. The decrease in PSA overtime could be due to the repeated practice of the presentations and the resulting increase in self-efficacy, rather than the mindfulness intervention.

Overall, the results of this research indicate that exposure to public speaking situations through VR may effectively reduce PSA and improve self-efficacy over time once individuals become accustomed to the environment. This insight leads to the practical implication of shaping evidence-based public speaking training aimed at reducing PSA in a way where multiple VR practice sessions are incorporated, which could address the growing problem of limited time and resources to implement public speaking practice in higher education curricula. Additionally, communicating that a moment of rest before giving a presentation could possibly reduce PSA levels is also valuable. This study demonstrated that it does not matter whether this moment is a mindfulness intervention or simply taking a moment to rest.

Type of Mindfulness Intervention

Considering the mindfulness intervention, a single session of mindfulness training before a presentation may not be enough to notably improve PSA or self-efficacy in the context of public speaking compared to not following mindfulness training. Some studies (Baer, 2003; Kirsch & Henry, 1979; Sharma & Kumra, 2022) suggest that mindfulness can influence PSA. For example, Kirsch and Henry (1979) used repeated self-administered mindfulness and desensitization methods between presentation sessions and found an improvement in subjective and behavioral signs of PSA. McKinney and Gatchel (1982) used a longer, 30-minute relaxation exercise to practice and found a decrease in self-report of anxiety. So, it might be beneficial to incorporate multiple, longer, and self-administered mindfulness sessions and teach individuals how to apply mindfulness techniques to public speaking situations. Additionally, integrating other mindfulness techniques into the intervention next to the body scan, such as breathing techniques and mental labelling (Tanay & Bernstein, 2013), could further enhance the effectiveness of mindfulness interventions. The correlation between self-efficacy and PSA emphasizes the importance of targeting self-efficacy beliefs in interventions aimed at reducing PSA.

Transfer to a Real-Life Context

This research primarily focused on these variables within a VR context. This offered a high environmental control, as participants faced an identical virtual environment with minimized external influences. However, non-VR studies have less control, and real-world settings are often not controlled at all and have less predictable outcomes. VR does not perfectly replicate this unpredictability. However, since research has pointed out that VR can elicit similar physiological and subjective distress in virtual public speaking settings as in real life (Lim et al., 2023; Owens & Beidel, 2015), it could be expected that the results regarding mindfulness, self-efficacy and PSA would also transfer to a real-life situation. Further research is needed to draw definitive conclusions regarding real-life situations where external factors play a role. Nonetheless, these findings offer insights into guidelines for optimizing practice sessions in VR.

Reliability and Validity

Regarding the self-report measures, a reliability analysis and confirmatory factor analysis were conducted on the questionnaires to assess reliability and validity. Items PSA6 and PSA17 were deleted because of a low Cronbach's alpha. For item PSA17, several participants indicated confusion about what was asked of them. This was because it was negatively worded. For item PSA6, the content focusing on effective focus rather than more clear anxiety symptoms may have misaligned with the other questions. In the subsequent factor analysis items M2_B, M4_B, PSA4_B, PSA8_B, and PSA12_B had a low factor loading on their respective factors and loaded on other factors. This could indicate that the items cover a slightly different sub-dimension of mindfulness and PSA compared to the other items. For instance, M2_B and M4_B seem to be about a more passive and automatic disengagement, while the other items suggest being more actively distracted. For the PSA items, PSA4_B, PSA8_B, and PSA12_B may not align well with the primary factor of PSA because they focus more on specific behavior (fidgeting, mistakes) or general positive outcomes (satisfaction) related to public speaking rather than encompassing the general experience of PSA. Furthermore, some of these items (M2_B, PSA12_B) suffered from possibly confusing phrasing or unclear meaning. This could explain these items' loadings onto a second, third or fourth factor. It was decided to make no further adjustments to the questionnaires since the model fit of the mindfulness and self-efficacy scales was good. Even though the fit was less for the PSA scale, most items had high factor loadings on the PSA construct. Furthermore, the questionnaire measurements would be complemented with the physiological measurements.

Practical implications

The findings from this research offer valuable practical implications for developing effective strategies to reduce public speaking anxiety (PSA) among individuals who struggle with this. One practical guideline is to design public speaking training that uses multiple VR practice sessions, like earlier research also suggested (Lim et al., 2023; Vanni et al., 2013). This can be in a setting of choice (classroom, office, theatre). This approach can enable repeated practice in a real-world resembling, controlled environment, which is usually not possible in higher education curricula due to limitations of time. Additionally, this research shows the potential benefit of adding a calming (listening) activity before presenting. This does not have to be a mindfulness training, since this research showed no differences in the results for the mindfulness and control conditions. This calming activity may contribute to lowering anxiety levels. By implementing these strategies and offering these types of training, more supportive environments are created, benefitting those who experience PSA.

Limitations

Several limitations should be considered when interpreting the results of this study. First, the mindfulness intervention consisted of a single 13-minute session, which may not have allowed participants enough time to develop mindfulness skills fully, especially if they were not already accustomed to mindfulness audios or guided meditation. In previous studies, participants often followed multiple mindfulness sessions a week as an intervention, with a longer duration of 30+ minutes (Chang et al., 2004; Kirsch & Henry, 1979; McKinney & Gatchel, 1982). Additionally, individual preferences regarding the mindfulness intervention, such as the extent to which the participant has confidence in the effects of relaxation training, the type of mindfulness exercises, or voice characteristics in the guided mindfulness intervention, could have influenced the outcomes (Menhart & Cummings, 2022; Tang & Braver, 2020).

Furthermore, participants delivered the same presentation three times, this was one they had prepared themselves and may have presented before. Presenting a familiar presentation could result in less anxiety and a higher self-efficacy. Familiarity that emerges with the VR environment, the content being presented during the experiment, as well as predictability of the experience might have influenced PSA, since participants get habituation anxiety (Lim et al., 2023; Rothbaum et al., 2006). Additionally, during the experiment, varying opinions on the VR environment's resemblance to real-life public speaking situations could have influenced participants' experiences. Some individuals mentioned they found the environment intimidating, not necessarily due to their discomfort with public speaking but rather because of the virtual audience's presence and “intense stares”. This, however, reflects experiences of presenting in real life environments and conditions, ensuring this study's ecological validity.

Regarding the measurement methods, using the wristband to measure EDA and BPM presented challenges, as the device's sensitivity to movement made it impossible to measure heart rate variability, the preferred parameter. Also, detailed EDA measurements require undisturbed data obtained through permanent skin contact, which was hard using a wristband on a moving wrist during presentations. In addition, when a CFA was conducted on the questionnaires, there could be improvement in the mindfulness and PSA scale. However, no adjustments were made for this thesis. Future research could focus on refining the model and questionnaires to improve fit and enhance theoretical interpretations. Conducting pilot tests and expanding participant data could offer valuable insights, strengthening theoretical interpretations and addressing the limitations.

Suggestions for Future Research

Future research should explore the impact of extended mindfulness training programs on the specific contect of public speaking anxiety and self-efficacy. These studies could use longer mindfulness training sessions of 30-45 minutes or a training program consisting of three to five mindfulness training sessions, possibly of extended duration, and, like Kirsch and Henry (1979) did, possibly self-administered. The sessions could also be integrated with other cognitive techniques or be directed toward the goal of feeling mindful before engaging in public speaking activities. It would also be beneficial to assess how individual differences, such as pre-existing mindfulness levels and prior public speaking experience, may influence the effectiveness of these programs. This could be measured at the start of the experiment.

Additionally, investigating the effect of public speaking in VR on PSA using unfamiliar presentation content for participants could provide valuable insights. This is because the observed decrease in PSA may also be due to being or getting accustomed to giving the same presentations during the experimental session rather than due to the intervention. Furthermore, researchers should examine the transfer of findings from the VR experiments to real-world scenarios. It is expected that these findings transfer to the real world, since having an authentic performance experience in VR makes it an accurate rehearsal tool as replacement from the real world (Frisby et al., 2020) and this used VR environment in the Ovation software has a realistic and authentic design. However, this could still be researched in the context of this specific research with mindfulness as one of the variables.

Finally, refinement of measurement tools could enhance the quality of future research. This could involve conducting pilot tests on questionnaires or employing more sensitive physiological measurement devices, such as electrodes connected to the fingers, since there is a high density of sweat glands in this area (Horvers et al., 2021). Additionally, qualitative measures like interviews or observations could provide deeper insights into participants' experiences.

In conclusion, this study contributes to the growing body of research on PSA by exploring the effects of mindfulness training within a virtual reality context. While the mindfulness intervention did not significantly impact PSA or self-efficacy, the findings highlight the potential benefits of repeated exposure to public speaking scenarios, particularly in VR environments, for reducing anxiety and enhancing confidence. This is especially relevant in higher education and workplace settings, where public speaking is a core skill necessary for personal development, educational success, career advancement, and effective job performance (Macey et al., 2023; Wang et al., 2020). The insights from this research help develop more effective intervention strategies and offer practical guidelines for those seeking to lower their public speaking anxiety, supporting their growth in both professional and personal domain.

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Appendices

Appendix A: Script Relaxation Audio

Made by Russel Chan

Intro:

00:00: Hi, welcome to this audio-guided cognitive training technique. You will now be provided with the instructions that guide you through the practice. Your goal is to follow the instructions for the entire duration.

00:15: In order to perform at your best and succeed in the things you do, it is necessary to fine-tune your attention. This is the aim of the technique.

00:23: Provide yourself the opportunity to participate fully. Establish the appropriate mindset you need to do your best.

00:32: Let's get started. You should be comfortably seated in an area without distractions. Interruptions typically also affect your focus. Interruptions like many extra movements in your body may disrupt you.

00:46: So as you are seated in your chair, let's get you as comfortable as possible. Feel free to shake out tensions you may have in your shoulders, neck, hands and fingertips. Your lower body, legs and feet. Have a quick stretch if needed. Once you are seated so comfortably, you should aim to remain still, so as you complete this practice without much movement at all. Lastly place your hands on your thighs either with the palms facing upwards towards the ceiling or palms down. This is up to you.

START

01:24: Start by closing your eyes - the first thing is to take awareness of your breathing and pause on it for a few moments.

01:34: Being aware of the breath, remain an observer of it. If it's fast let it be fast, if it's slow let it be slow. Make no attempt to change the speed of your breathing.

02:00: See if you can feel the coolness of the breath and warmth as you inhale and exhale.

02:14: Try to hear the sound of your heart beating, the pulse and silence between the ears.

Body rotation:

02:30: In the next stage, I will be naming different body parts and you will be doing two things with your mind.

02:37: Firstly, as you hear the name of the body parts, you will bring your awareness to each of these body parts without movement and repeat the name of these body parts within your mind.

02:49: Once again, bring your awareness to the different body parts and mentally repeat the name of these body parts within your mind. Starting with the right hand thumb, the right index finger, middle finger, ring finger, little finger. Back of the right hand, the palm, creases in the palm.

03:16: The right wrists, forearm, elbow, upper arm, shoulder, armpit, right side of the chest, waist, hip, thigh, shin, calf, ankle, heel, instep, ball of the right foot, the right big toe, 2nd, 3rd, 4th, 5th.

03:55: Moving onto the left side of the body, the left-hand thumb, the left index finger, left middle finger, ring finger, little finger. Back of the left hand, the palm, creases in the palm.

04:21: The left wrist, forearm, elbow, upper arm, shoulder, left armpit, left side of the chest, waist, hip, thigh, shin, calf, ankle, heel, instep, ball of the left foot, the left big toe, 2nd, 3rd, 4th, 5th.

05:04: In the next stage, let go of the mental repetition and only bring your awareness to each of the body parts as it is named.

05:14: Firstly, feel your heels meeting the ground, and the ground meeting your heels, the calves against the clothing, the back of the knees, the back of the thighs, the buttocks on the chair, lower back, middle back, upper back. Take your awareness down and up the spine 3 times quickly. Take awareness at the back of your shoulders, between the scapulars.

06:03: The back of your upper arm, the elbows, back of your forearms, back of the hands, the wrists, back to the elbows, back to the upper arms, back of your shoulders, the base of your neck, the upper part of your neck, the back of your head, the hairline through to your forehead.

06:47: The left temple, the right temple, the left eyebrow, right eyebrow, space between the eyebrows, space between the eyebrows, space between the eyebrows. The left eye, the right eye, where the eyelids meet. Bridge of the nose, tip of the nose, left nostril, right nostril, both nostrils together.

07:40: The left cheek, the right cheek, the upper lip, lower lip, where the lips meet. Chin, front of the throat, top of the chest, centre of the abdomen, front of your pelvis, the tops of your thighs, the tops of your kneecaps, the shins, top of the foot, the top of the toes.

08:32: Take awareness of your whole right foot, the whole right foot, the whole left foot, both feet together, the awareness of the whole right leg, the whole left leg, both legs together. Awareness of your left arm, awareness of your right arm, both arms together. Awareness of the left torso, the right side of the torso, the whole torso together. Be aware of the left side of your face, the right side of your face, the whole face.

09:49: Be aware of the front of your body, be aware of the back of your body. The lower part of your body, the upper part of your body. Then take awareness of your whole body, not this side, not that side, not left, not right, not upper, not lower. Take awareness of your whole-body, your whole body, your whole body, your whole body, your whole body.

Breath awareness:

10:44: As you sit, let us return back to your breath, watch the rise and fall of your chest.

10:59: Trace the air as you inhale and exhale out of your body. 11:07: Watch your breath and stay focused on it with curiosity. 11:47: When your mind wanders of, no problem, come back to your breath again.

Exit:

12:15: Once again, become aware of your body. The points of contact between your body and the chair, your feet on the floor

12:28: Take awareness of the position of your body within the room, of the room within the building, take your awareness and externalise even further now.

12:45: Introduce small movements into your body, wriggle your fingers and toes, followed by larger ones, your hands and feet. Bring some movement in your neck. The practice is now complete, have a stretch, do what’s right for you.

13:05: You may already open your eyes. Thank you for your practice, I hope you enjoyed that. You may now open your eyes again if you haven’t, and carry on with the next part of your day.

Appendix B: Baseline Questionnaire Questions

The questionnaire for the experiment, with the subscales mindfulness, self-efficacy and public speaking anxiety.

Q0. What is the user-ID you've been given for this experiment? If you don't remember, ask the researcher.

Demographic questions

Q1. What is your gender?

a. Female
b. Male
c. Other
d. Prefer not to say

Q2. What is your age?

Q3. What do you do?

a. I'm a full-time student.
b. I'm a part-time student.
c. I'm an employee at the university.
d. Other

Q4. How often have you given presentations before? On a scale from 1 to 10, with 1 being never and 10 being very often.

Q5. Have you ever used VR before?

e. Yes, once or a few times
f. Yes, a lot
g. No

Appendix C: Mindfulness Scale

Mindfulness

Answer the following statement about the state of relaxation you felt during your presentation.

1	2	3	4	5
not at all	slightly	moderately	very	extremely

M1. I was finding it difficult to stay focused during giving the presentation.

M2. I was presenting without paying attention (to what you're saying or doing).

M3. I was preoccupied with the future or the past during the presentation.

M4. I was doing the presentation automatically, without being aware of what I was doing.

M5. I was rushing through the presentation without being really attentive to it.

Appendix D: Self-Efficacy Scale

Answer the following questions about how you feel regarding public speaking after this presentation.

1	2	3	4	5
not at all	slightly	moderately	very	extremely

SE1. How confident are you that you have the basic skills to perform well when you give public speeches?

SE2. How much do your thoughts and worries bother you during situations in which you have to present? *

SE3. How much does your nervousness bother you during presentations? *

SE4. Is it possible for you to perform well in a public speaking setting in spite of any weaknesses you may have in this skill?

* Reverse-coded

Appendix E: Public Speaking Anxiety Scale

How much do you agree with the following statements about how you felt during public speaking in the previous presentation?

1	2	3	4	5
not at all	slightly	moderately	very	extremely

PSA1. I found giving a speech terrifying.

PSA2. I was afraid that I would be at a loss for words while speaking.

PSA3. I was nervous that I would embarrass myself in front of the audience.

PSA4. If I made a mistake in my speech, I would have been unable to re-focus.

PSA5. I was worried that my audience would think I am a bad speaker.

PSA6. I was focused on what I was saying during my speech.*

PSA7. I was confident when I gave the speech.*

PSA8. I felt satisfied after giving the speech.*

PSA9. My hands shook while I gave the speech.

PSA10. I felt sick before speaking in front of the audience.

In questionnaire 2 and 3: I felt sick before speaking in front of the virtual audience.

PSA11. I felt tense before giving the speech.

PSA12. I fidgeted before speaking (making small movements (mostly with hand and feet)) due to nervousness.

PSA13. My heart pounded when I gave the speech.

PSA14. I sweated during my speech.

PSA15. My voice trembled while I gave the speech.

PSA16. I felt relaxed while giving the speech.*

PSA17. I did not have problems making eye contact with my audience.*

* Reverse-coded

Appendix F: Assumption of homoscedasticity and linearity

Figure F

Plotted Residuals vs Fitted Values