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Public Speaking Anxiety among Norwegian Adolescents – Comparing self-led Virtual Reality Exposure Therapy to waitlist control

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Preface

I would like to thank everyone who has made this paper possible, and who has been with me on this incredible journey. I would like to thank Tine Nordgreen for an excellent supervision. I also want to give a warm thank you to Smiti Kahlon, who has kindly allowed me to analyze the data from her study and who has given me guidance and support in all parts of this process. A big thank you to my parents, who have supported and cheered me on from the beginning. Last, but not least, I want to thank Lisa Padilla from NewPathVR in San Fransisco, who was the first one that introduced me to the possibilities of Virtual Reality in the field of mental health.

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Abstract

Aim: Public speaking anxiety (PSA) refers to the anxiety an individual experiences while anticipating, preparing for or speaking in front of other individuals. Today, several recommended standard treatments are available, and with technological development new digital treatment approaches have been explored. An example is Virtual Reality Exposure Therapy (VRET), which has shown promising results in the treatment of PSA. Nevertheless, research on the use of VRET is still small, and almost exclusively limited to data from adult samples. The current study aimed to examine the efficacy of self-led VRET on adolescents experiencing PSA. *Method:* The analyzed data came from a larger four-armed, and two-phased, randomized controlled trial with 100 adolescents. This sub-study analyzed preliminary data on 30 adolescents during the first phase of the trial. Primary and secondary measures measured PSA-symptoms and social anxiety symptoms over time. Linear mixed models and repeated measures analysis of variance was applied to analyze whether there was a significant symptom reduction over time between the group receiving virtual reality therapy compared with the waitlist control-group. *Results:* The results showed significant within-group and between-group interaction effects over time for three out of five measures. *Conclusions*: Preliminary results suggest that VRET is promising and can be a valuable and effective tool in reducing PSA-symptoms in adolescents. Nevertheless, further research is needed to further examine the effects of VRET on those under 18-years of age.

Keywords: social phobia, public speaking anxiety, Virtual Reality Exposure Therapy, intervention

Sammendrag

Mål: Prestasjonsangst (PSA) refererer til angsten et individ opplever ved forutser, forbereder seg på eller snakker foran andre individer. I dag er det flere tilgjengelige standardbehandlinger, og med den teknologiske utviklingen har nye digitale behandlingsmetoder blitt utforsket. Et eksempel er Virtual Reality Exposure Therapy (VRET), som har vist lovende resultater i behandlingen av PSA. Likevel er forskning på bruk av VRET fortsatt liten, og nesten utelukkende begrenset til data fra den voksne populasjonen. Denne studien hadde som mål å analysere effektiviteten av selvledet VRET på ungdom. *Metode:* Den analyserte dataen kommer fra en større to-faset randomisert kontrollstudie med 100 ungdommer. Denne sub-studien analyserte foreløpige data på 30 ungdommer i løpet av den første fasen av studien. Ved bruk av primær- og sekundærmålinger ble graden av PSA-symptomer analysert over tid. En lineær mikset modell og en variansanalyse ble anvendt for å se om det var en signifikant symptomreduksjon over tid mellom gruppen som mottok VRET sammenlignet med kontrollgruppen. *Resultater:* Resultatene viste signifikante interaksjonseffekter innenfor gruppe og mellom gruppe over tid for tre av fem målinger. *Konklusjon:* Resultatene fra denne sub-studien tyder på at VRET er et lovende og effektivt behandlingsverktøy for å redusere PSA-symptomer hos ungdom. Likevel er det nødvendig med ytterligere forskning for å undersøke effekten av VRET på barn og ungdom under 18 år.

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Introduction

In the past three years, there has been a significant increase in the prevalence of mental health disorders. According to World Health Organization, almost 970 million people were living with a mental health disorder worldwide in 2019 (Institute of Health Metrics and Evaluation, 2022). Alarmingly, this number rose dramatically in 2020 following the COVIC-19 pandemic, with research giving evidence for a 26% - 28% increase in both anxiety and depression (World Health Organization, 2022). Today, children and adolescents between 5-17 years-of-age constitute of almost one third of the world's population, and in 2022 this includes almost 1.2 billion of the world's population (Kerling, 2011; Erkskine et al, 2017; United Nations Children's Fund, 2022). In total, mental health problems affect 10 – 20% of children and adolescents worldwide, and account for a large portion of the global burden of disease (Kieling et al., 2011).

Anxiety disorders are the most prevalent of mental health disorders and are associated with a high burden of illness in both children and adults (Bandelow, 2021). Surveys have found that an estimated 33.7 % of the population have had an anxiety disorder at least once during their lifetime. Among all mental health disorders, anxiety disorders like panic disorder, generalized anxiety disorder (GAD), social anxiety disorder (SAD), specific phobias, and separation anxiety disorder, are the most common (Jacobi et al, 2014; Bandelow & Michaelis, 2015). Furthermore, evidence suggests that anxiety disorders are more comorbid than other mental disorders - both with each other and with other psycho-physiological disorders (Toft et al. 2005).

Social anxiety disorder (SAD)

Studies have shown that social anxiety disorder (SAD) is one of the most common of anxiety disorders, and the third most common mental health disorder after depression and substance abuse (Kessler et al. 2005). Recent estimates suggest that SAD has an estimated lifetime prevalence of 12.1 % in the US population (Kampmann et al, 2016). It has been associated with profound negative consequences and impairment in many areas in life on a personal, social, and societal level (Alonso et al, 2004; Leigh & Clark, 2018). According to the American Psychiatric Association (2013), the onset of SAD can be due to a gradual development through a series of individual and/or environmental factors or triggered by a specific event or situation. It is found to have an age of onset between 10-13 years and is shown to have symptoms that are both debilitating and persistent once they occur (Jefferson et al, 2001).

The *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013) and *International Classification of Diseases* (ICD-10; World Health Organization, 2019) have slightly different approaches to categorizing SAD. ICD-10 (World Health Organization, 2019) classifies social anxiety disorders under *F.40.1 Social Phobias,* with a summarized description of the various psychological, behavioral, and physiological criteria for SAD. Examples include fear of scrutiny and criticism, low self-esteem, blushing, nausea, and avoidance of the feared social situations. ICD-10 also includes a category for social anxiety in childhood; *F.93.2 Social Anxiety Disorder of Childhood.* This category is specified to be only used if symptoms are present in childhood, are severe in nature and cause problems in social functioning (World Health Organization, 2019).

On the other hand, DSM-5 classifies SAD as consisting of different subtypes or forms in which a person experiences social anxiety and defined as a "*marked fear or anxiety about one or more social situations in which the individual is exposed to possible scrutiny by others*" (American Psychiatric Association, 2013, p. 202). DSM-5 further specifies that the symptoms of SAD can not be attributed to other factors, like medical disorders, substance use or other mental health disorders (American Psychiatric Association, 2013). The fear or anxiety must cause significant distress, be out of proportion to the actual threat and lead to either avoidance or endurance of the feared social situations. DSM-5 also includes fear of negative self-evaluation as a part of the diagnosis; the fear of being negatively evaluated and rejected if shown any symptoms of anxiety or distress. A new addition to DSM-5 is the *"performance specifier"* for SAD, which is added if the anxiety or fear is restricted to speaking or performing in public (American Psychiatric Association, 2013, p. 202).

Public Speaking Anxiety (PSA)

Epidemiologic studies have shown that public speaking anxiety (PSA) is the most reported fear in the general population (Sawyer, 2016), with one third of the general population reporting severe levels of anxiety when speaking to a larger audience - and another one third of this group reporting significant discomfort and distress due to diagnosed PSA (Stein et al, 1996).

PSA is categorized in DSM-5 (American Psychiatric Association, 2013) and ICD-10 (World Health Organization, 2019) as a form of social anxiety and refers to the anxiety that an individual experiences while preparing to speak in front of others or giving a speech (Gallego et al, 2022). According to Blöte et al (2009), empirical studies conducted on the relationship between SAD and PSA give evidence for PSA being a subtype of SAD that is "*quantitatively*

and qualitatively" different from other subtypes of social anxiety (p. 305). Among the different subtypes of social anxiety, fear of public speaking has been found to be the highest prevalent fear (Blöte et al, 2009). This is supported by studies conducted on speech anxiety, which found that 97% of individuals with social anxiety disorders also experiencing impairing symptoms of PSA (Beidel & Turner, 2017; In addition to being the main fear in PSA (specific performance subtype), fear of public speaking seems to be a common fear in generalized and non-generalized SAD. This is important to take into consideration to correctly diagnose, assess and consider which treatment options might be most effective to implement in a clinical setting (Blöte et al, 2009).

PSA in childhood and adolescence

Speaking in public is an important social component in an individual's life – as the individual progresses through his or her life, relationships, education and career. Longitudinal studies on the onset of PSA suggest that it is found to have low onset in early childhood (Wittchen et al. 1999). Research on risk factors in childhood has however identified individual and environmental factors like shyness, inhibited temperament, increased reactivity in the automatic nervous system and amygdala, and differences in serotonin and dopamine levels compared to control groups. However, the factors that can contribute to the development of social anxiety disorders are complex and can include a variety of contributing and interacting elements (Schneier, 2006).

Empirical studies have found that the occurrence of PSA has been shown to increase with age through the adolescent years, with a median age of onset of 13 years-of-age (Kessler et al. 2005). Throughout the years, studies have shown that mental health disorders are in fact the

leading cause of disability for individuals under 25 years-of-age (Erskine et al, 2017). Similar findings have also been the case for occurrence of PSA, with 90 % of the PSA cases found to occur by the age of 23 (Kessler et al, 2005).

Research by Reeves et al (2022) highlights how PSA and SAD can have drastic consequences and create challenges for an individual in all areas of life. The implications of PSA have been well-documented, with studies showing how it can lead to higher levels of underachievement in academic situations, school drop-out, unemployment rates, social withdrawment and isolation (Amoringen, Mancini & Farvolden, 2003; Jefferson, 2001).

Current treatments for PSA

There are several standard treatment options available for individuals with PSA, including cognitive behavioral therapy (CBT), insight therapy, psychodynamic therapy, EMDR and visualization therapy (Ebrahimi et al, 2019). In the first meta-analysis conducted on treatment of PSA since 1989 (Allen et al, 1989), Ebrahimi et al (2019) analyzed the efficacy of face-to-face psychological interventions across 30 RCTs, concluding that the standard psychological interventions measured were equally effective in reducing PSA – both at post- and follow-up. According to Ebrahimi et al (2019), the most common treatment options for PSA have been based on cognitive and/or behavioral principles, with cognitive behavioral therapy (CBT) being the widest used psychological intervention method. An additional, and interesting, finding was CBT was found to have additional effect as treatment improvement continued to follow, even after discontinuation of treatment (Ebrahimi et al, 2019).

National Institute for Health and Care Excellence (NICE) has since 2013 recommended CBT as a standard intervention for social anxiety disorders in children and adolescents. CBT is an evidence-based and structured approach to psychotherapy that typically lasts between 5-20

sessions and has been applied to a wide array of disorders (Fenn & Byrne, 2013). In a large-scale meta-analysis conducted by Otte (2011), CBT was found to have a medium-to-high efficacy across social anxiety disorders. While seven RCTS reported an efficacy of .62, eleven effectiveness studies (non-RCTs) found CBT to be highly effective with effect size of 1.04 (Otte, 2011).

In-vivo exposure therapy (IVET) is often used as a part of a CBT-intervention and involves systematically exposing the individual through a graded hierarchy of situations which according to the level of fear they provoke in the individual. Studies have demonstrated the efficacy of IVET for treating PSA (Lawm et al., 1994; Newman et al., 1994), with the exposure typically involving completing a hierarchy of public speaking tasks in front of an audience. In this way, the individual is provided the opportunity to directly being confronted with their fears in reality (Abramowitz et al., 2019), and thus challenge their negative beliefs and cognitions about their competence and social skills

Challenges and treatment gap

Research gives strong evidence for the importance of early treatment on the diagnosis of PSA (Jefferson, 2001; Ebrahimi et al, 2019). However, even though there are several standard and effective treatment-approaches available (Jefferson, 2001), a consistent finding is that a significant amount of those suffering from PSA and SAD do not seek treatment (Shafran et al, 2009). Furthermore, a large meta-analysis on the barriers of treatment-seeking behavior was conducted by Valesco et al (2020), finding that around 75% of adolescents with mental health problems were reluctant to seek help and were not in any contact with mental health services. Most standard treatments require a substantial commitment, time and in most cases that the individual seeking treatment is physically present (Jefferson, 2001).

Current standard treatments, especially in-vivo exposure therapy, have several limitations – further fueling a treatment gap in the treatment of anxiety disorders (Shafran et al, 2009). Exposure therapy can be difficult due to its nature, as allowing the individual to face their current anxiety-provoking situations may not be an inaccessible, impractical or intangible option (Bouchard et al., 2017). For example, it can be quite difficult and unrealistic to consistently gather large audiences as a part of public speaking exposure sessions. Exposure therapy, based on the cause of the anxiety, can also become a time-consuming and expensive intervention for therapists and their patients – and one that can be difficult to execute in a controlled manner (Garcia-Palacios et al., 2007).

It has been shown that there is a dire need for a treatment option that tackles limitations of current treatment options for PSA – and can bridge the gap between the need and accessibility of an effective treatment method.

Virtual Reality Exposure Therapy

Over the past few decades, there has been an increasing interest in using virtual environments to help people overcome their anxiety (Wiederhold & Bouchard, 2014; Miller et al, 2012). Virtual Reality (VR) consists of using a VR-medium (which often consists of a VR-head mounted display) that the user can put on to see and interact with a programmed 3D-environment or through 360° videos. This allows the user to experience virtual environments resembling the feared real-life situations, and enable exposure to the feared stimuli (Morina, Kampmann & Brinkman, 2015).

Studies conducted in the past 12 years have given evidence for VRET being an effective intervention-method for PSA and has shown promise in reducing symptoms of PSA in both

adolescents and adults (Bouchard, 2011; Kahlon, Lindner & Nordgreen, 2019; Lee et al, 2021; Reeves et al, 2021). Even though studies on adolescents in VRET treatment is limited, some studies have been conducted with promising results. Kahlon, Lindner & Nordgreen (2019) conducted a study with 28 participants between the ages of 13-16. During the study, a brief psychoeducation was followed by a one-hour VRET (with tasks of varying difficulties) ending with a summary including how to practice exposure in real life. Participants were measured at baseline and post the 1-hour VR session, and the results yielded a significant decrease in measures of PSAS ($d = 1.53$), with the effects maintained at follow-up. Lindner et al (2019) found similar results in their randomized controlled trial exploring the efficacy of VRET on PSA, and saw a significant and stable decrease in symptoms of PSA for the VR-groups – with the self-led VRET group showing a high effect of VRET on the decrease of PSA symptoms (Cohen's $d = 1.37$).

In the past 10 years, VR-technology has additionally become increasingly more affordable and has therefore become an increasingly popular option in the treatment of mental health disorders, and particularly in treatment of PSA and SAD (Freeman et al, 2017). By using therapist-guided or self-guided VR, VRET creates an opportunity where the individual can confront their fears in a virtual world, similarly to what the individual would have experienced in real life (Krijn et al., 2004). Research by Garcia-Palacious et al (2007) has for example found that a higher rate of patients prefer VRET compared with other more traditional psychological interventions like in-vivo exposure therapy.

VRET offers some advantages that touch upon the limitations of the current standard psychological interventions, with evidence suggesting that VRET is a) less time-consuming, b) offers lower treatment costs, c) facilitates easy access and control of the virtual stimuli the

patient is exposed to during VRET-sessions (Hartanto et al., 2014). Furthermore, it offers a greater degree of flexibility than other interventions, in that it both can be performed within a therapist's office or in an at-home setting (Carl et al., 2019).

Aim and hypothesis

Given the debilitating consequences of PSA, this is a disorder that can have a profound effect on young individuals - both now and in their future. The objective of this study was to help fill the existing gap in the research sphere - and examine the effect of a VRET intervention for treatment of PSA in a sample of adolescents.

The main research question was whether self-guided VR treatment for adolescents with PSA could yield better treatment effects on PSA-measures compared to control. The aim of the study can be divided into two main parts:

a. Analyze whether there is a significant reduction in primary and secondary outcome measures for each group over time

b. Compare the change between the groups over time

It is hypothesized that, in comparison with control, those receiving VRET-treatment will improve on standardized measures of public speaking anxiety.

Method

Setting

This study is a part of a project of the Introducing Mental Health Through Adaptive Technology (INTROMAT), which is funded by the Norwegian Research Council. The project's

aim was to integrate psychology and ICT to create better digital solutions to prevent and treat mental health disorders. INTROMAT consists of five main projects; 1) Relapse prevention for patients with bipolar disorder, 2) Cognitive and emotional control training adapted to patients with ADHD, 3) Job-focused treatment of patients with depression, 4) Early intervention and treatment for social anxiety disorder (SAD) in adolescents and 5) Social support for women who have experienced gynecological cancer. The main vision of the INTROMAT-project is to connect evidence-based psychological practice with innovative technology in order to meet the need of mental health treatment and access.

Scoping review

An overview search was conducted to get a thorough and updated overview on the use of VR in treatment of PSA and SAD in adults and adolescents, and the results and implications of previous empirical studies in the field. The first overview search was conducted on 22/01/22, across four databases: a) PsychInfo, b) Web of Science, c) Medline and d) Cochrane Library. The following search words were used: Virtual Reality Exposure Therapy AND (VR OR Virtual Reality) AND Public speaking AND Social Anxiety AND (Intervention OR Study OR Trial). The inclusion criteria was an empirical article published in the last 12 years (2010-2022).

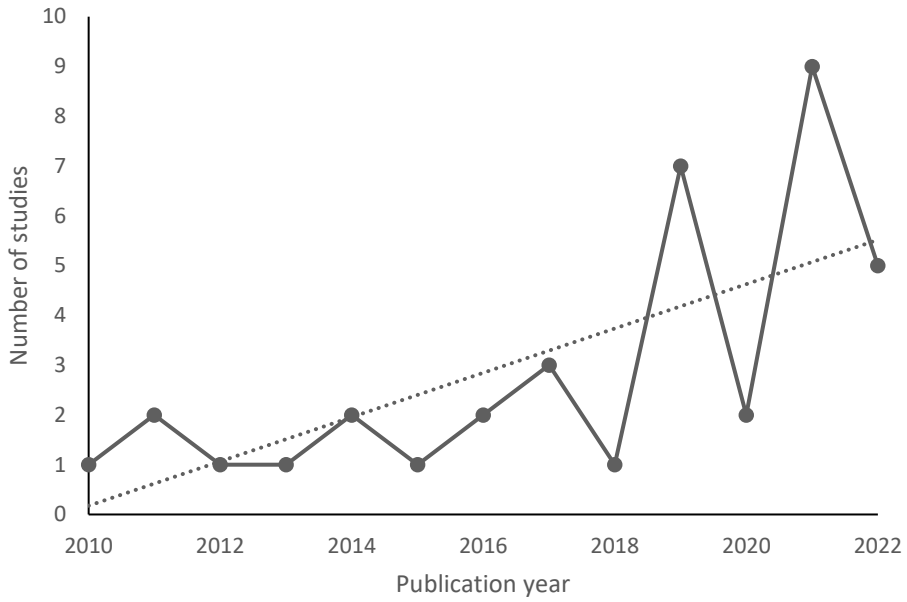
After an overview over the results, a scoping review was conducted across the four databases on 21/02/21 and 15/08/22 respectively to identify trials/studies/interventions published between 2010 and 2022. The scoping review yielded 295 records identified throughout all the databases, consisting of; Web of Science (149 records), PsychInfo (76 records), Medline (36 records) and Cochraine Library (34 records, of which were 33 trials). After removal of duplicate records and the implementation of pre-determined exclusion criteria, 43 full-text articles

remained - which were fully reviewed and articles falling into one or more exclusion categories, excluded from the final list. The review yielded a final result of 37 articles/studies.

The results of the scoping review provided valuable information that was collected and systemized in a table. An interesting finding was that research on the use of VR for the treatment of PSA and SAD has increased drastically in the last 12 years, with 64 % of the studies collected during the literature search published between 2019 and 2022. A graph visualizing the results and the trendline of the scoping review is included below (Figure 1). From the graph, we can see a significant increase in empirical studies evaluating the effect of VR on reduction of SAD and PSA-symptomology. Another important finding is that among the 37 empirical studies, only two focused on adolescents, conducted by Kahlon, Lindner & Nordgreen (2019) and Robin et al (2022), while the rest of the studies only included participants from 18 years and above. These findings show that with the increasing research on VRET on treatment of PSA/SAD, most of the studies to this date have been conducted using adult-samples - leaving a visible gap in the understanding of the processes and effects of VR in treating a younger population below 18 years-of-age.

Figure 1

Scoping Review results: Number of VRET empirical studies on PSA/SAD symptomology



Study design

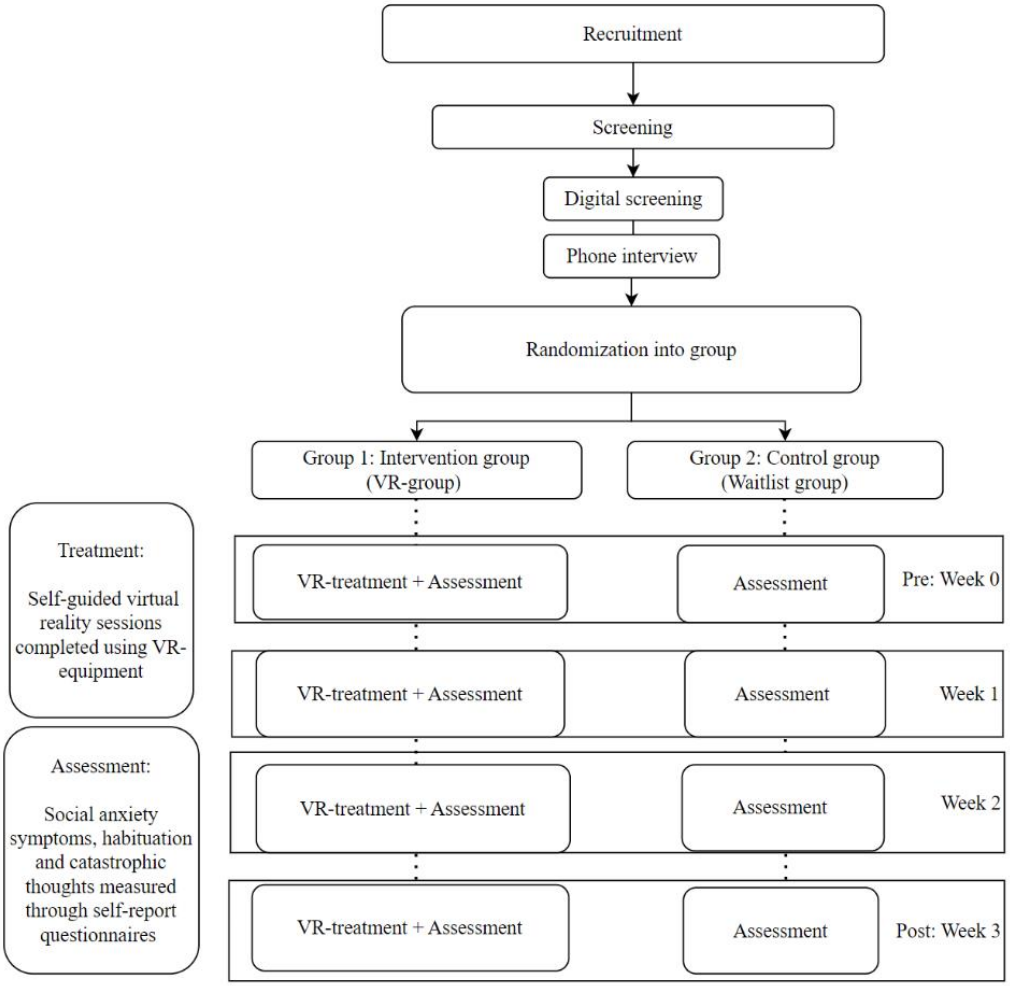
The present study is a subproject of a randomized control trial (between-subjects design) with the aim to recruit a non-clinical sample of N=100 participants that will be randomized to four groups; 1) Gamified VR exposure therapy group *(group 1)*, 2) Gamified VR exposure therapy followed by an online exposure program promoting in-vivo exposure *(group 2)*, 3) Online psychoeducation group followed by the online exposure program *(group 3)* and 4) waitlist group followed by online psychoeducation *(group 4)*. The study is divided into two phases (phase 1 and 2), with each lasting a total of three weeks. This paper will focus on analyzing and comparing the preliminary results of phase 1 of the study, for group 1 (VR-group) and group 4 (WL- group).

Interventions

In phase 1 of the study, the VR- group got access material and completed a series of self-guided VR exposure sessions, while the WL-group consisted of filling out weekly self-reported assessments. After phase 1 of the study was complete, the VR-group received no further treatment, and together with the WL-group was assigned to complete weekly outcome measures for three more weeks. A partial overview of the full study is visualized below (Figure 2), highlighting the main focus of this sub-study.

Figure 2

Overview of the study



Note: Assessment included PSA-symptoms in four measures, Public Speaking Anxiety Scale (PSAS), Habituation, Catastrophic Thoughts, Social Interaction Anxiety Scale (SIAS) and Social Phobia Scale (SPS)

Recruitment procedure

The recruitment started in September of 2020, with a consecutive start for each participant after completion of the recruitment and screening process. The recruitment of participants was done from junior high schools in Bergen municipality, where the study was presented as a training program for adolescents with PSA. Information about the study was distributed through various channels; presentations in classrooms by a study member, social media channels (such as Facebook and Instagram), newspaper advertisements, posters at the schools and public bulletin boards.

Interested participants would from the information presented be directed to the study website, where they could find the full information about the study and a link to a secure platform where they could go through an initial digital screening process. This consisted of filling out screening questions of whether PSA causes distress and/or avoidance of oral presentations at school - and fill out the Public Speaking Anxiety Scale (PSAS). The participants also provided their contact information. The recruitment of the participants happened on a rolling-basis, after assessing the results from the initial screening of all the interested participants.

Inclusion criteria for this study were a) adolescents aged 13-16 years who are b) living in the Bergen area. In addition, they had to c) have a PSAS score > 55 and d) have reported distress or negative consequences of PSA in their daily life. The exclusion criteria for the study were a) ongoing treatment for mental health problems (like psychoactive medication and/or

psychotherapy), b) impaired stereoscopic vision and/or balance problems hindering the full VR experience and c) difficulty in reading and understanding Norwegian text.

After the initial digital screening process, a member from the study team contacted the eligible participant (or the parents) for a 15-30 minute telephone interview. The aim of the interview was to complete the screening process and make a final decision based on the inclusion/exclusion criteria for the study. During the interview, the participant/parent were also asked about how PSA interfered in their daily life and functioning - before a final decision of inclusion was made. The participant was then randomized, during the telephone interview, to one of the four groups and then given information about the group that they are allocated to. The randomization consisted of a block randomization list generated by the site randomization.org with 10 participants in each block. For technical reasons, the randomization took place before the participants were given access to the pre-assessment material.

During the telephone interview, all participants who have passed the inclusion criteria got access to the online platform. The online platform (with the assessment and the intervention program) was secured through a platform that requires a bank-issued identification (Bank ID) to log in and access. Finally, the participants or their parents (if the participant was under 16 years old) needed to provide online informed consent before the intervention procedure.

Ethics statement

This study has been registered and approved by the Regional Ethical Committee South – EAST (REK 606228) and informed consent was obtained from each participant older than 16 years of age, or parent if younger, prior to enrollment.

Virtual Reality Exposure Therapy (VRET)

The intervention program was fully self-guided, in comparison to a therapist-guided intervention, with digital material that the participants could access from home via the online platform and a VR- device. One or two days after the participants in the VR-group got access to the online platform and filled out the consent form and the pre-screening forms, they were given the VR-equipment through a physical meeting (which is arranged again 3 weeks after the intervention for a return of the VR-equipment).

In phase 1 of the study, the VR-intervention *(for group 1)* consisted of participants using the Oculus Quest VR-device and completing several VR-sessions using the device. The VR application used in the study was created by professional VR developer Attensi AS, including various gamification elements in the application, such as challenges, performance feedback level progression and awards. All participants and parents received notifications via SMS (adolescents) and/or e-mail (parents) when a new assessment or modules have been made available to them, as well as regular activity-reminders. User interaction was done through a graphical interface, with the handheld controller used for mouse-like pointing and clicking. The VR-intervention has been derived from an exposure therapy protocol based on the inhibitory learning model.

The participants in the VR-group started the VR application by finding themselves in a gray room, which gave them the option to start a task/exercise out of a list (figure 3) or configure their own exercise (figure 4).

Figure 3

The participants would be presented with a table of tasks to choose from and complete, with new tasks being unlocked when all the previous tasks were completed

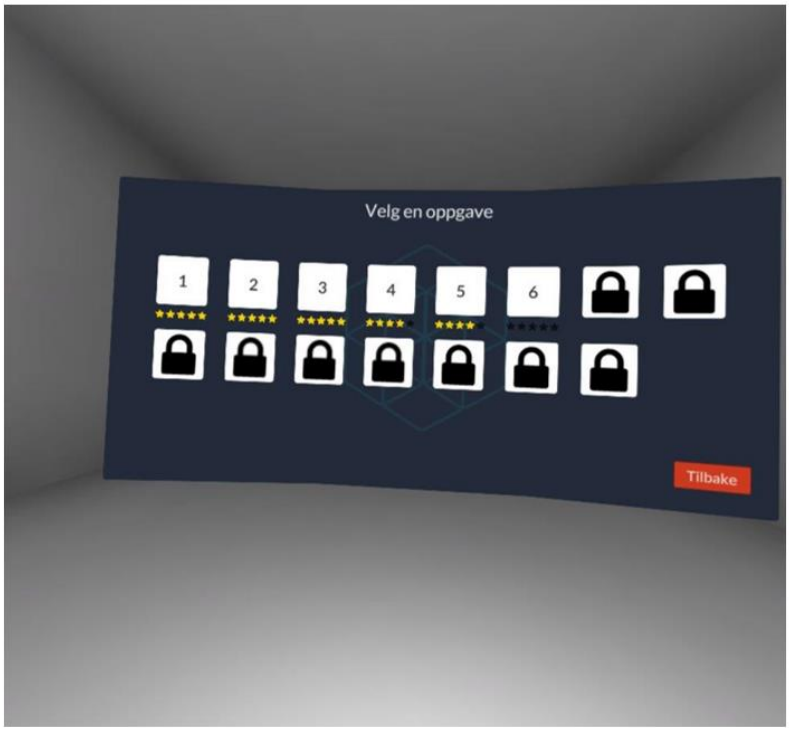
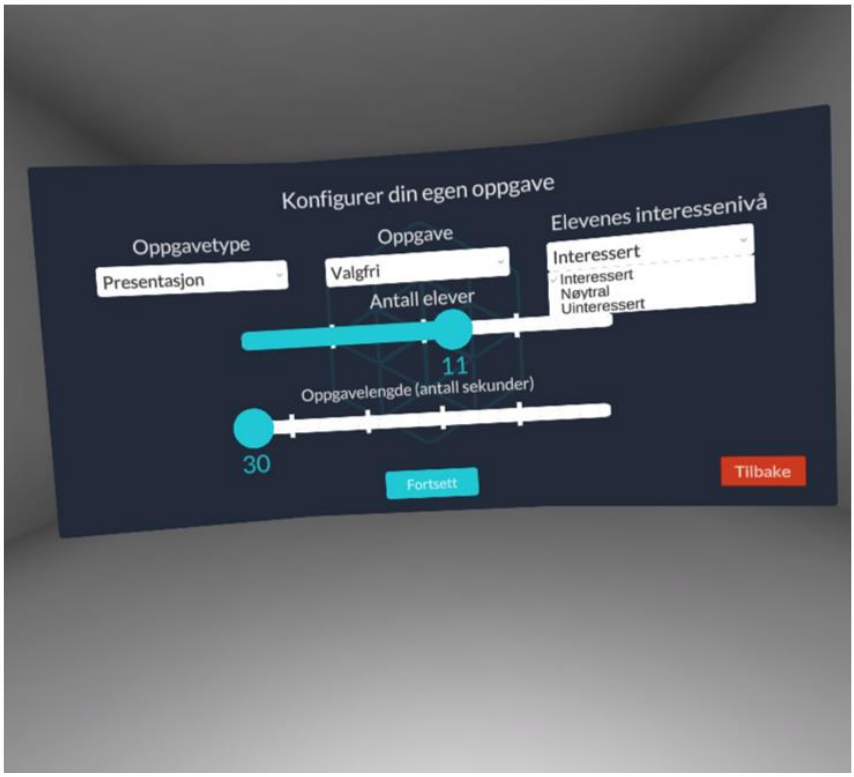


Figure 4

In addition to pre-configured tasks, the participants also had the option to customize their own tasks/exercises



The intervention consisted mainly by completing a set of speech exposure tasks of increasing difficulty, ranging from artificial speech exercise (e.g. counting down from 60) to improvised speeches on specific topics. The VR application featured two different modes; *progress mode* and *free practice mode*. All participants in the VR-group would start in progress mode, and upon completing the first five progress mode levels could unlock the free practice mode. In *progress mode*, the user was tasked with sequentially completing 15 levels with varying challenges, each a unique combination of four parameters: audience size, audience sentiment, task duration, and type of task (oral presentation in front of the classroom or reading out loud in English/Norwegian sitting in the middle of the classroom). In comparison, in *practice mode*, the

user could construct their own tailored exposure task by varying the same parameters used to create the individual levels.

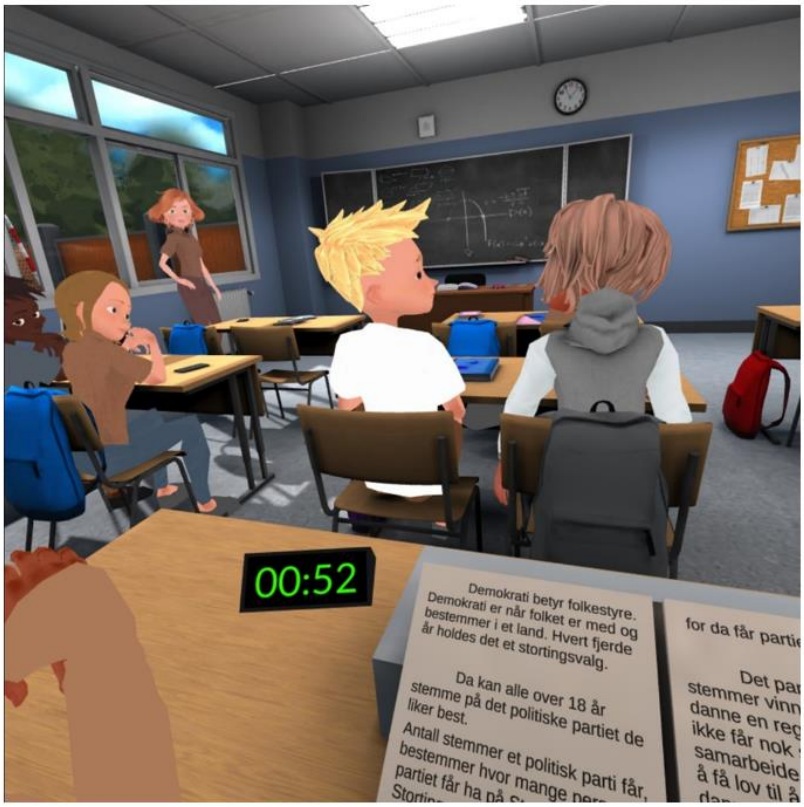
All VR exposure exercises were conducted in a virtual scene resembling a typical Norwegian classroom (figure 5 and 6). This virtual classroom included 14 human characters depicted to be approximately 13—16 years old, sitting at desks with their gaze directed at the participant by default. The classroom scenario is visualized below, showing what the participants saw during speech performance tasks when using the VR-device.

Figure 5

An example of a classroom-scenario during a speech performance task

Figure 6

A participant performing a times speech exercise by reading aloud pre/configured text



After receiving instructions on the task to be completed (in an empty gray corridor when wearing the VR-glasses), the user then reported catastrophic beliefs by selecting from a pre-supplied list and rates total catastrophic belief expectancy using a visual analogue scale 0—100, before beginning the exercise itself. After completing the task, the user rated their maximum subjective unit of distress experienced during the task using a visual analogue scale 0—100, and also answered whether their catastrophic beliefs were materialized. The user was then given the objective task performance feedback based on sound and/or pseudo-gaze patterns (e.g. looking around the classroom).

Outcome Measures

An essential part of conducting a psychological treatment is being able to thoroughly assess the treatment outcome using a valid and psychometrically reliable assessment tool – that can both serve as an assessment and effect-tracking tool. In measurement of anxiety disorders, self report scales have been an important and effective measurement tool in both measuring current clinical status and treatment processes and outcome (Mattick & Clarke, 1998).

Social anxiety symptoms were measured with Public Speaking Anxiety Scale (PSAS) and Social Anxiety Interaction Scale (SIAS) /Social Phobia Scale (SPS). Furthermore, measures of habituation and catastrophic thoughts were collected. All the self-report questionnaires in this study were translated to Norwegian for this study, after an assessment had been made about the suitability of the self-report questionnaires given the age group of this study. The complete overview of all the measures and the internal consistency for each measure, is presented in table 1 below.

Table 1

Internal consistency for primary and secondary outcome measures

Outcome measures	α*	Time			
		Pre	Week 1	Week 2	Post
PSAS	.716	X	X	X	X
Catastrophic thoughts	NA	X	X	X	X
Habituation	NA	X	X	X	X
SIAS/SPS	.915	X			X
Gatineau Presence Scale	.473				X
Simulator Sickness	.868				X

* α = measure of internal consistency (Cronbach' s alpha)

Note: PSAS = Public Speaking Anxiety Scale, SIAS

Primary outcome measures

PSAS

Public speaking anxiety scale (PSAS; Bartholomay, 2016) served as the primary outcome measure, and was administered a total of four times independent of group allocation; at baseline (pre), week 1, week 2 and week 3 (post). This 17-item self-report questionnaire measures Public Speaking Anxiety using a five-level likert scale, ranging from 1 ("*not at all*") to 5 ("*extremely*"), with five of the items reverse coded, and with scores ranging from 17 (lowest) to 85 (highest).

According to Bartholomay and Houlihan (2016), PSAS has been found to have a high internal consistency, with Cronbach's alpha at .938. Initially proposed by Lang (1951), it is based on the three-component symptoms model of anxiety, assessing speaking anxiety through

cognitive (8 items), behavioral (4 items) and physiological (5 items) properties (Bartholomay & Houlihan, 2016) - with scoring ranging from 17 to 85. Reports of PSAS have shown high internal consistency for the three anxiety subscales; with cognitive at α = .881, behavioral α =.747 and physiological α =.867. In addition, it has been found to be highly correlated with other measures of anxiety, like SIAS and SPS (Bartholomay and Houlihan (2016).

In our sample of 30 participants, the internal consistency was calculated to be high at baseline (α =.716), with cognitive subscale showing α = .561, behavioral α = .358 and physiological α = .596.

Secondary outcome measures

SIAS-6 and SPS-6

Secondary outcome measures included the short versions of Social Interaction Anxiety Scale-6 (SIAS-6; ref) and Social Phobia Scale-6 (SPS-6; ref) for the assessment of social fears at baseline and post (week 3). SIAS-6 and SPS-6 consists of six items each on a scale ranging from 0 (not at all) to 4 (very much).

SIAS-6 and SPS-6 are self-report measures that have shown good psychometric properties in measuring different, yet related aspects of social phobia (Peters et al, 2012). According to Mattick and Clarke (1998), both measures have shown high internal consistency and good test-retest reliability – with the scales having an internal consistency (Cronbach's) of α =.93(SIAS-6) and α =.89 (SPS-6) and test-retest reliability (over 4 and 12 weeks) of r =.92 (SIAS-6) and r= .91-.93 (SPS-6).

Furthermore, The SIAS-6 and SPS-6 has shown high correlation with the original SIAS/SPS and a high diagnostic validity for SAD - in addition to a strong sensitivity to treatment-associated change and a time-effective tool for measuring social anxiety symptoms (Peters et al, 2012).

Catastrophic thoughts and habituation

Self-report measures of 1) catastrophic thoughts and 2) habituation (discomfort) were conducted at pre (baseline), week 1, week 2 and post (week 3). Catastrophic thoughts were measured using a 1-item scale consisting of a statement rated on a scale from 0-100: *"If I hold a presentation today, I am sure that the most aversive consequence is likely to happen"*. Habituation was also measured using a 1-item scale with a statement rated on a scale from 0-100: *"If I was supposed to do a presentation today, my body would react strongly by: sweating, increased heart rate, shaking, difficulties breathing, feeling nauseous or having a bad stomach"*.

Statistical Analysis

All analyses were carried out in SPSS version 26 and 28. PSAS, SIAS/SPS, Catastrophic thoughts (CT) and Habituation served as dependent variables in the analysis, with independent variables *Time* and *Group*. The independent variable Time included measurements done before, during and after treatment (Pre, Week 1, Week 2 and Post/Week 3) for all measures excluding SIAS-6/SPS-6, which was measured at two timepoints, before and after treatment (Pre and Post/Week 3). All participants were included in the data analysis.

In order to explore our research question and draw any conclusions on our hypothesis, the sample data was analyzed using descriptive statistics (observed data) and inferential (estimation) statistics. The missing data was analyzed using an MCAR test to see whether the data is missing completely at random. Descriptive data was obtained using SPSS, and this study used the mean of each measure taken at all time-points for both groups, to compute *Cohens d* - defined as the calculation of a difference between two means. Cohen's d is computed by taking the difference between two means (M1-M2) and dividing it by the standard deviation of either group - given that the variance between the two are homogenous (Becker, 2000). Becker (2000) notes the value of effect-size measures in indicating the magnitude of a treatment effect, and this was therefore an important first step in the analysis of the results from the study.

Mixed Linear Model (MLM)

To measure the treatment effect of VR for PSAS, CT and Habituation, Mixed Linear Models (MLM) was conducted at four time points. MLM allowed us to analyze the data from the different time-points from each participant (and take in account the missing and the non-independent data) in an unbiased way (Meteyard & Davies, 2020). In addition, compared to other models (like for example a traditional regression/anova), MLM offers advantages in both 1) its handling of missing data and 2) its handling of non-independent data based on a within-subjects design, when multiple data-points are collected from each source/participant (Brauer & Curtin, 2017).

Repeated Measures Analysis of Variance (ANOVA)

While SPS-6/SIAS-6 is a shortened version of both SPS and SIAS used in the study, it was additionally interesting to analyze the individual results of SPS and SIAS. To measure the

effects of VRET on results from SPS-6 and SIAS-6, a repeated measure ANOVA was conducted.

Results

Demographic data

The demographic data is presented in Table 2, which is composed of gender and age, and shows the distribution of the sample according to gender and age, in addition to the mean and SD for age in each group.

Table 2

Demographic data

Participants N = 30	Gender		Age
	Male	Female	Mean age (SD)
VR group	3	12	14.5
WL group	2	13	13.9
Total	5	25	14.2

Note: VR-group = 15 participants receiving VRET, WL-group = control group, SD = Standard deviation

Within- and between-group effects for primary and secondary measures

Observed data

Table 3 presents observed data for primary and secondary measures for both VR- and WL-group, with mean scores and standard deviations (SD) at each timepoint, in addition to effect size values (Cohens' d) for both groups. For the primary measure PSAS we identified a

within-group medium-to-large effect size for the VR-group of d = 0.86. Compared to the VR-group, the WL-group saw a significantly lower effect-size for all measures from baseline to post.

Table 3

Estimated data

Outcome measures	Mean (SD)									
	Group	Pre	N	Week 1	N	Week 2	N	Post	N	Cohens' *d*
PSAS	VR	65.93 (7.68)	15	59.64 (9.11)	11	51.36 (20.05)	11	57.27 (12.04)	11	0.8575
	WL	63.67 (5.11)	15	62.85 (6.37)	13	61.00 (6.61)	8	62.77 (5.07)	13	0.1768
CT	VR	68.93 (25.83)	15	49.64 (26.98)	11	47.70 (26.52)	10	53.18 (29.04)	11	0.6312
	WL	54.33 (20.60)	15	51.23 (17.64)	13	48.13 (20.10)	8	58.08 (19.01)	13	- 0.1891
Habituation	VR	75.93 (28.68)	15	54.45 (36.37)	11	45.60 (34.00)	10	57.73 (36.05)	11	0.5587
	WL	75.13 (16.78)	15	75.62 (20.23)	13	79.13 (10.09)	8	82.54 (12.08)	13	- 0.5068
SIAS	VR	9.87 (5.20)	15	N/A		N/A		9.82 (5.91)	11	0.0089
	WL	10.73 (5.26)	15	N/A		N/A		9.31 (5.84)	13	0.2555
SPS	VR	9.40 (5.93)	15	N/A		N/A		6.91 (6.92)	11	0.3864
	WL	11.27 (6.36)	15	N/A		N/A		10.62 (6.54)	13	0.1007

Note. CT = Catastrophic Thoughts, N = Number of participants, Post = Measures at week 3, Cohen's *d* = effect size for post

A linear mixed-effects model analysis was conducted for primary measure PSAS, in addition to secondary measures CT and Habituation. The results yielded a significant main effect for the independent variable *Time* , on measures of PSAS; F(3,62) = 7.13, p = .000, Habituation; F(3,61) = 4.86, p=.004 and CT; F(3,61) = 3.28, p = .027. Significant interaction effects are observed for time*group on PSAS; F(3,62)= 4.69, p = .005, Habituation; F(3,61) = 6.94, p = .000 and CT ; F(3,61) = 3.38, p =.024. The results from MLM analysis showing the mean (SD) and confidence interval for each measure are presented in table 4 and table 5 below.

Table 4

Mixed models analysis for primary outcome PSAS and CT and habituation

Outcome measures	Mixed Models Analysis (MLM): Estimated means for *Time * Group*									
	G	Pre		Week 1		Week 2		Post		*p*
		Mean (SE)	CI	Mean (SE)	CI	Mean (SE)	CI	Mean (SE)	CI	Sig.
PSAS	VR	65.93 (2.01)	[61.86, 70.01]	60.17 (2.15)	[55.85, 64.50]	59.31 (2.19)	[54.92, 63.71]	57.46 (2.50)	[53.14, 61.79]	.005
	WL	63.67 (2.01)	[59.59, 67.74]	63.30 (2.07)	[59.13, 67.48]	62.26 (2.28)	[57.69, 66.83]	62.95 (2.07)	[58.77, 67.13]	
CT	VR	68.93 (6.10)	[56.63, 81.24]	47.94 (6.55)	[34.78, 61.09]	56.54 (6.68)	[43.13, 69.95]	55.08 (6.55)	[41.92, 68.23]	.024
	WL	54.33 (6.10)	[42.03, 66.64]	53.63 (6.29)	[40.97, 66.30]	55.12 (7.00)	[41.12, 69.11]	57.45 (6.29)	[44.79, 70.12]	
Habituation	VR	75.93 (6.71)	[62.31, 89.56]	54.12 (7.02)	[39.94, 68.30]	56.52 (7.10)	[42.19, 70.86]	61.81 (7.02)	[47.63, 75.99]	.000
	WL	75.13 (6.71)	[61.51, 88.76]	75.88 (6.84)	[62.03, 89.74]	78.34 (7.31)	[63.63, 93.04]	80.72 (6.84)	[66.87, 94.57]	

Note. G = group, SD = Standard Error, CI = Confidence Interval, Post = Measures at week 3, *p* Time * Group = p-value of the interaction effect between time and group (sig. for $p < .05$)

A repeated measures analysis of variance (ANOVA) was conducted for the secondary measures of SIAS-6 and SPS-6 separately. Results showed that there was not a statistically significant effect on reduction of scores on SPS-6 based on time, $F(1,22) = 3.321$, $p = .082$, Wilk's $\Lambda = .869$. Similarly, the results showed a non-significant effect on time * group, $F(1,22) = 1.218$, $p = .282$, Wilk's $\Lambda = .948$. Results showed also that there was not a significant effect on reduction of scores for SIAS-6 for both time and group * time.

Further analysis revealed a non-significant effect of time for $p = .082$, and Group * time for $p = .282$ for SPS-6. Similarly, results for SIAS revealed a non-significant effect for Time, with $p = .365$, and on Group * Time, with $p = .533$. The full results of the repeated measures ANOVA for interaction effects for Group * Time are included below in Table 5.

Table 5

Repeated Measures ANOVA for secondary measures SIAS and SPS

Outcome measures	Repeated Measures ANOVA: Estimated Marginal Means Group * Time					
	G	Pre		Post		*p*
		Mean (SE)	CI	Mean (SE)	CI	Sig.
SIAS	VR	10.09 (1.64)	[6.68, 13.50]	9.82 (1.77)	[6.15, 13.49]	.533
	WL	10.77 (1.51)	[7.63, 13.91]	9.31 (1.63)	[5.93, 12.69]	
SPS	VR	9.73 (1.67)	[6.25, 13.20]	6.91 (2.02)	[2.71, 11.11]	.282
	WL	11.31 (1.54)	[8.11, 14.50]	10.61 (1.86)	[6.75, 14.48]	

Note. G = group, SE = Standard Error, CI = Confidence Interval (Lower, Upper), Pre = measured at baseline, Post = measures at week 3, *p* = p-value of the interaction effect between pre and post for Group * Time (sig. for $p < .05$)

Discussion

The aim of this study was to examine the effect of a VRET intervention in a sample of 30 adolescents compared to a WL-group. The main focus of the study was to explore whether the primary measure PSAS, and the secondary outcome measures of SPS and SIAS, Habituation and CT yielded significantly different results in the VR group than in the no-treatment WL-group. The results showed that VRET, as a stand-alone treatment, can produce significant therapeutic gains and significantly ease self-reported social anxiety symptoms in adolescents.

A finding consistent with our first aim of the study was the large effect-size of reduction on scores of PSAS from pre to post for the VR-group on the primary measure PSAS. However, the results also showed a difference in effect across the different measures. Most notably, the effect was lowest for measures of SIAS-6, which measures anxiety associated with initiation and maintenance of social interactions (Zsido et al, 2021).

The second aim of this study was to analyze whether there is a significant change in symptom-reduction between the VR group compared to the control group over time. In the study, significant between-group effects were observed, especially for the primary measure of PSAS. Through calculation and comparison of effect sizes, the results indicate that in comparison to control, those adolescents who received VR-treatment improved on standardized measures of PSA and negative evaluation. For SIAS-6 and SPS-6, the results yielded mixed effects both in terms of observed and estimated data comparison. It is unclear why measures of SIAS-6 and SPS-6 did not yield significant effects, but one possible explanation can be that both measures were only taken at baseline and post and thus did not provide sufficient data to fully paint the change in scores throughout the three-week intervention.

These findings are found to be consistent with other studies conducted on the effect of VRET in treatment of SAD and PSA among adolescents and adults (Kahlon, Lindner & Nordgreen, 2019; Kampmann et al, 2016; Takac et al, 2019; Anderson et al,2017; Bouchard et al, 2017; Kim et al, 2020; Lee et al, 2021; Reeves et al, 2021; Zainal et al, 2021; Yadav et al, 2022). Other RCT studies (like Reeves et al, 2021 and Kahlon, Lidner & Nordgreen, 2019) also suggest that in comparison to control, those receiving VRET have a significantly higher decrease in PSA symptoms. Additionally, studies have also compared VRET with traditional IVET, giving evidence that both interventions have a similar efficacy rate (Anderson et al, 2013). Anderson et al (2013) conducted an RCT, which explored this, including both a VRET-group, IVET-group and a WL control-group. Results showed that both the VRET and IVET-group has a significant effect in reducing PSA compared with the WL control group. The VRET and IVET group showed a similar effect on PSA-scores, and these results were similar on follow-up measures taken at 6 months and 12 months post-intervention (Anderson et al, 2013)

Challenges and limitations

There are several limitations that arise both prior, during, and after the completion of this sub-study. Firstly, the study included a sample of 30 adolescents. Compared to previous RCT studies on VRET and PSA, for example by Anderson et al (2013) and Kampmann et al (2016), a large sample size could provide more reliable and valid results. The sample was also geographically dense, since the participants were chosen through the advertisement in a very specific geographic area in Norway, which can affect the validity of the results.

Furthermore, this sub-study measured PSA-symptoms using self-form questionnaires. SAD and PSA is usually diagnosed by a combination of in-person assessment and standardized self-report scores, where the individual assesses their level of anxiety in social situations (Myers et al, 2016). However, using only self-report measures can provide their own challenges in terms of accurately assessing symptoms, and research has given evidence for that effects of interventions measured solely using self-report measures produced higher level of efficacy compared to studies who used behavioral and physiological measures (Ebrahimi et al, 2019).

Other VRET studies have additionally also included the use of physical measures as well as psychological, which can further provide additional information about the state of anxiety during public speaking tasks and anxiety reduction assessment(Kahlon, Lindner and Nordgreen, 2019)

Future directions

This sub-study explored the efficacy of VRET on symptom-reduction among a Norwegian adolescent sample, with preliminary findings demonstrating a significant reduction in PSA-

symptoms of those adolescents that received the VRET-treatment compared to the control-group. The results of this study are important on several levels. Firstly, they provide another stepping-stone to further explore the possibilities of new technology in the field of healthcare. In 2004, Smith explored the concept of "clinical transformation" - looking into how new research and technological advancements can shape the future of healthcare. Thimble (2013) further assessed the application of new technology into the field, highlighting the importance of high-quality research, safety, confidentiality and usability in bringing technology into the healthcare sphere. With increasing research in VR and other digital technologies in mental health treatment, it can have the possibility of shaping a) the accessibility of mental health services, b) patient-health provider communication and c) assessment and treatment of mental disorders. With the changing world, it will be important that healthcare will follow the advancements made in technology.

Conclusions

The results indicate that Virtual Reality Exposure Therapy (VRET) can be an effective intervention for treatment of PSA among adolescents. Research on using VRET in the treatment of PSA can offer valuable insight in how new and low-threshold digital treatment methods can help provide safe and effective treatment options for patients seeking help. Although there has been a highly noticeable increase in research on digital technologies and mental health, especially in the use of VRET, it will be important to further conduct high-quality studies to strengthen the evidence base, efficacy, and safety of digital treatments like Virtual Reality Exposure Therapy (Reeves et al, 2022).

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