Virtual Reality Exposure Therapy for Adolescents with Public Speaking Anxiety

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Thesis for the degree of Philosophiae Doctor (PhD)
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Scientific environment

The thesis is part of INTROMAT (Introducing personalized TReatment Of Mental health problems using Adaptive Technology; 2016-2022), based at Haukeland University Hospital and led by associate professor Tine Nordgreen. The INTROMAT project was awarded as one of the three ICT Lighthouse call projects, funded by the Norwegian Research Council (NFR no 259293). The project's goal was to use innovative Information and Communications Techonology (ICT) when developing interventions targeting mental health problems and increase the use of technology. The interventions were developed by a cross-disciplinary and cross-sectoral team, including 14 partners from human-computer interaction, modeling, machine learning, psychological and medical health, and users.

YoungSpotlight was one of five clinical sub-projects in the INTROMAT project, as part of work package 4: "Clinical Testing", led and supervised by Tine Nordgreen. This sub-project targeted adolescents with public speaking anxiety with a short-term goal of reducing public speaking anxiety symptoms when presenting in the classroom, and a long-term goal of preventing the risk of developing generalized social anxiety disorder. This sub-project started in September 2017 and formally ended in April 2022, and involved the following partners: Haukeland University Hospital, Youwell AS, Attensi AS, Stockholm University, and University of Oslo.

Attensi AS developed the virtual classroom through Virtual Reality technology. YouWell AS developed the digital platform for the online programs. Associate professor Philip Lindner at Stockholm University and Karolinska Institutet provided the treatment protocol used for the VR part of the project. Associate Professor Rolf Gjestad, Research Department at Haukeland University Hospital, contributed to the statistical analysis. In addition, the physiological and Virtual Reality data were analyzed using machine learning by Professor Jim Tørresen, Ph.D. Farzan Noori, and Ph.D. Ulysse Côte-Allard, Department of Informatics at the University of Oslo. These data were published elsewhere.

The Ph.D. training program was conducted at the Graduate School of Clinical and Developmental Psychology (CDP), Department of Clinical Psychology, Faculty of Psychology, University of Bergen. There was also a connection to the research groups “Technology and mental health” and “Bergen Research Group for Innovation, Growth, Health, and Technology” (BRIGHT).

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Smiti Kahlon, May 12, 2022.

Abstract

Background: Public Speaking Anxiety (PSA) is one of the most common fears reported by adolescents. PSA involves the fear of being negatively evaluated, followed by a feeling of being embarrassed or humiliated when speaking in front of others. Providing state-of-the-art in-vivo exposure therapy for PSA is difficult due to the logistics of recruiting an actual audience trained to act as the feared stimuli. An attractive way of resolving this obstacle is through Virtual Reality (VR) technology, which is capable of creating an immersive experience of being in front of a virtual audience, as if it was real.

Although there are several randomized controlled trials demonstrating the clinical efficacy of VR exposure therapy for adults with PSA, little is known about its clinical effects on adolescents. Moreover, no past study has evaluated self-guided and automated VR interventions for adolescents with PSA.

Aims: This thesis addressed these key knowledge gaps by exploring the clinical effects and feasibility of both therapist-guided and self-guided, and automated VR interventions for adolescents with PSA. The aim of Paper I was to investigate the feasibility and the clinical effects of a therapist-guided, single-session VR-intervention for adolescents with PSA, using low-cost consumer VR hardware. The primary aim of Paper II was to investigate the clinical efficacy of a self-guided, automated, and gamified VR intervention compared with waitlist and self-guided online programs. A secondary aim was to explore whether the VR intervention led to an increase in subsequent exposure tasks during the online exposure program compared to those receiving the online psychoeducation and exposure program. The aim of Paper III was to investigate whether interventions targeting PSA also led to a reduction in symptoms of perfectionism and whether symptoms of perfectionism moderated the clinical efficacy of self-guided interventions for PSA.

Methods: Two clinical trials provided data for three studies: one non-randomized feasibility and pilot study (Paper I) and a two-phased, four-armed randomized controlled study (Paper II and III). Both trials investigated effects and moderators of

treatment: baseline generalized social anxiety symptoms and presence in the virtual environment (Paper I) and whether perfectionism moderated treatment outcome (Paper III). Self-reported PSA were assessed during the intervention and follow-up period in both studies, in addition to heart rate measurements during the VR exposure in Paper I, self-reported symptoms of generalized SAD in Paper II and III, and perfectionism in Paper III. The non-randomized feasibility and pilot study in Paper I included N=27 adolescents who participated in a therapist-guided, 90-minutes single-session VR intervention at the clinic. The two-phased, four-armed randomized controlled study in Paper II and III included N=100 adolescents who participated in a six weeks digital self-guided interventions program. The adolescents were randomized into four groups, with the following phase one + phase two intervention; 1) VR only, 2) VR + online exposure program, 3) Online psychoeducation + exposure program, 4) Waitlist + online psychoeducation program.

Results: Results from Paper I revealed a significant decrease in PSA symptoms from pre to post, and symptoms remained stable at one- and three-month follow-up. Based on feedback from the adolescents, the feasibility of the intervention was increased during the trial, resulting in no missing data. Baseline generalized social anxiety symptoms and presence did not moderate the clinical effects. There was a small increase in heart rate during the VR exposure tasks.

Results from Paper II revealed a significantly greater reduction in PSA symptoms among the adolescents who received the VR intervention compared to the the waitlist group. The results also demonstrated that VR + online exposure program was as equally effective as compared to VR only and online psychoeducation + exposure program. Moreover, all groups had a significant reduction in PSA symptoms. Contrary to the hypothesis, adolescents who received VR training did not complete a higher number of in-vivo-exposure tasks during the online exposure program compared to those receiving online psychoeducation and exposure program. The clinical effects remained stable at three-month follow-up.

Results from Paper III revealed that the interventions did not reduce perfectionism at a group level, however, there were significant individual differences in changes over time. A decrease in perfectionism was associated with a larger reduction on all outcome measures from post to follow-up. There were no significant interaction effects between PSA symptoms and the pre-treatment level of perfectionism. High pre-treatment levels of perfectionism was associated with poorer long-term outcomes for both groups receiving the online exposure program.

Conclusions: In sum, this thesis contributes to the growing evidence base for VR exposure therapy, and is among the first to demonstrate the potential of both therapist-guided and self-guided, VR interventions for adolescents in general and with PSA in particular. The results indicate that VR may serve as an indicated prevention program for adolescents with PSA. The studies included in the thesis is conducted through a strong design with feasibility and piloting as a first step before evaluating, for the first time with this target group, the clinical effects in a randomized controlled trial. Moreover, the thesis has investigated relevant moderators of treatments, specifically the role of perfectionism and how it may hinder treatment improvement. These results can provide guidance on how to optimize future interventions for the large group of adolescents with PSA. Future studies should investigate whether VR interventions have a long-term preventive effect on the development of generalized social anxiety as this remains unclear for this age group.

Sammendrag

Bakgrunn: Presentasjonsangst er en av de vanligste fryktene blant ungdom. Angsten innebærer en redsel for å bli negativt evaluert, etterfulgt av en følelse av å bli flau eller ydmyket når man snakker foran andre. Eksponeringsterapi for presentasjonsangst er utfordrende å gjennomføre, da en trenger et reelt publikum som kan fungere som det fryktede stimuli. Virtual Reality (VR) kan være løsningen, da teknologien er i stand til å skape et virtuelt publikum, som kan oppleves som ekte.

For voksne med presentasjonsangt finnes det flere randomiserte kontrollerte VR-studier som viser gode kliniske effekter, men en vet lite om effekten relatert til ungdom. Ingen studier har tidligere evaluert effekten av selvveiledet, automatiserte og spillbaserte VR-intervensjoner for ungdom med presentasjonsangst.

Mål: Denne oppgaven adresserte aktuelle kunnskapshull ved å kartlegge den kliniske effekten og gjennomførbarheten av to VR-intervensjoner for ungdom med presentasjonsangst: en terapeutveiledet og en selvveiledet, automatisert og spillbasert intervensjon. Målet med Artikkel I var å undersøke gjennomførbarheten og den kliniske effekten av en terapeutveiledet, enkelt-sesjons VR-intervensjon for ungdom med presentasjonsangst. Hovedmålet med Artikkel II var å undersøke den kliniske effekten av en selvveiledet, automatisert og spillbasert VR-intervensjon sammenlignet med venteliste og en selvveiledet nettbasert intervensjon. Et sekundært mål var å undersøke om VR-intervensjonen førte til en økning i påfølgende eksponeringsøvelser under det nettbaserte eksponeringsprogrammet, sammenlignet med de som mottok nettbasert psykoedukasjons- og eksponeringsprogram. Målet med Artikkel III var å undersøke om intervensjonene rettet mot presentasjonsangst også førte til en reduksjon i symptomer på perfeksjonisme og om symptomer på perfeksjonisme modererte den kliniske effekten av intervensjonene for presentasjonsangst.

Metode: To kliniske studier ga data for tre studier: en ikke-randomisert gjennomførbarhet- og pilotstudie (papir I) og en to-faset, firearmet randomisert kontrollert studie (papir II og III). Begge studiene undersøkte effekter og moderatorer

av behandling: symptomer på generalisert sosial angst ved baseline og tilstedeværelse i det virtuelle miljøet (artikkel I) og om perfeksjonisme modererte behandlingsresultatet (artikkel III). Selvrapporterte symptomer på presentasjonsangst ble innhentet under intervensjons- og oppfølgingsperioden i begge studiene, i tillegg til hjertefrekvensmålinger under VR-eksponeringen i Artikkel I, selvrapporterte symptomer på generalisert sosial angst i Artikkel II og III, og perfeksjonisme i Artikkel III. Gjennomførbarhets- og pilotstudien i Artikkel I inkluderte N=27 ungdommer som deltok i en terapeutveiledet, 90-minutters VR-intervensjon på én sesjon ved klinikken. To-faset, firearmede randomiserte kontrollerte studien i Artikkel II og III inkluderte N=100 ungdommer som deltok i et seks ukers digitalt selvveiledet intervensjonsprogram. Ungdommene ble randomisert i fire grupper, med følgende fase én + fase to intervensjon; 1) Kun VR, 2) VR + nettbasert eksponeringsprogram, 3) Nettbasert psykoedukasjon + eksponeringsprogram, 4) Venteliste + nettbasert psykoedukasjonsprogram.

Resultater: Resultater fra Artikkel I viste en signifikant reduksjon i presentasjonsangstsymptomer fra pre til post, og symptomene holdt seg stabile ved en og tre måneders oppfølging. Basert på tilbakemeldinger fra ungdommene, ble gjennomførbarheten av intervensjonen økt i løpet av studien, noe som resulterte i ingen manglende besvarelser ved oppfølging. Symptomer på generalisert sosial angst ved baseline og tilstedeværelse modererte ikke de kliniske effektene. Det var en liten økning i hjertefrekvensen under VR-eksponeringsoppgavene.

Resultater fra Artikkel II viste en signifikant større reduksjon i presentasjonsangstsymptomer blant ungdommene som mottok VR-intervensjonen sammenlignet med ventelistegruppen. Resultatene viste også at VR + nettbasert eksponeringsprogram var like effektivt sammenlignet med kun VR og nettbasert psykoedukasjon + eksponeringsprogram. I tillegg hadde alle fire grupper en signifikant reduksjon i presentasjonsangstsymptomer. I motsetning til hypotesen fullførte ikke ungdommer som mottok VR-intervensjon et høyere antall in-vivo-eksponeringsoppgaver i løpet av nettbasert eksponeringsprogram sammenlignet med

de som mottok nettbasert psykoedukasjon og eksponeringsprogram. De kliniske effektene holdt seg stabile ved tre måneders oppfølging.

Resultater fra Artikkel III viste at intervensjonene ikke reduserte perfeksjonisme på gruppenivå, men det var signifikante individuelle forskjeller i endringer over tid. En nedgang i perfeksjonisme var assosiert med en større reduksjon på alle utfallsmål fra post til oppfølging. Det var ingen signifikante interaksjonseffekter mellom presentasjonsangstsymptomer og nivået av perfeksjonisme før behandling. Høye nivåer av perfeksjonisme før behandling var assosiert med dårligere langsiktige resultater for begge gruppene som mottok det nettbaserte eksponeringsprogrammet.

Konklusjon: Denne oppgaven bidrar til det voksende evidensgrunnlaget for VR-eksponeringsterapi, og den første som demonstrerer potensialet til både terapeutveiledet og selvveiledet VR-behandling for ungdom generelt, og spesielt for de med presentasjonsangst. Resultatene indikerer at VR-behandling kan fungere som et indisert forebyggingsprogram for ungdom med PSA. Studiene som inngår i oppgaven er gjennomført ved hjelp av et solid design. Gjennomførbarhet og pilotering var første trinn, før man for første gang med denne målgruppen evaluerte de kliniske effektene i en randomisert kontrollert studie. I tillegg har oppgaven undersøkt relevante moderatorer av behandlinger; rollen til perfeksjonisme og hvordan den kan hindre bedring. Disse resultatene kan være veiledende for hvordan optimalisere fremtidige intervensjoner for ungdom med presentasjonsangst. Fremtidige studier bør undersøke om VR-terapi har en langsiktig forebyggende effekt på utvikling av generalisert sosial angst da dette fortsatt er uklart for denne aldersgruppen.

List of Publications

Kahlon, S., Lindner, P., & Nordgreen, T. (2019). Virtual reality exposure therapy for adolescents with fear of public speaking: a non-randomized feasibility and pilot study. *Child and adolescent psychiatry and mental health*, 13(1), 47. doi:10.1186/s13034-019-0307-y

Kahlon, S., Lindner, P., & Nordgreen, T. Gamified Virtual Reality exposure therapy for adolescents with public speaking anxiety: A four-armed randomized controlled trial. Under revision in *Behaviour Research and Therapy*

Kahlon S., Gjestad, R., Lindner, P, & Nordgreen, T. Perfectionism as a predictor of change in digital self-guided interventions for public speaking anxiety in adolescents. A secondary analysis of a four-armed randomized controlled trial. Submitted.

Abbreviations

PSA	Public Speaking Anxiety
SAD	Social Anxiety Disorder
IVET	In-vivo Exposure Therapy
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
CBT	Cognitive Behavioral Therapy
PE	Psychoeducation
EXP	Exposure
SPS	Social Phobia Scale
SIAS	Social Interaction Anxiety Scale
EDI-P	Eating Disorder Inventory – Perfectionism
PSAS	Public Speaking Anxiety Scale
SUD	Subjective Unit of Distress
DSM-V	Diagnostic and Statistical Manual of Mental Disorders, 5th Edition
ICD-11	International Classification of Diseases- 11th revision
RCT	Randomized Controlled Trial

Contents

1. INTRODUCTION

"According to most studies, people's number one fear is public speaking. Number two is death. Death is number two! Does that sound right? That means to the average person, if you go to a funeral, you're better off in the casket than doing the eulogy"

~Jerry Seinfeld ~

1.1 Purpose and scope of this thesis

Public Speaking Anxiety (PSA) is one of the most common fears and onsets in early adolescence, with around 50 % reporting PSA at the age of 13 years (Stein et al., 1996). PSA involves the fear of being negatively evaluated when speaking in front of others (Grant et al., 2005) and may cause severe impairment for adolescents, affecting their education (Ferreira Marinho et al., 2017), social life (Stein et al., 1996), life quality and is associated with a poorer mental health (Wittchen et al., 1999). As PSA may be persistent and continue into adulthood (Hofmann et al., 1999), there is a need for early intervention, thus preventing the long-term negative consequences of PSA.

In-vivo exposure therapy is the state-of-the-art treatment for PSA and anxiety disorders (National Institute for Health and Care Excellence, 2013). However, in-vivo exposure therapy is challenging when it comes to PSA as it requires many people trained to act as an audience. With the latest advances in Virtual Reality (VR) technology, VR exposure therapy is becoming more common. VR benefits by being able to computer-generate a virtual animated audience, resulting in exposure settings that are easily available for clinicians and patients (Lindner, 2020). Several review studies have documented the clinical efficacy of VR exposure therapy for adults with PSA (Carl et al., 2019; Morina et al., 2021; Reeves et al., 2021), however, there is limited evidence on the clinical effects of VRET on adolescents (Kothgassner & Felnhofer, 2020).

The overall aim of the thesis is to explore the effects of a new generation of automated Virtual Reality intervention as a self-guided intervention for adolescents with PSA. The thesis comprises two quantitative studies; one non-randomized feasibility and pilot study and one two-phased, four-armed randomized controlled study. Together, the thesis fills a gap in the existing literature on the clinical effects of VRET on adolescents with PSA. In the following sections, I will provide a summary of the literature, and discuss the methodology, results and scientific and clinical implications of the papers.

1.2 Public Speaking Anxiety

Public Speaking Anxiety (PSA) involves the fear of being negatively evaluated when speaking in front of others, followed by a feeling of embarrassment or humiliation (American Psychiatric Association, 2013). Public speaking is an essential skill used in everyday life, including educational and occupational life. Even though public speaking activities are a part of everyday life, it is one of the most feared situations. A study among university students found that they reported public speaking as their most common fear, more often than any other fear, including death (Dwyer & Davidson, 2012).

PSA causes many people to avoid public speaking situations altogether or suffer through them. In adulthood, PSA affects private and work life (Stein et al., 1996) in the context of family gatherings, school meetings, staff meetings, job interviews, and conferences. For adolescents, PSA has a negative impact as they avoid participating in activities such as speaking out loud in the classroom or asking a question (Ferreira Marinho et al., 2017).

1.2.1 Public Speaking Anxiety defined

PSA has been defined and labeled in several ways, from early research on communication apprehension (McCroskey, 2009), to speech fear, fear of public speaking, social speech fright, speech anxiety, audience anxiety, and performance anxiety. The terms refer to the same phenomena and are often more of a reflection of

the perspectives of the user (Schlenker & Leary, 1982). In this thesis, the term public speaking anxiety is used instead of the term performance anxiety, consequently excluding anxiety related to other types of performance - such as acting, dancing, playing an instrument, or singing in public.

1.2.2 Understanding PSA

Lucas is 14 years old and is in the 9th grade. He plays guitar and basketball, has many friends, and enjoys school. Lucas finds it awful to present in front of the class. He is terrified that the others in the class will see that he is nervous and that they will think that he is squeamish or stupid. To deal with the situation, he tends to hide his body, either by sitting down or by standing behind a desk when presenting. He speaks fast and low and looks down at the floor to avoid eye contact. He also wears a baseball cap when presenting so that no one will notice when he blushes.

Fear is a normal response and a protective survival mechanism from an evolutionary perspective (Andreassi, 2010). When experiencing a potentially dangerous situation, the body reacts by activating the sympathetic branch of the autonomic nervous system and releasing the chemicals adrenalin and noradrenalin. The activation of this system creates physical changes in the body, making us ready to *fight-or-flight,* and allowing us to react instantly by fighting and confronting the situation or by fleeing the situation (Andreassi, 2010). In today's western society and everyday life, the *fight-or-flight* mechanism is less often activated due to actual danger, but it is still essential when managing dangerous situations such as car traffic or fires.

In contrast to fear, anxiety occurs when there is no actual danger, but our mind believes that there is (Dias et al., 2013). As there are no real physical threats involved in public speaking situations, the term anxiety is most appropriate. A central framework for understanding PSA, originally developed by Lang (1971), proposes that anxiety comprises three components involving physiological, subjective/cognitive, and behavioral components. These components may co-occur equally, one of the components may be more dominant than the other, or one of the components may activate the others. The physiological component includes

physiological symptoms due to the activation of the autonomic nervous system. Typical bodily symptoms are; an increase in heart rate, rapid breathing, sweating, blushing, muscle tension, and high pulse (Andreassi, 2010). Many also fear these symptoms as the primary problem and that it may cause a panic attack (World Health Organization, 1993). The subjective/cognitive components include i.e. the fear of saying something embarrassing, the mind going blank, or suddenly stopping talking. The fear of being negatively evaluated makes their focus shift inwards, looking for signs and evidence of a threat (Clark & Wells, 1995), thus, affecting their presentation. The behavioral component includes strategies one might seek when experiencing anxiety. This is why some people avoid presentations altogether or use safety behaviors during a presentation (Clark & Wells, 1995), such as talking at a rapid pace to finish as quickly as possible or wearing a turtleneck, so others won't notice that they are blushing.

1.2.3 PSA in a continuum of severity

Some nervousness before a presentation is regarded as normal. At moderate levels, the activation sharpens our mind and makes us perform better and stay in focus, for instance, when writing a dissertation (Barlow, 2004). However, when the level of anxiety starts interfering with our lives and our daily functioning, we move from a normal condition into an unhealthy one. Researchers suggest that PSA can be placed in a continuum of severity from 1) PSA as a specific subtype of SAD; 2) PSA as one of several anxiety-provoking situations as a part of generalized SAD, and 3) PSA as a part of several and more chronic symptoms in avoidant personality disorder (Furmark et al., 2000).

The first categorization describes PSA as a “performance only” subtype of Social Anxiety Disorder (SAD), which is also recognized in the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013). DSM-5 defines SAD as “a marked, or intense, fear or anxiety of social situations in which the individual may be scrutinized by others” (American Psychiatric Association, 2013), and includes a “performance only” subtype, restricted to speaking or performing in front of others (American Psychiatric Association,

2013). International Classification of Disorders (ICD-10; World Health Organization, 1993) defines PSA as a non-generalized type of the diagnosis Social Phobia, restricted to situations such as eating in public, public speaking, or talking to the opposite sex. Social Phobia is defined as "a fear of scrutiny by other people in comparatively small groups (as opposed to crowds), leading to avoidance of social situations" (World Health Organization, 1993). In order to set a Social Phobia diagnosis, psychological, behavioral, and autonomic symptoms must be primarily related to symptoms of anxiety. The symptoms cannot be secondary to other symptoms such as delusions or obsessional thoughts. The anxiety symptoms must be dominating in one or more social situations, with predominant avoidance behavior. In extreme cases, avoidance behavior can result in total social isolation (World Health Organization, 1993).

The second categorization includes PSA combined with other social fears, recognized as "generalized Social Anxiety Disorder" (Blöte et al., 2009). Generalized SAD involves the fear of scrutiny in both interaction and performance situations. Interaction situations involve several types of social interactions outside the family circle where they may be evaluated or observed by others, such as eating or drinking in public, talking with strangers, ordering food, or being surrounded by many people (World Health Organization, 1993).

The third categorization is the severe form of "Avoidant Personality Disorder (APD)". ICD-10 describes the disorder as being "characterized by an enduring pattern of avoidance of social situations and interpersonal contact due to overwhelming feelings of social inadequacy and a hypersensitivity to negative evaluation or rejection*"* (World Health Organization, 1993).

Whereas generalized SAD shows a significantly higher impairment than PSA and has other diagnostic criteria, studies show a high overlap between generalized SAD and APD. For instance, Turner et al. (1992) found that 75 % of the patients diagnosed with generalized SAD also met the criteria for APD. The study further showed that the main difference between these two lies within symptom severity and impairment.

1.2.4 Prevalence

PSA is reported as the most common fear in the general population with prevalence rates ranging from 16.1 % (Tillfors et al., 2008) to 63.9 % (Ferreira Marinho et al., 2017) among university students. One large community study (Wittchen et al., 1999) of 3021 adolescents aged 14-24 years found that the median age of onset for PSA was 14 for males and 15 for females. Females (9.5 %) had a higher lifetime prevalence than males (4.9 %), and about one-third of the adolescents with PSA also met the criteria for generalized SAD (Wittchen et al., 1999). In another study of a community sample (Stein et al., 1996), they telephone interviewed 399 residents. The findings from the study showed that one-third of the respondents reported excessive PSA symptoms, and only 5 % of the individuals with PSA reported having PSA as their only social fear (Stein et al., 1996).

Those with PSA as their only social fear have qualitative and quantitative differences from other subtypes (Blöte et al., 2009). A review study found that the individuals with the "performance only" subtype of SAD have a later onset of the fear, are less associated with childhood factors, are not shy or behaviorally inhibited, and are not familial compared with those having the generalized SAD subtype (Blöte et al., 2009).

1.2.5 Etiology

Many factors have been identified and associated with the development and maintenance of anxiety (Stemberger et al., 1995). Both biological markers and genetic predisposition, and environmental factors may contribute to the development of anxiety disorders. Most presumably, it may be explained by the combination of these potential factors (Beidel & Turner, 2007). For instance, researchers have identified the hippocampus, as well as the hypothalamus, as central brain regions related to stress hormones glucocorticoids and the activation of the fight-or-flight response (McEwen, 2007). Personality traits, such as being shy, behavioral inhibition, neuroticism, and negative self-image, have been identified as potential risk factors for anxiety disorders (Blöte et al., 2009; Tsui et al., 2017). In a review study (Field, 2020), the authors also identified familial risk factors, such as parental overcontrol,

paternal worry, emotional abuse, and a history of anxiety in biological relatives. Furthermore, loneliness, peer rejection, stressful peer relationships, i.e., bullying (Field, 2020) or other negative life events (Aune et al., 2020) were also predictors of anxiety.

One study investigated differences in etiology between participants with the subtypes PSA and generalized SAD, including normal controls (Stemberger et al., 1995). The participants with only PSA reported a higher rate of traumatic social conditioning experiences compared to participants with generalized SAD (56 % vs. 40 %), with only the PSA group being significantly different from normal controls. However, there is no evidence suggesting one specific etiological pathway to anxiety, and each individual may present its own pathway, including different factors. The etiology behind anxiety is therefore complex and remains unclear (Stemberger et al., 1995).

1.2.6 PSA in adolescence

In children, fear and anxiety are signs of healthy cognitive maturation and that they are meeting developmental milestones (Davis et al., 2019). Although the peaks in fear and anxiety are regarded as mostly normal, each developmental stage is associated with a risk of developing different anxiety disorders. For example, infants begin to develop separation anxiety around six months of age (Battaglia et al., 2016). Most children outgrow anxiety around three years of age. However, for some children, the anxiety may be persistent. Children with high levels of separation anxiety at 1.5 years with an increasing trend throughout 4-5 years may be vulnerable to developing a pathological separation anxiety disorder.

Autonomy and interdependence are main themes in the developmental shift from childhood to adolescence (Larson & Richards, 1991). Instead of being dependent and only relying on parents, the adolescents become gradually more reliant on their peers and learn social cues and how to interact with others in order to set the ground rules for adulthood. At this stage of life, there is also a developmental peak of public self-consciousness, making adolescents aware of how others might perceive them (Rankin

et al., 2004). The sudden awareness can make them vulnerable to PSA as they are more sensitive and fear how others might evaluate them (Beidel & Turner, 2007).

1.2.7 Consequences of PSA in adolescents

Emma is 13 years old and is in the 8th grade. She plays handball three times a week and is otherwise happy to be with her friends. She thinks most things at school go well, apart from reading aloud in class and giving presentations. Reading aloud is uncomfortable because she is afraid of saying something wrong, and that others will think she is weird. It still tends to go well as long as she reads very slowly and accurately. Presentations are worse. She is most afraid that the class will start laughing at her while she stands in front of them or that they will think she is stupid. The fear of what the others think has become so strong that she now completely avoids presentations by being away from school.

Most adolescents with PSA experience severe impairment in everyday life, affecting life quality and functioning in several domains (Stein et al., 1996). If persistent, it can lead to avoidant behavior, maintaining the anxiety and resulting in academic and occupational difficulties, comorbidity and poorer mental health, and interpersonal difficulties.

PSA is related to difficulties with school functioning, including the ability to participate actively in class, complete oral assignments, and interference with the ability to attend school (Ferreira Marinho et al., 2017). Students have sought help due to an inability to speak aloud in classes when required, which may, in the worst case, put an end to their academic careers (Powell, 2004). They report that they become so nervous during oral presentations that their minds become blank, and they cannot answer simple questions. The anxiety leads to a performance at a level well below their capabilities, as they are not capable of showing their true potential (Powell, 2004). Consequently, adolescents have an increased risk of dropping out of school. In one study, 25 % of 1426 high school students reported that PSA was the primary reason for dropping out (Monroe et al., 1992). Further, it was also a reason why many

students did not pursue higher education due to their PSA-related symptoms. This may also be associated with poorer financial circumstances in adulthood (Wittchen et al., 1999) and unemployment (Stein et al., 1996).

Researchers suggest that the negative consequences of PSA increase at a linear level as the number of social fears increases (Stein et al., 2000). PSA combined with other social fears may therefore cause severe mental health problems and is associated with comorbid disorders such as nicotine substance use, depressive disorders, panic anxiety, and specific phobias (Wittchen et al., 1999). Moreover, around one-third of those with PSA are at risk of developing generalized SAD (Wittchen et al., 1999).

Adolescents with pervasive PSA report more feelings of loneliness and are more socially isolated and report lower quality of life compared to non-anxious peers (de Lijster et al., 2018), as their social fears and avoidance prevent them from interacting and participating in activities. As a result, they also report relationship challenges, with fewer friends and poorer quality (de Lijster et al., 2018) and more frequently report unmarried status in adulthood (Stein et al., 2017).

1.2.8 Preventing long-term negative consequences of PSA

Very few adolescents with PSA seek mental health advice. One epidemiological study found that only 10.9 % of those with PSA only and 27.3 % of those with generalized SAD make contact with a therapist (Wittchen et al., 1999). A study on 145 GP-referred adult patients for SAD treatment reported having anxiety-related complaints for 14 years on average (Nordgreen et al., 2018). By the time they receive help, they have significant impairment. Of the 145 adults, one out of three were on sick leave, received a disability pension or were unemployed.

One reason for not seeking mental health advice may be due to stigma, lack of knowledge about anxiety and being concerned about confidentiality (Gulliver et al., 2010). A common misconception is that PSA cannot be treated, and that shyness is a fixed personality trait (Sareen & Stein, 2000). Parental factors may also be involved, as they are usually the ones who ask for a referral (Creswell et al., 2014). Moreover, they may not always recognize the symptoms of anxiety (Salloum et al., 2016).

Therefore, it is of great importance to develop efficacious prevention programs for adolescents with PSA for two main reasons. First, efficacious prevention programs are important in order to reduce complaints and improve active participation at school and in the leisure time for adolescents with PSA. Second, efficacious prevention programs are important in order to prevent negative long-term consequences of PSA, including the development of SAD at a later stage. This is in line with evidence that suggests that treating the specific PSA can reduce the future development of generalized social anxiety disorder (Hofmann et al., 2006).

Prevention is defined as "measures adopted by or practiced on persons not currently feeling the effects of a disease, intended to decrease the risk that that disease will afflict them in the future" (Gordon Jr, 1983, p. 109). Prevention programs can be sorted into three different categories; universal, selective, and indicated prevention (Gordon Jr, 1983). Generally, universal prevention programs target the entire population without considering individual risk factors. Selective prevention programs target a specific population with the risk of developing the specific disorder in mind. Indicated prevention programs, however, target people who are already showing signs of the specific disorder in mind (Gordon Jr, 1983), the latter being the most relevant for adolescents with PSA.

In order to reach out to adolescents with PSA and lower their threshold in seeking help, indicated prevention programs utilized through school may have the greatest public health impact (Kessler, 2003). As the help is offered at a familiar environment, the threshold in seeking help may be lowered as they may associate it with school-related activities. Moreover, the adolescents and the parents do not have to actively seek and find the help they need (Werner-Seidler et al., 2017). A recent review study (Hugh-Jones et al., 2021) found that indicated school-based programs have proven to be efficient in reducing anxiety symptoms with effect sizes exceeding those produced by universal school-based programs. The authors found large effect sizes at post-test (−0.58 to −2.40) for 22 % of the studies and large effect sizes at follow-up (−0.41 to −1.01) in 46 % of studies (Hugh-Jones et al., 2021). In one study from Norway (Aune & Stiles, 2009), junior high school students aged 11-14 years from two

municipalities participated in a randomized controlled trial. Students from one municipality in Norway received the intervention "The Norwegian Universal Preventive Program for Social Anxiety" while students from another municipality served as a comparison group. The intervention program included parents, school health services, teachers, and other relevant school employees. Students who received the intervention had a significant reduction in social anxiety symptoms from pre to post-treatment. Furthermore, students with syndromal social anxiety reported a decrease in symptoms. In addition, there was also a decrease in number of students who developed syndromal social anxiety following the intervention compared to the control group. Effect sizes were moderate to large (Aune & Stiles, 2009).

Targeting PSA may also lead to a positive effect on life quality and self-esteem (Martinsen et al., 2021). An indicated prevention program called "EMOTION, Kids Coping" targeted anxious and depressive school children aged 8-12 years. The study found that by targeting anxiety and depressive symptoms, the children also experienced an improvement in quality of life and higher self-esteem following the intervention compared to the control groups (Martinsen et al., 2021).

1.3 Theoretical approaches to psychological interventions for PSA

Several interventions targeting PSA have been developed and utilized within different theoretical rationales, i.e., cognitive or behavioral therapy, insight therapy, psychodynamic therapy, EMDR, and visualization therapy (Ebrahimi et al., 2019). National Institute for Health and Care Excellence (2013) guidelines for phobias and anxiety recommends cognitive behavioral therapy (CBT) as the first-line psychological intervention for adolescents due to its strong evidence. Randomized controlled studies show that about two-thirds of adolescents who receive CBT gain remission at post-treatment (Seligman & Ollendick, 2011), and clinical effects are maintained at follow-up (Nevo & Manassis, 2009). CBT is also the most common approach for preventing the development of anxiety disorders and lowering anxiety

symptoms, with school-based prevention programs showing small to moderate effects (Werner-Seidler et al., 2017).

A recent meta-analysis found no difference in clinical effects between PSA interventions utilized within cognitive or behavioral therapy and PSA interventions utilized within other theoretical approaches (Ebrahimi et al., 2019). However, the authors of the meta-analysis recommend interpreting this finding with caution. The group including other theoretical approaches than cognitive or behavioral therapy is a highly heterogeneous group consisting of interventions utilized within several types of theoretical approaches. Thus, more studies are needed to conclude the clinical effects of interventions that do not fall within cognitive or behavioral therapy (Ebrahimi et al., 2019).

1.4 Cognitive behavioral therapy

Cognitive behavioral therapy for anxiety disorders has evolved from behavioral therapy to the development of cognitive therapy, followed by the integration of cognitive and behavioral therapy (Seligman & Ollendick, 2011). During behavioral therapy, operant conditioning and classical conditioning stood central. One of Watson's students, Mary Cover Jones, was one of the first to apply behavioral techniques on children with fears and phobia, with "Little Peter" and systematic desensitization as the most known experiment. Aron Beck instigated the concept of cognitive therapy based on the assumption that changing cognitions would change one's emotions and behavior. The development of cognitive therapy led to the integration of cognitive behavioral therapy (CBT) (Seligman & Ollendick, 2011).

One of the most central cognitive behavioral models for PSA is explained through Clark and Wells (1995) cognitive model of social anxiety. The model proposes that anxious adolescents enter a feared public speaking situation based on previous experience. This triggers a set of catastrophic beliefs, which activates their anxiety and leads to changes in emotional, cognitive, physiological and behavioural symptoms that are intended to protect them from harm, although leading to a

maintenance of their anxiety. As the activation of anxiety causes them to focus their attention on themselves rather than focusing on the assignment, they use the internal information of as evidence of how others might perceive them, while ignoring all other information (Clark & Wells, 1995).

In order to overcome the feared public speaking situations, CBT interventions for PSA include the central component exposure therapy (Sewart & Craske, 2020). In exposure therapy, they face the feared stimuli which causes anxiety in safe environments and in various formats. The most common form of exposure therapy is through in-vivo exposure therapy (IVET), which exposes them to the feared stimulus in real life. Other types of exposure include imaginal exposure (exposure to images or mental images) and interoceptive exposure (exposure to bodily sensations).

Traditionally, exposure therapy has been guided and explained through emotional processing theory (Foa & Kozak, 1986). This theory emphasizes reducing within and between-sessions subjective units of distress (SUD's) as the primary indicator of successful treatment. The goal of the treatment is that 1) the patients report physiological responses to the anxiety-provoking situations, 2) their anxiety reaction has a gradual reduction during the exposure, and 3) a new session starts with a lower initial anxiety reaction than the previous one.

Emotional processing theory proposes that exposure therapy is efficient due to the activation of an existing fear structure and encoding it by adding incompatible information, leading to a reduction in fear (Foa & Kozak, 1986). A fear structure includes a stimulus (i.e., a presentation) - response (i.e., sweating) association and its meaning (i.e., "they think I am dumb"), which is stored in memory. A non-fear structure replaces this through the experience of incompatible information. The incompatible information causes *habituation* and weakens or erases the association between the preexisting stimulus and response, leading to a reduction in SUD's. The habituation can occur through prolonged exposure to the feared stimuli or by repeated exposure to the feared stimuli through graded hierarchical exposure (Foa & Kozak, 1986).

Although many adolescents may habituate to the anxiety, several experience relapse at a later point. In addition, some may also experience remission without habituating (Sewart & Craske, 2020). Therefore, the inhibitory learning model proposes an alternative theory for explaining the mechanisms involved in effective exposure therapy (Craske et al., 2008). According to the inhibitory learning model, the original fear structure is not erased, but inhibited through a new, secondary learning that competes with the original fear structure. Moreover, the inhibitory learning model suggests that it is the violation of the catastrophic beliefs which causes symptom reduction and not the habituation to the symptoms as formerly believed. Inhibitory learning has more focus on tolerating the anxiety rather than waiting for habituation and learning that it is safe to experience the symptoms as well as learning that the feared stimuli are safe. The inhibitory learning model is also different from the habituation model by not requiring a graded hierarchy with exposure sessions but can vary in exposure context, locations, stimuli, and internal state (Craske et al., 2008).

The inhibitory learning model's primary goal is to replace the catastrophic beliefs with new learning through exposure (Sewart & Craske, 2020). The inhibitory learning is greater when the expectancy is violated maximally, defined as *expectancy violation.* Therefore, each exposure task begins with asking questions about what they think will happen, making it as objective as possible. The new learning is consolidated at the end of each task when they are asked what actually happened and what they have learned (Sewart & Craske, 2020). Another strategy is *deepened extinction*, where multiple extinguished fear cues are combined and presented at once. This has shown to maximize long-term learning instead of including only one fear cue at a time (Rescorla, 2006). Moreover, the learning process is most efficient by including the “element of surprise”, meaning that there is a large discrepancy between what they think will happen and what actually happens (Sewart & Craske, 2020).

1.5 Predictors of treatment outcome

Although CBT interventions are effective in reducing anxiety symptoms, only one third of the adolescents are in remission at post-treatment (Baker et al., 2021). Therefore, it is important to investigate what predicts a good treatment outcome to optimize the interventions.

A wide range of studies have investigated predictors of treatment outcomes in adolescents with anxiety. For instance, high baseline levels of maternal and teacher-reported child/adolescent internalizing psychopathology, high baseline levels of maternal self-report of depression (Southam-Gerow et al., 2001), single-parent household, ethnic minority background (Kendall & Sugarman, 1997), and magnitude of change in subjective unit of distress (SUDs) over the course of treatment (Benjamin et al., 2010) have been associated with a poorer treatment outcome.

However, a systematic review comprising 32 anxiety studies found that the majority of the studies on adolescents did not identify moderators of treatment outcome in terms of demographics (age, gender, ethnicity, IQ) nor clinical factors (duration, type of diagnosis, pre-treatment, severity, comorbidity) (Nilsen et al., 2013). Similar findings were also reported in a recent meta-analysis which included 17 studies on adolescents and anxiety (Baker et al., 2021). The authors were not able to identify any moderators of treatment outcome in terms of treatment variables (group delivery format, greater number of treatment hours, disorder-specific treatment, and type of control treatment) and demographic variables, i.e. ethnicity. The non-significant finding might be because most studies report data from both child and adolescent sample and very few investigate adolescents separately, leading to few studies included in these analysis (Baker et al., 2021).

1.5.1 Perfectionism

Samira is 15 years old and is in the 10th grade. She runs a dance, gymnastics and book club in her spare time, in addition to working at Glitter on the weekends.

Samira has started to get nervous before oral presentations, because she is afraid of not being good enough. She usually starts reading about the topic of the presentation many weeks before she is to give it, and she rehearses for several hours every day to be ready for the presentation. Although Samira gets good grades and feedback from her friends, she rarely thinks she is good enough, and she always finds things she could have done better.

Perfectionism has been widely investigated and associated with a number of mental health disorders (Limburg et al., 2017). Researchers regard perfectionism as a transdiagnostic process, and is considered as a risk and a maintaining factor for many disorders, such as anxiety, depression, and eating disorders (Egan et al., 2011), although there is still limited evidence on adolescents (Wuthrich et al., 2020).

Perfectionism is defined as having unrealistic high standards in performance situations and being preoccupied with the need of being observed as flawless by others (Hewitt & Flett, 1991). One of the most central theories describes perfectionism as multidimensional, comprising three dimensions; other-oriented perfectionism, self-oriented perfectionism, and socially prescribed perfectionism (Hewitt & Flett, 1991). Other-oriented perfectionism is defined as having high standards towards others. Self-oriented perfectionism is defined as holding unusually high standards towards themselves, striving to meet these standards, and evaluating themselves negatively if they fail to meet these standards. Socially prescribed perfectionism is defined as striving for perfection based on external factors, and believing that others will be critical if they do not meet those expectations. The two latter are the most relevant for adolescents (Hewitt & Flett, 1991). Factor analysis of the multidimensional dimensions results in two aspects of perfectionism; maladaptive and adaptive aspects (Frost et al., 1993). Maladaptive perfectionism, also referred to as perfectionistic concerns, comprises concern over their mistakes, insecurity regarding performance ability and self-negative evaluation. Adaptive perfectionism, also referred to as perfectionistic striving, is regarded as a healthier trait, as the adolescents with perfectionistic strivings do not engage in the self-negative evaluation (Frost et al., 1993).

While adaptive perfectionism can be beneficial, the maladaptive type is associated with lower performance (Madigan, 2019). A review study found that maladaptive perfectionism showed a moderate to strong association with test anxiety, whereas adaptive perfectionism had a small positive, yet nonsignificant relationship with overall test anxiety (Burcaş & Creţu, 2021). Another systematic literature review (Wuthrich et al., 2020) showed that high pre-treatment levels of maladaptive perfectionism in adolescence is associated with increased performance anxiety. However, few of the studies in the review were conducted on adolescents, and more research and evidence is needed on a younger population (Wuthrich et al., 2020).

Researchers believe that maladaptive perfectionism can lead to non-effective treatment, or even deterioration (Shahar et al., 2004). For instance, in a study with children aged 6-13 years with anxiety disorder, they found that high pre-treatment levels of self-oriented perfectionism predicted poorer treatment outcomes at post and follow-up (Mitchell et al., 2013). Another study found that children aged 6-13 years with low pre-treatment level of perfectionism gained higher treatment outcomes following a CBT program targeting anxiety symptoms (Essau et al., 2012). One reason for this may be that maladaptive perfectionism causes difficulties in engaging with the therapist due to the high standards and self-critical evaluation. As they are preoccupied by being the "perfect" patient, this can be a hinder in gaining remission (Hewitt & Flett, 2002). Adolescents with these perfectionistic traits may therefore benefit from other intervention modalities than face to face (Shahar et al., 2004).

1.6 Intervention modalities targeting PSA

PSA interventions can be delivered through various modalities, such as face to face, pharmacological and surgical treatment, and through the use of technology, such as internet- delivered interventions and Virtual Reality. In general, a meta-analysis found no difference in effect size between the ways interventions are delivered (Ebrahimi et al., 2019). This provides unique opportunities in reaching out to individuals with regards to scalability and dissemination, as well as lowering the threshold for those who may be reluctant to seek face to face treatment. However,

they only identified one study targeting PSA in adolescence, and more research is still needed on this target group (Ebrahimi et al., 2019). In the following section, a brief summary of the treatment modalities for PSA will be provided, with evidence from the adult and adolescent population.

1.6.1 Face to face

Face to face treatment is the most common mode of treatment delivery for PSA, and can be delivered individually with several sessions, or in a group format. Individual CBT consists of regular meetings with the therapist with one hour sessions, once a week, for a prolonged period of 8 weeks or more (Öst, 1989). During a session the patient discusses their problems and distress, and the therapist offers help and provides guidance on how to cope with their problem (McCann & Pieter le, 2006), with in-vivo exposure therapy typically conducted in-between sessions.

Group therapy is considered as more cost-effective and a more feasible option compared to individual therapy with several sessions (Leader, 1991). Group therapy involves more patients and can also involve more than one therapist. The therapy includes more dynamic processes, peer feedback and group sharing. Group therapy can be beneficial as some might find it discomforting sitting alone with a therapist, as well as finding comfort when knowing that others share the same experiences (Leader, 1991). In the case of PSA, group therapy also makes it possible to practice on their communication skills, by providing an exposure setting. One study on CBT group therapy targeting adults with PSA showed that group therapy was more efficacious than a credible placebo group on self-report assessments (Heimberg et al., 1990), however, the results from behavioral and physiological assessments were smaller and more inconsistent.

CBT treatments for anxiety disorders have undergone an extreme development in order to shorten the length of the therapy and make it more cost-effective. With Öst's (1989) development of One-Session-Treatment (OST), one can treat specific phobias with only one intensive session lasting for around 3 hrs. The main component of OST is massed exposure, with a series of behavioral experiments that are developed in

order to test and disconfirm their catastrophic thoughts. Following the session, it is recommended that they continue with exposure in a naturalistic environment in order to enhance the clinical effects (Öst, 1989). The OST intervention method (Öst, 1989) is originally developed for adults, however, in the last years there has been growing evidence on utilizing this on adolescents with some adaptations (Davis III et al., 2019). A review study concluded that OST is an effective intervention for children and adolescents with specific phobia (Ollendick & Davis, 2013). Adolescents also tolerate this type of intervention well and show a positive attitude towards it (Davis III et al., 2019)

Although OST is developed for specific phobias, it has also been shown to be efficacious in treating PSA (Hindo & González-Prendes, 2011). This can be related to the fact that individuals with PSA share some similarities with those who have specific phobia, such as heightened physiological arousal (Hook & Valentiner, 2002), and is qualitatively and quantitatively different from generalized SAD (Blöte et al., 2009). One pilot study investigated the clinical effects of one session treatment on adults with PSA symptoms (Hindo & González-Prendes, 2011), and included graduated exposure to public speaking group exercises with additional homework as part of the maintenance program. The results showed significant changes in PSA symptoms from pre to post, and the clinical effects were maintained at follow-up.

1.6.2 Pharmacological treatment

Selective serotonin reuptake inhibitors (SSRI's) are the first-line treatment for anxiety disorders in pharmacological treatment (Farach et al., 2012). However, around half of the patients have mild to moderate side effects. SRRI's are also associated with increased suicidal ideation, and especially adolescents need to be monitored carefully. Benzodiazepines are prescribed as a short-term acute treatment, such as prior to a presentation. However, the effect disappears quickly, which can encourage long-term reliance on the drug (Farach et al., 2012).

1.6.3 Surgical procedures

Endoscopic thoracic sympathectomy (ETS) is a surgical treatment for patients with excessive sweating and facial flushing (Jadresic et al., 2011). The procedure involves cutting the sympathetic nerves, and studies have reported high satisfaction for patients going through this kind of treatment. However, non-surgical treatment is always considered as first line treatment, as the procedure is an invasive method and irreversible (Jadresic et al., 2011). Botox can also block the nerve signal and cause a reduction in sweating (Neumayer et al., 2005). However, it requires regular treatment as the effects are only temporary, expensive and requires local anesthesia. These methods should therefore only be recommended when other methods fail.

1.6.4 Internet interventions

The availability of modern consumer technology makes this an attractive way of delivering mental health intervention. A prominent example is internet-delivered cognitive behavior therapy (iCBT) where the therapy is delivered over the Internet, demonstrating large clinical improvements, low deterioriation and high patient satisfaction (Titov et al., 2018). This approach dates back to the millennium and solve many of the barriers experienced with more traditional therapy, such as being able to treat a higher number of patients and providing services to those living in remote areas (Nordgreen et al., 2018). It is more flexible, easily available, and provides anonymity and privacy for the adolescents, thus, reducing the stigma experienced with seeking mental health services (Sweeney et al., 2019).

Internet-delivered interventions consist of modules that are assigned to them at a regular basis. The modules include educational texts about the disorder, including home assignment and worksheets that they have to conduct and fill out during the intervention (Titov et al., 2018). The intervention can be delivered in a therapist-guided or a self-guided format. The guided format includes therapeutic support with guidance once a week typically through a chat function or phone calls, whereas in a self-guided format the patients go through the intervention on their own with no or minimal contact with a therapist (Haug et al., 2012).

Therapist-guided internet-delivered interventions are associated with more effectiveness, adherence as well as lower dropout rates in adolescents (Lehtimaki et al., 2021). However, self-guided internet-delivered interventions have the advantage of reaching out to many individuals, are cost-effective, and reduce the concern of stigma and embarrassment in adolescents (Sweeney et al., 2019), and may therefore be provided as part of stepped care treatment (Haug et al., 2012). A recent review investigated the clinical effects of internet-delivered interventions for adolescents aged 11-19 years (Wickersham et al., 2022), with the majority of the interventions involving minimal contact with a therapist. The study found that internet-delivered interventions were comparable to face-to-face therapy (Wickersham et al., 2022).

When it comes to PSA, one review study concluded that internet-delivered interventions targeting PSA have similar treatment effects as conducting the treatment face to face (Ebrahimi et al., 2019). One study investigated the efficacy of the self-guided internet-delivered intervention “Talk to me” and compared this with treatment delivered by a therapist and a waiting-list control group (Botella et al., 2010). A total of 127 university students were included in the study and randomized to the three groups. The study found equal efficacy with large effect sizes in both interventions and both groups improved significantly more than the waiting-list condition, with maintained improvement at one-year follow-up. Another study investigated the efficacy of an internet-delivered self-guided program with or without the combination with group exposure sessions on university students with social phobia and public speaking fears (Tillfors et al., 2008). The study did not find any significant difference between the self-guided program alone and the combination with group exposure.

1.7 Virtual Reality

CBT interventions include the central component in-vivo exposure therapy. However, in-vivo exposure therapy (IVET) presents some logistical challenges when it comes to PSA: First, IVET requires access to individuals who can act as an audience, which can be difficult to arrange, costly and time-consuming. Second, it is difficult to

conduct the exposure outside of the office, due to therapist-patient confidentiality. This often leads to assignment in-between sessions, where the adolescents have to complete exposure tasks independently, i.e., in school settings. As the therapy requires exposing themselves to their fear, they may drop out of treatment, or use safety behaviors that diminish the exposure effects (Blakey & Abramowitz, 2016). Third, even the therapist might be afraid of conducting the exposure tasks, as they worry that the exposure scenarios will be too stressful for the patient. One study found that some therapists do indeed have strong opposing beliefs against exposure therapy, finding it unethical, potentially harmful and intolerable for patients (Deacon & Farrell, 2013). And fourth, perfectionistic attitudes due to the presence of a therapist may hinder the treatment response (Hewitt & Flett, 2002).

Virtual Reality technology offers a solution to some of the logistic challenges in providing exposure therapy. Virtual Reality (VR) refers to the illusion of being present in an artificial environment, most commonly through the use of Head-Mounted Displays (HMD) (Lindner, 2020). The technology has become increasingly accessible for regular consumer use during the last decade, including off-the-shelf consumer hardware and software. VR as an intervention method for adolescents has a tremendous potential. Given its low barriers and playful elements, it is especially relevant for adolescents as their lives are surrounded by technology (Bioulac et al., 2018). Moreover, adolescents with anxiety report a high acceptability rate with regards to VR interventions (Joshua N. Kelson et al., 2021). Thus, VR intervention can serve as early intervention and prevention for this group and lower their threshold for seeking mental health advice (Meyerbröker & Morina, 2021).

1.7.1 Presence and immersion

Presence and immersion are vital factors describing user experience in VR. Presence is referred to as the subjective experience of being in another world (Lee, 2004), and distinguishes VR from other technology. Presence in VR is a perceptual illusion, yet, a powerful illusion as the user acts with the environment just as he or she would have done in a natural environment. Immersion relates to the experience of being deeply involved in a game. While reading a book or playing a video game may also make

one feel immersed, however, they still do not feel physically transported into another world (Lindner, 2020). Other researchers may also define immersion as the objective response to the Virtual Reality environment and is more related to the technology involved. Thus, more advanced technology can lead to a higher immersion (Slater, 2018).

Although presence and immersion are different constructs, they are also interrelated. A higher immersion is associated with a higher presence, but a person in a system with low immersion can still experience presence. It may require that they break from the immersiveness and use mental imagery and associations from the real world to "fill the gaps" in the virtual environment (Slater, 2009).

A higher sense of presence is considered a central psychological mechanism in VRET as it has been associated with higher levels of anxiety. However, in SAD the effect size of the correlation between presence and anxiety level is smaller compared to other anxiety disorders, and the direct causal relationship between presence and anxiety is not known (Ling et al., 2014). There has been limited research on the association between presence and anxiety the last decade, although a study from 2019 suggest a bidirectional relationship between both presence and fear (Gromer et al., 2019).

1.7.2 VR history

The history of Virtual Reality begins already in the 1960s with the use of head-mounted displays (HMD) in the computer (Sutherland, 1968) and flight industry (Furness, 1986). It was not until the 1990's that the VR technology evolved and thereby received interest from clinical researchers (Rothbaum et al., 1996; Slater et al., 1999). However, it required expensive equipment with high-end computers, and the HMD's at that time were heavy and bulky with low resolution, and users easily experienced cyber sickness (Rebenitsch & Owen, 2016). There has been rapid development in VR technology the last decade. It is only in the last five or so years that VR technology has become easily available for the regular consumer, creating many opportunities for psychological interventions. Samsung Gear VR introduced

mobile VR devices used together with a compatible smartphone running the VR applications and launched a new generation of VR consumer hardware and software. Today, VR technology has developed further as freestanding HMD's, i.e. Oculus Quest, which includes inside-out motion and hand tracking (Lindner, 2020).

1.7.3 VR exposure therapy (VRET)

Virtual Reality Exposure Therapy (VRET) involves creating a virtual environment with the feared stimuli without the need for great resources, providing new opportunities for exposure therapy. Moreover, the exposure therapy in VR can be easily controlled by the therapist (Morina et al., 2021). As it is easily available for both the therapist and the patient, it may also be less stigmatizing by maintaining the therapist-patient confidentiality when exposure can be conducted at the therapist's office.

VRET for PSA offers a virtual audience readily available for both the therapist and the patient. The feared situations in VR are generated by using 360° videos or through computer-generated animated audiences. Both stimuli modalities present distinct advantages and disadvantages: 360° videos have great visual realism and can be developed rapidly and are more cost-effective than computer-generated VR environments. Yet, the applications are limited by not being interactive (Yeo et al., 2020), whereas computer-generated virtual environments can, in the same manner as common video games. However, especially with mobile headsets, computational limitations lowers the theoretical visual realism. When using social stimuli, this may result in the "uncanny valley" phenomenon (Mori et al., 2012), wherein near-perfect human stimuli is perceived as uncomfortable, compared to perfectly human-like or even less human-like. For this reason, VR developers may choose to use semi-realistic avatars, who instead display high behavioral realism (Lindner et al., 2017).

Meta-analyses of randomized controlled trials have demonstrated equal efficacy when comparing VRET and IVET for agoraphobia, specific phobia (Wechsler et al., 2019), and SAD (Horigome et al., 2020; Morina et al., 2021). However, one meta-analytic review suggests that the clinical effects of VRET for SAD diminish at

follow-up when compared to IVET (Horigome et al., 2020) and another reported effect sizes favoring IVET (Wechsler et al., 2019). Additionally, review studies suggest that both treatment methods have similar dropout rates (Horigome et al., 2020). A meta-analysis on specific phobias further documented that the clinical effects can be generalized to the real world (Morina et al., 2015).

VRET has proven to be an efficient method for adults with PSA (Donker et al., 2019; Ebrahimi et al., 2019; Kampmann et al., 2016; Lindner et al., 2019; Miloff et al., 2019). One review study found 13 out of 14 studies to report positive results from VRET interventions for PSA (Daniels et al., 2020). A more recent meta-analysis found that VRET was more effective in reducing self-reported PSA symptoms when compared with waiting lists with large effect sizes (d = 1.39), although IVET was marginally superior to VRET (Reeves et al., 2021).

However, there is limited research on the clinical efficacy of VRET for PSA in children and adolescents. One systematic review (Kothgassner & Felnhofer, 2020) found only four published studies on VRET in the age group 8-16 years, whereas only one of the studies targeted PSA. A more recent review investigated VRET for adolescents with psychological distress (Joshua N. Kelson et al., 2021), and identified only two pilot studies targeting PSA and SAD. One recent study investigated whether brief exposure training in front of a virtual audience using 360º videos reduced anxiety in children aged 9-12 years (Sülter et al., 2021). One class of school children was allocated to the VR training, and another was allocated to a VR control (at home) condition. The VR training reduced their anxiety and showed the potential of using VR for a younger population. However, there is still a need for controlled trials and more research to generalize the findings to adolescents.

1.7.4 From therapist-guided to self-guided VRET

Most of the VR interventions targeting PSA so far have been therapist-guided, where the therapist gives instructions on how to conduct the exposure therapy (Lindner et al., 2019). The intervention format is more reliant on the therapeutic alliance to reach the therapeutic goal. Self-guided, automated VRET benefits by being cost-effective

as it does not require trained therapists, and can be disseminated as self-help at clinics, as part of blended treatment or available at the regular app store, thus making interventions easily available for the adolescents (Lindner, Miloff, et al., 2020). Moreover, the self-guided version enables more autonomy and perceived control to the participant (Premkumar et al., 2021).

One study combined therapist-guided one-session treatment (Öst, 1989) with the use of VR technology (Lindner et al., 2019). The study included 50 adult participants with PSA who were randomized to either one-session therapist-guided VR treatment followed by an internet-delivered exposure program or a waiting list. Participants who received the VR treatment had a significant reduction in self-reported PSA symptoms compared with the waiting list, with large effect sizes. The waitlist group later received access to an internet-administered version of the same VR intervention in a self-guided format. The results from the study showed that those receiving self-guided VRET for PSA also had a significantly large reduction in PSA symptoms (Lindner et al., 2019). More recently, a study with a total of 44 undergraduate students diagnosed with SAD were randomized to a self-guided VR intervention using 360° videos or waitlist. The study showed moderate to large effect sizes in reduction of anxiety symptoms for the VR intervention compared with waitlist (Zainal et al., 2021). There is also growing evidence on the clinical efficacy of self-guided, automated VRET for other specific phobias, i.e. spider phobia (Miloff et al., 2019), fear of heights (Freeman et al., 2018), and agoraphobia in patients with psychosis (Freeman et al., 2022).

Self-guided, and automated VRET may include different parameters of virtual public speaking threats, which could improve the clinical efficacy and induce anxiety (Premkumar et al., 2021). Varying challenges may include 1) audience size, 2) the reaction of the audience, 3) exposure task situation, 4) exposure task instructions, and 5) duration of the task. Manipulation of the audience size and audience reaction provides a variety of exposure situations (Anderson et al., 2013), and research shows that manipulating these elements may induce anxiety (Pertaub et al., 2002). Different exposure situations and combining them with different instructions (i.e., the

instructions on what they are going to say) and the task's duration provide different ways of conducting exposure in the same computer-generated virtual environment, in accordance to the inhibitory learning model (Craske et al., 2008).

The most novel form of self-guided VR is developed as a “Serious Games”, designed as an entertainment as well as a learning process. Serious Games includes a learner-centered approach, and facilitates learning through interactive elements (Checa & Bustillo, 2020). Serious Games may include gamification elements such as badges and achievements, progression levels, performance ratings, increasing difficulties, points, and goals in order to increase their engagement (Lindner, Rozental, et al., 2020). Gamification elements have been previously investigated on spider phobia, with promising results (Lindner, Miloff, et al., 2020). Users rated this treatment method as appealing and the gamification elements were successful in framing the intervention as a Serious Games rather than psychotherapy (Lindner, Rozental, et al., 2020). If adolescents regard this as serious games rather than treatment, this may be even more appealing as most adolescents are accustomed to gaming (Fleming et al., 2017) and dominate the VR market (Garrett et al., 2018). Thus, automated and gamified VRET may have a potential to reach out to individuals who otherwise would not seek help.

1.8 Aims

The overall aim of the thesis was to explore the effects of a new generation of automated Virtual Reality interventions as a self-guided intervention for adolescents with public speaking anxiety, with the main goal of reducing the complaints they experience at the moment, as well as preventing long-term negative consequences of PSA. The thesis took a quantitative approach with focus on change in PSA and SAD symptoms before, during and after participating in a VR intervention. The thesis presents results from two studies; a feasibility and pilot study described in paper I, and a randomized controlled study described in paper II and III.

1.8.1 Aims and research questions paper I

In the first paper, the aim of the study was to investigate whether a therapist-guided VR intervention for adolescents was feasible, by conducting a non-randomized feasibility and pilot study. The study protocol was an adapted version of the 3 hrs single session therapist-guided VRET intervention for adults with PSA (Lindner et al., 2019). The study wished to investigate changes in PSA symptoms before and after the intervention and compare the effect sizes to the adult version. The study also examined potential moderators of treatment, as well as monitoring heart rate and examine the physiological response to the intervention.

The research questions for paper I were: Is Virtual Reality a feasible method for adolescents with public speaking anxiety? Are the clinical effects of the adapted version similar to the original protocol tested on adults? Does high baseline generalized social anxiety symptoms and presence in the virtual environment moderate treatment outcome? And last, what are the physiological responses to the VR intervention?

1.8.2 Aims and research questions paper II

In the second paper, the aim was to investigate the clinical efficacy of a self-guided, automated and gamified VR intervention, and whether VR intervention led to an increase in subsequent exposure tasks during the online exposure program. This was conducted in a two-phased, four-armed randomized controlled trial, by analyzing changes in symptoms before, during and after the intervention.

The research questions for the paper II were: What is the clinical efficacy of self-guided Virtual Reality Exposure Therapy for adolescents with PSA when compared with waitlist and online (internet-delivered) self-guided programs? And, does VR and the additional exposure program facilitate more in-vivo exposure tasks compared to those who receive the online psychoeducation program with the additional exposure program?

1.8.3 Aims and research questions paper III

In the third paper, we investigated the associations between perfectionism and the clinical efficacy when receiving self-guided interventions for PSA. The primary aim was to investigate whether an intervention targeting PSA also decreases symptoms of perfectionism. The second aim was to investigate whether symptoms of perfectionism moderated the clinical efficacy of self-guided interventions for PSA.

The research questions for paper III were: Does an intervention targeting PSA also decrease symptoms of perfectionism? Does perfectionism moderate the clinical efficacy of digital self-guided interventions for PSA?

2. METHODS

The papers laying the foundation of the thesis include two studies; a feasibility and pilot study (paper I) and a randomized controlled study (paper II and III).

2.1 Feasibility and pilot study: paper I

Paper I was a non-randomized feasibility and pilot study with assessments at pre, post, one-month, and three-month follow-ups.

Feasibility is defined as "an overarching concept for studies assessing whether a future study, project or development can be done" (Eldridge et al., 2016, p. 15), and is conducted as a first step as a preparation to a future randomized controlled trial. The feasibility studies can be divided into "randomized pilot studies, non-randomized pilot studies, and feasibility studies that are not pilot studies. Thus, feasibility studies is an umbrella term and pilot studies are a subset of the feasibility studies. Non-randomized pilot studies such as the study in Paper I evaluate parts of the intervention that will be carried out in a future RCT, but without the randomization of the participants (Eldridge et al., 2016).

2.1.1 Participants, setting and procedure

Adolescents from Bergen Municipality, Norway, were recruited in two periods; spring 2018 and autumn 2018. Information about the study was presented in classrooms at two high schools. In addition, adolescents received written information about the study with a link to the study website. Parents, school health services, and headmasters at the schools in Bergen received the same information through e-mail. Information about the study was also promoted using Facebook.

To participate in the study, interested participants would fill out the online screening, which included the Public Speaking Anxiety Scale (PSAS; (Bartholomay & Houlihan, 2016)) and Social Interaction Anxiety Scale (SIAS; (Mattick & Clarke, 1998)). To be included, adolescents had to be between 13 and up to 16 years old, confirm that they were afraid of speaking in public, and had to report symptoms of

PSA on the PSAS measurement. Exclusion criteria were assessed during the following phone interview which were: psychological or pharmacological treatment for mental health disorders, balance problems, and lack of stereoscopic vision that would have a negative impact on the VR experience.

A total of 38 interested participants filled out the online screening, whereas $N = 27$ participants were included. The sample consisted of 6 males (22%) and 21 females (78%), with a mean age of 14.22 years ($SD = 0.64$). Parental consent was obtained at the very start of the training session from all adolescents under 16 years old.

2.1.2 Intervention

The intervention was adapted from a treatment protocol for adults with PSA (Lindner et al., 2019), which is based on Öst's one-session treatment for specific phobias (Öst, 1989), and combined with VR exposure therapy. Whereas the Lindner trial was a 3 hrs single session, and consisted of around eight exposure tasks with a duration of one to three minutes each, the current trial was reduced to 90 minutes with around seven exposure tasks with a duration of one to two minutes each. Moreover, the psychoeducation and the exposure session was adapted in order to fit a younger sample and included more examples they could relate to, as asking open questions may often result in an "I don't know" answer. And last, the adapted protocol included a phone interview two weeks following the training session in order to promote in-vivo exposure and increase adherence for data collection purposes.

Whereas the study by Lindner et al. (2019) used a commercialized VR scenario from the App Store market, the current study used a tailored VR intervention specifically designed for an adolescent group with a Norwegian classroom environment. The scenario was developed by Attensi AS, and presented on a VR cardboard headset (for approx. 60 USD) and Apple iPhone 7. The VR scenario developed for this purpose was an animated classroom, consisting of ten virtual avatars in the same age range as the participant, sitting at their desks, acting as an audience with some body movements, while the participant was standing in front of the class. The application

also included an empty neutral classroom in order to conduct the initial setup of the VR equipment. In addition, there was a lobby where each exposure task started and finished.

Figure 1

Screenshots from the VR application

The session was therapist-guided and lasted for 90 minutes, consisting of 1) psychoeducation 2) exposure using Virtual Reality, and 3) a summary of the session and promoting in-vivo exposure. The goal of the session was to promote inhibitory learning by disproving their catastrophic beliefs through exposure tasks. The therapists conducting the training had prior experience with CBT, in addition to participating in a 4 hours VR-treatment protocol workshop.

The participants met at Haukeland University Hospital. The session began with psychoeducation, with information about CBT, PSA in general, and treatment rationale and case formulation of their anxiety. Following the psychoeducation, the participants put on the VR device and conducted a test trial in the empty, neutral classroom before starting the VR exposure tasks with guidance from the therapist. The participants were presented with a total of seven VR exposure tasks with varying difficulty and each lasting for 1 to 2 minutes. They only wore the VR device during

the actual exposure tasks. Each task required entering and leaving the full classroom from the lobby, and included the following steps:

1) the participants received instructions for the presentation they were about to give, and reported their catastrophic beliefs and their expectations
2) the participants wore the VR device, entered the full classroom from the lobby, and gave the presentation in front of the animated audience. During the exposure, the therapist audio-taped their presentations. As soon as they completed the exposure task, they went back to the VR "lobby" and took off the VR device.
3) immediately after the exposure, the participants rated the quality of their presentation, and whether the catastrophic beliefs occurred or not, and subjective unit of distress (Sripada & Rauch, 2015)
4) the participant and the therapist listened to the audiotape using mental imagery and by acting as if they were one of the audience members in the same virtual scenario.
5) the participants rated the quality once again and whether there were any discrepancies between their catastrophic beliefs and what really happened.

At the end of the session, there was a summary round and the adolescent received a handout, with instructions on how to practice in real life (in-vivo exposure).

2.1.3 Measurements

Public Speaking Anxiety Scale (PSAS; Bartholomay & Houlihan, 2016) is a 17-items questionnaire, measuring symptoms of PSA on a 5-point Likert Scale, ranging from 1 (not at all) to 5 (extremely). A higher sum score indicates more symptoms of anxiety. The scale has three subscales measuring behavioral, cognitive, and physiological aspects of PSA. The scale was originally developed for adults. However, user testing with adolescents did not present any misinterpretations of the scale. The scale was translated to Norwegian using scientific standards (back-translation). Cronbach alpha at prescreening was 0.76

The Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) is a 20-items questionnaire, measuring symptoms of generalized SAD, and includes symptoms related to social interaction situations. The scale ranges from 1 “not at all characteristic or true of me” to 4 “extremely characteristic or true of me”, with a higher sum score indicating more symptoms. Cronbach’s alpha at screening was 0.86.

Gatineau Presence Questionnaire (GPQ; Laforest et al., 2016) is a five items questionnaire, measuring the degree of presence experienced in the VR scenario on a scale from 0 to 100. A higher average score indicates a high sense of presence.

Physiological data: By using a wearable Empatica E4, the study collected heart rate data which was synchronized with the data obtained from the VR headset registering when they were in a lobby or a full classroom. Heart rate data from the time spent in the lobby was compared with the data from the time spent in the full classroom.

2.1.4 Statistical analysis

Power calculations prior to the trial showed that in order to gain 80 % power to detect a within-group effect size of d>0.5, a sample size of at least N = 26 was required. A smaller effect size was estimated as previous studies normally include several sessions while the study in paper I only included a single session.

Data were analyzed using SPSS Statistics version 24. Outcome data were analyzed using linear mixed-effects models, with restricted maximum likelihood, unstructured random effects, covariance matrices, random slopes and intercept. The analysis included PSAS as the dependent variable in all models, with a binary independent time variable (0=both screening and pre, 1=post). Moderation analysis was conducted with a binary moderator (high vs low), the same time variable and the interaction thereof. Long-term effects were investigated in a separate linear mixed model with a new numeric time variable (0=post, 1 = one-month follow-up, 3 = three-month follow-up). Effect sizes were calculated using the formula: $Pre_m - Post_m / SD_{pre,}$ where pre and post are based on estimated means, and SD_{pre} is calculated using the formula $SD = standard\ error\ x\ \sqrt{N}$. Heart rate data were analyzed using linear mixed

models, with random slopes and intercept. Period-average heart rate served as the dependent variable and period, defined as during exposure (in full classroom) or in between exposure (in lobby), served as the independent variables.

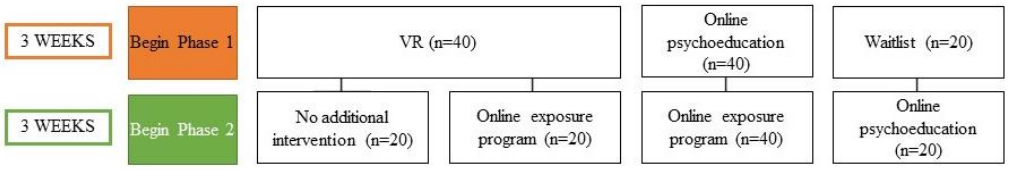
2.2 Randomized controlled study: paper II and III

The study conducted in Paper II and III was a two-phased four-armed randomized controlled study with pre, post, three-month, and 12 month follow-up, as well as weekly measures. Each phase had a duration of three weeks, giving a total of six weeks of intervention.

The participants were allocated to four groups with the respective phase one + phase two intervention: 1) VR + no additional intervention (VR only), 2) VR + online exposure program (VR + online EXP), 3) Online psychoeducation + online exposure program (online PE + EXP), and 4) Waitlist + online psychoeducation program (waitlist + online PE) (See Figure 2).

Figure 2

Two-phased, four-armed RCT design



Randomized controlled studies are considered to be the gold standard. In a RCT study, participants are randomly assigned to one or more groups. Assuming the randomization works, the participants in the groups should be similar. Randomizing

patients reduces the risk of unbalance between the participants and ensures that their characteristics are similar between the groups before starting the intervention. Hence, any observed treatment effect is a result of the intervention received, rather than individual differences (Vader, 1998).

2.2.1 Participants, setting and procedure

The first round of recruitment began in March 2020. A few days later, Norway was in a complete lockdown due to the Covid-19 pandemic. As the adolescents participating in the training program would have difficulties in conducting exposure training, the recruitment process was delayed, and the first 30 participants were excluded from the analysis. A second round of the recruitment process started in September 2020 and ended in March 2021. Covid-19 pandemic was still ongoing, with varying restrictions throughout this period.

The adolescents were recruited from Bergen Municipality as well as surrounding areas. Information about the study was distributed through the same channels as in the feasibility and pilot study. In addition, the study was also promoted through a Facebook and Instagram profile and through an advertisement on a Snapchat health service channel. Posters and brochures were distributed to nearly all schools in Bergen. Furthermore, a collaboration with Bergen Municipality's school health services facilitated the recruitment process by distributing information about the study through email.

The adolescents were invited to the study by accessing the study website UngSpotlight.no (YoungSpotlight) and filling out the online screening assessment. In order to be included, the participants had to 1) answer yes to the questions "Are you afraid of speaking in front of your class?" and "Do you avoid speaking in front of your class if possible?", 2) report symptoms on PSAS (Bartholomay & Houlihan, 2016) of 55 or more, with a cut-off score based on the median score from the previous study 3) be aged between 13-16 years old, 4) reside in Bergen Municipality or surrounding areas, 5) and leave their phone number.

A member of the study team conducted a phone interview with the eligible participants meeting the inclusion criteria. Exclusion criteria were assessed during the phone interview which was conducted with parents and/or adolescents. The exclusion criteria were the following: 1) reading difficulties, 2) balance problems or an impairment in vision which could affect the VR experience, 3) psychological or pharmacological ongoing treatment making it difficult to participate in the training program. A final decision regarding inclusion was made at the end of the phone interview based on the inclusion and exclusion criteria. If unsure, the participants were discussed in a study team meeting and a final decision was made in collaboration.

A total of 253 completed the online screening, whereas $N = 100$ adolescents were enrolled in the study. Of the included participants, 84 were females and 16 males, with a mean age of 14.2 years ($SD = 0.99$).

Enrolled participants were randomly assigned to one of four groups and given information about the intervention during the same phone call. They received access to a digital platform with consent form and pre-assessments immediately after the interview. Informed consent was obtained digitally by parents or adolescents if aged 16. Those allocated to the VR intervention met with a member of the study team within the next few days and received a VR device they would borrow for the following three weeks. In addition, the VR groups received a handout with instructions on how to start the application and a phone number in case they needed technical support.

2.2.2 Interventions

A total of three digital self-guided interventions were designed for this purpose; Virtual Reality, online psychoeducation program and online exposure program.

Virtual Reality

Attensi AS developed the VR scenario which was presented on Oculus Quest. The application was an automated and gamified Virtual Reality environment, consisting of a typical Norwegian classroom and a computer-generated audience. The classroom

included 14 virtual avatars depicted to be approximately 13-16 years sitting at their desks with their gaze directed at the participant (See Figure 3 for VR application screenshots). The participants had to complete 15 predefined public speaking related exposure tasks with varying challenges, based on four parameters; 1) audience reaction, 2) the number of audience, 3) duration of the task, and 4) task assignment, based on two different exposure scenarios; talking in front of the audience or sitting by the desk and reading out loud from a book in Norwegian or English. Gamification elements included progression levels, and performance star ratings. In order to proceed to the next "level" they had to receive a minimum of 4 out of 5 stars, based on predefined threshold levels of pseudo-gaze, i.e. looking at the audience, and whether they spoke out loud. The threshold levels were set through a thorough user testing by the clinicians involved in the developmental process. Moreover, a second environment was "unlocked" as soon as they completed the first five levels, where they were able to manipulate their own exposure tasks based on the different automated elements.

The exposure tasks were based on inhibitory learning. Each task began in an empty grey corridor where they received task instructions. Following the instructions, the participant reported expected catastrophic beliefs by selecting one from a pre-defined list. Having completed the exposure task the participants rated their SUD's on a scale from 0 to 100. Moreover, the participant reported whether the catastrophic beliefs occurred and what they have learned before they eventually received a star rating and could proceed to the next level.

Figure 3

VR application screenshots

Online Programs

YouWell AS developed the digital platform used for the online programs in the RCT study. The platform includes two front-ends; 1) the adolescent's/parent's front-end for accessing the modules, filling out assessment and consent forms, and 2) the therapist's front-end used for monitoring the progress of the adolescents, including an editing tool for creating and modifying the content and the work-flow of the online programs. In order to access one of the front-ends, they had to log in with a secure, digital two-factor authentication signature. In addition to the online programs, the adolescent received all weekly assessments through the digital platform and were notified by SMS or e-mail. They also received notifications if they remained inactive for four days.

Figure 4

BitMoji Avatars

Most of the text in the online programs were delivered through three BitMoji avatars, which you have been introduced to in the introduction section of this thesis. Emma, Lucas and Samira were depicted to be in the same age range as the adolescents and experienced PSA in different ways (see Figure 4). Emma avoided public speaking situations altogether, Lucas was afraid that others would notice his nervousness, whereas Samira's main concern was that her performance was not perfect. The adolescents got familiar with the avatars and how they managed to cope with their anxiety throughout the program.

Online Psychoeducation program

The online Psychoeducation (online PE) training lasted for three weeks and consisted of three modules, with access to one module per week. Online PE program focused on normalizing about PSA, educating about cognitive behavioral therapy (CBT), and getting familiar with their own vicious circle of thoughts, feelings, bodily symptoms, and behavior.

The first module consisted of information regarding PSA, how thoughts, feelings, bodily symptoms and behavior are interrelated, and how they can recognize their own vicious circle. The second module consisted of information regarding typical catastrophic beliefs related to PSA and how they can challenge these thoughts. The third module consisted of information regarding typical safety strategies and how

these may maintain their anxiety in public speaking related situations. In addition, they received information about self-focusing behavior and exercises related to shifting their focus (see Figure 5).

Figure 5

Online Psychoeducation program

Online Exposure program

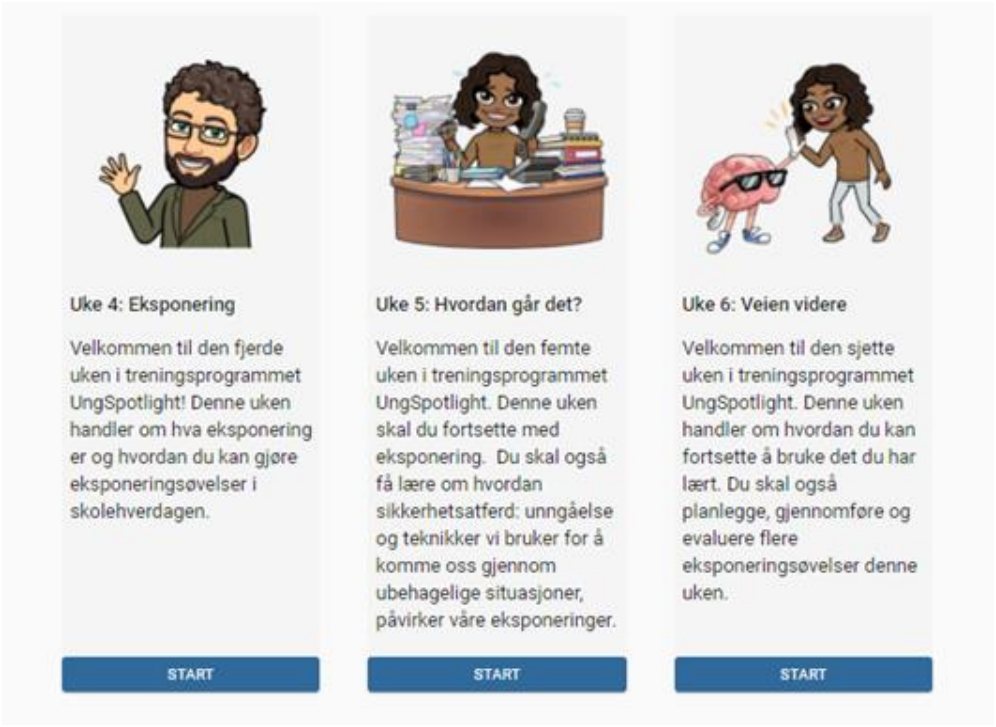
The online Exposure (online EXP) training lasted for three weeks and consisted of three modules, with access to one module per week. The training program focused and promoted the importance of in-vivo exposure tasks, and how to distance themselves from safety strategies and their catastrophic beliefs. They were advised to complete at least three exposure tasks per week during the online exposure program.

The first module of the online exposure program consisted of information regarding the importance of exposure and how to plan and conduct exposure tasks related to

public speaking situations. The second module of the online exposure program focused on how to identify safety strategies and removal of these while exposing themselves to the feared public speaking tasks. The last module focused on how to continue practicing and relapse prevention (see Figure 6).

Figure 6

Online exposure program



Adjustments to the intervention and treatment protocol

Originally, the plan was to recruit N=160 to 1) VR (n=40), 2) Online PE (n=40), VR + online PE (n=40) and waitlist (n=40) in the first phase. In the second phase, half of the participants allocated to the intervention programs would receive a transitional online exposure program (n=60), while the other half would only receive weekly

assessments, and the waitlist group would receive an online PE program. As the pandemic led to a half year of delay in recruitment, we had to make some adjustments and a somewhat simplified, new treatment protocol was made.

2.2.3 Measurements paper II and III

Public Speaking Anxiety Scale; PSAS (Bartholomay & Houlihan, 2016) was administered to assess symptoms of PSA at pre-treatment, post and follow-up, as well as weekly measures. To be included, the participants had to report a total symptom score of 55 or more at screening. The threshold was set based on the data collection from the feasibility study, by using the median score. See section 2.1.3 for more details. Cronbach's alpha at pre-screening was 0.76.

Social Interaction Anxiety Scale (SIAS) and *Social Phobia Scale (SPS).* The short version of the Social Interaction Anxiety Scale (SIAS) and Social Phobia Scale (SPS) (Peters et al., 2012) was administered in the RCT study. The questionnaire combined is a 12-item questionnaire, measuring generalized social anxiety symptoms on a scale from 0 (not at all) to 4 (extremely). A combination of the Social Interaction Anxiety Scale (SIAS) 6 and the Social Phobia Scale (SPS) 6 has proven to be a validated assessment to measure the more generalized form of social anxiety and gives us a short screening tool that is easy to assess (Peters et al., 2012). The short version is also tested on adolescents with adequate psychometric properties (Zsido et al., 2021). Cronbach's alpha at pre-screening was 0.84 for SIAS-6 and 0.90 for SPS-6.

Numbers of completed in-vivo-exposure tasks. One hypothesis for the RCT study was that the group receiving VR as a first step would complete more subsequent in-vivo exposure tasks during the online exposure program in phase two compared to the group receiving online PE. The lowered threshold hypothesis (Lindner et al., 2021) could explain why individuals receiving VR intervention continue to have a long term improvement after discontinuation of VR in the years that follow due to subsequent in-vivo exposure (Anderson et al., 2017). This was measured by summing up the number of completed forms, ranging from zero to seven completed exposure tasks.

Harmful effects. Deterioration rates were assessed as defined by the reliable change index formula, where *SE* is pre-treatment standard error, *S_k* is the standard deviation and *r* is the reliability coefficient.

$$d = 1.96 \ \llbracket SE \rrbracket \ \_diff = 1.96 S\_k \sqrt{(2(1-r))},$$

A score difference of +/-10 indicated a significant deterioration or positive change in symptoms, whereas a score in between was considered as no change in symptoms.

Additional measurements paper III

Eating Disorder Inventory 2 - Perfectionism (EDI-P): EDI-P (Lampard et al., 2012) is a 6-item questionnaire, measuring the degree of perfectionism in different aspects of life. The scale is a 5-point Likert scale from 0 (not at all) to 4 (all the time).

2.2.4 Statistical analysis paper II

Mixed effects power calculations determined the sample size. Based on previous research, the study expected to find large differences between the active VR intervention and the waitlist control in phase one. A priori power analysis showed that for the first contrast between VR arm and waitlist arm, a sample size of 20 in the waitlist arm and 40 in the VR arms would be sufficient to detect a Cohen's d>0.8. This included the assumption of 30 % dropout rates in the waitlist arm and 20 % in the VR arm. A higher dropout rate was estimated for the waitlist group as the VR arm would be more appealing. For the second contrast between VR arm and online PE, a sample size of 40 in the online PE arm was required in order to detect a Cohen's d>0.6, with the assumption of 20 % dropout in both arms.

Data were analysed using SPSS Statistics, version 24. In order to investigate group differences, chi-square test for gender and ANOVA tests for age and outcome measures were conducted. Treatment outcomes were analyzed using linear mixed models and included a numeric time predictor separated for phase one and phase two. In phase one, the two VR groups were combined in the analysis as both groups received the same intervention. The VR groups in phase one served as a reference with two contrasts; 1) online PE, and 2) waitlist. In phase two, VR + online EXP

served as a reference with two contrasts; 1) only VR, and 2) online PE + online EXP. Observed data were used in order to calculate the effect sizes, based on the formulas (M1 – M2) / SD1 and (post1M – post2M) / SDpost1 for within-group effect sizes, and (M_{group1} – M_{group2}) / SD_{pooled} for between-group effect sizes.

An independent sample t-test with bootstrapped, bias-corrected confidence intervals (k=10 000 repeats) investigated whether VR + online EXP facilitated subsequent exposure compared with online PE + EXP.

2.2.5 Statistical analysis paper III

Descriptive statistics were reported using SPSS version 26, and Mplus version 8.7 was used for latent growth curve models (LGM). The LGM analysis included a weekly time variable and intercept was set to pre-treatment level. The reference group for all analysis was waitlist + online PE. The best-fitted model for the outcome measures PSAS, SPS and SIAS resulted in two trajectories; one for the intervention period (0-6 weeks), and one for the follow-up period (6-18 weeks). For EDI-P, the best fitted model included three slopes; 0-3 weeks, 3-6 weeks and 6-18 weeks. After having established the best fitted unconditional growth models, these were combined into multivariate LGC models. The main effects model included levels and change in PSAS, SIAS, SPS predicted by intervention group and levels and change in EDI-P. The interaction model included pre-treatment EDI-P * intervention group as predictors in order to explore whether perfectionism moderated the clinical effects of the self-guided interventions.

2.3 User involvement

The World Health Organization (2016) emphasizes the importance of involving users in order to improve the quality of the health services and giving the users more control over the services they are given. In Norway for instance, health care services have a duty by law to include users in the intervention development (Helsedirektoratet, 2017). User involvement has in general positive effects by providing users with increased information and accessibility of the health care

services, and is associated with higher user satisfaction, resulting in greater therapeutic alliance, and greater clinical outcomes (Kujala, 2003).

Thus, both studies had a focus on user involvement during the developmental phase, by including adolescents in the same age range as the participants. In the non-randomized feasibility and pilot study, four adolescents conducted user testing and provided feedback on the VR scenario. In addition, two of the adolescents participated in the 90-minutes training session, and gave feedback on the intervention and the assessments. In the randomized controlled study, four adolescents tested the VR scenario and inspired further adaptation of the scenarios. Moreover, they conducted usability testing of the online programs. At the end of the developmental phase, adolescents tested both the VR intervention as well as the online programs in order to ensure there were no technicality issues.

2.4 Ethical considerations

Both studies followed the ethical guidelines and was approved in accordance with the Regional Committee for Medical and Health Research Ethics: Non-randomized feasibility and pilot study: REK 2017-1521, and RCT study: REK 60628. Parental consent/informed consent from adolescents was obtained in both studies.

3. RESULTS

3.1 Summary of paper I

The feasibility of the intervention was increased halfway during the trial, by adjusting five elements: 1) increasing parent involvement through e-mail/telephone contact, which also improved adherence rates 2) the time of distribution of gift card was changed from 1 month to 3 month to increase adherence, resulting in no missing data, 3) the value of the gift card was increased from 100 NOK to 300 NOK due to the workload, 4) including short breaks during the session due to the intensiveness, and 5) the total duration of training session increased from 90 minutes to 2 to 2.5 hours.

Linear mixed models analysis revealed a significant decrease in PSA symptoms by an average of 12.23 points reduction from pre to post ($d = 1.53$) and improvements remained stable at follow-up. Moderation analysis showed no difference in treatment effects with regards to baseline generalized social anxiety symptoms and level of presence experienced in the VR scenario. Physiological data revealed a small increase in heart rate during the VR exposure tasks compared with in-between exposure.

3.2 Summary of paper II

In phase one, the linear mixed models demonstrated a significant decrease in PSA symptoms with a 2.14 points reduction per measure point. The participants receiving the VR intervention had a 1.68 greater reduction in PSA symptoms over time compared to the waiting list ($d_{between} = 0.61$). The difference over time was not significant between the groups online psychoeducation (online PE) and VR. However, post hoc analysis comparing online PE with waiting list was also not significant, which indicates that VR was superior to online PE. Linear mixed models on the secondary outcome SPS-6 revealed a significant main effect on time. As no group differences were identified over time, we conducted post-hoc analysis to investigate within-group effects. The analyses revealed a significant decrease for the

VR intervention, (d_{within} = 0.42), but not for online PE and waiting list. Linear mixed models on the secondary outcome SIAS-6 was not significant.

In phase two, the linear mixed models demonstrated a significant decrease in PSA symptoms with 1.42 points reduction per measure point. However, no group differences were identified. Linear mixed models on the secondary outcome SPS-6 revealed a significant main effect on time, but no group differences. Post hoc analysis demonstrated a significant decrease for the participants receiving online PE + EXP intervention (d within = 0.46), but not for VR and VR + online EXP. Linear mixed models on the secondary outcome SIAS-6 was not significant.

Bias-corrected, bootstrapped independent samples t-test (k=1000) demonstrated that VR + online EXP group did not conduct more exposure tasks compared to the group receiving online PE + EXP.

At the end of phase one, 11 out of 32 respondents (28%) from the VR group, and 5 out of 16 (31%) from the online PE group reported significant reliable change, whereas the remaining respondents reported no change in symptoms. The waitlist group reported no change in symptoms. At the end of phase two, 33 % of the respondents in the VR + online EXP group, and 18 % from the online PE + EXP group reported significant reliable change.

From post to follow-up, linear mixed models demonstrated a non-significant change in PSAS symptoms with a 2.80 points reduction in symptoms for VR + online EXP, and no significant group differences were found. Linear mixed models on the secondary outcome measure SPS-6 was not significant. Participants in the waitlist group had a significantly higher reduction on the secondary outcome SIAS-6 compared with the VR + online EXP group.

3.3 Summary of paper III

Latent growth curve modeling showed that adolescents receiving an intervention targeting PSA did not have a reduction in EDI-P symptoms over time at mean level.

However, the results showed there were statistical significant individual differences in changes over time from 0-3 weeks, 3-6 weeks and 6-18 weeks.

The main effects model revealed that a change score in EDI-P did not predict change in PSAS, SPS and SIAS from pre to post. However, there was a significant long-term effect where adolescents with reduction in EDI-P had a stronger reduction in PSAS ($p = .011$), SPS ($p = .016$), and SIAS ($p = 0.09$) from post to follow-up, in addition to significant group effects.

No interaction effects were found for PSAS and pre-treatment levels of EDI-P from pre to post, nor from post to follow-up for the four groups.

On the secondary outcome measure SIAS, significant interaction effect from pre to post indicated a stronger decrease in SIAS when EDI-P pre-treatment levels were high compared to low in the VR + online EXP group. However, a significant interaction effect from post to follow-up indicated a weaker reduction in SIAS when EDI-P pretreatment levels were high compared to low for both groups receiving the online exposure program.

On the secondary outcome measure SPS, there were significant interaction effects from pre to post, indicating a weaker reduction in SPS symptoms when EDI-P pre-treatment levels were high compared to low in the VR only group, and stronger reduction in SPS symptoms for those with higher pre-treatment levels EDI-P compared to low for both groups receiving the online exposure program. A significant interaction effect from post to follow-up indicated a weaker reduction when EDI-P pre-treatment levels were high compared to low for the online PE + EXP group.

4. DISCUSSION

The overall aim of the thesis was to explore the clinical use of Virtual Reality interventions for adolescents with PSA. This was conducted through two quantitative studies; one non-randomized feasibility and pilot study with an adapted version of a therapist-guided VR intervention, and one randomized controlled study exploring the clinical efficacy of an automated and self-guided VR intervention, with both passive and active control groups. Both studies investigated moderators of clinical effects, namely; the role of presence in the virtual environment, high baseline levels of generalized social anxiety symptoms (Paper I), and pre-treatment levels and changes in perfectionism (Paper III).

In the following, the main findings and how they can be related to and added to the existing scientific literature will be discussed. Methodological and ethical concerns in the studies will also be discussed. Furthermore, the section will discuss the topic of clinical implications, innovation and exploitation, and future directions, and finally concluding remarks.

4.1 Paper I: Feasibility and pilot results of a therapist-guided Virtual Reality intervention for adolescents with PSA

The research questions for Paper I were: Is Virtual Reality a feasible method for adolescents with public speaking anxiety? Are the clinical effects of the adapted version similar to the original protocol tested on adults? What are possible moderators of the treatment effects? And last, what are the physiological responses to the VR intervention?

The study was a non-randomized feasibility and pilot study, including 27 adolescents who participated in a therapist-guided, 90-minutes training session at the clinic. It was an open study, with assessments at pre, one-week post, and one- and three-month follow-up after the training session. The study had four aims: First, the study tested the feasibility of the adapted version of a therapist-guided VR intervention for

adolescents with PSA. Second, the study piloted the clinical outcomes. Third, the study investigated whether the experience of presence in the VR scenario and baseline generalized social anxiety moderated the treatment effects. And fourth, the study investigated whether there was an increase in heart rate during the VR exposure scenarios.

Feasibility results

The study used an adapted protocol of the adult version developed and used by Lindner et al. (2019). The Lindner trial included a 3 hrs single session, consisting of around eight exposure tasks with a duration of one to three minutes each. Three elements in the adolescent version were adapted prior to the trial. First, the psychoeducation and the exposure session was adapted to a younger sample, including more examples instead of asking open questions which can often result in an "I don't know" answer. Second, the session was reduced from 3 hrs to 90 minutes, by reducing the number of exposure tasks to around seven tasks with a duration of one to two minutes each. Third, the protocol included a phone interview two weeks following the training session in order to promote in-vivo exposure and increase adherence for data collection purposes. Whereas the Lindner study (Lindner et al., 2019) used a commercialized VR scenario from the App Store market, the feasibility and pilot study used a tailored VR intervention specifically designed for an adolescent group. The scenario featured a typical Norwegian classroom with virtual avatars in the same age range as the adolescents.

Experiences halfway throughout the trial resulted in further adaptation of the adolescent version: First, a lack of parent involvement in the beginning of the trial resulted in higher attrition rates on the follow-up measurements. Thus, the study sought to reduce the attrition rates by increasing parent involvement and providing detailed information about the study and the importance of follow-up measurements at the beginning of the training session. Second, the time point of distribution of the gift card at one-month follow-up resulted in high attrition rates at three-month follow-up measurements. By moving the distribution of the gift card from one-month to

three-month follow-up, the study did not have any missing follow-up data in the second period. Third, the workload for the adolescents was higher than expected as the training session was intensive and the session rarely completed within 90 minutes as originally planned in the protocol. Therefore, short breaks were added during the training session in order to give some relief from the intensiveness and the total duration of the session was extended from 90 minutes to 2 - 2, 5 h. They were also compensated by increasing the value of the gift card from 200 NOK to 300 NOK due to the extra workload.

Experiences from a clinician perspective showed that the adolescents experienced anxiety during the VR exposure tasks. For some of the adolescents, the anxiety experienced during the VR intervention was too strong that the exposure tasks had to be conducted in smaller steps. Although data was not collected systematically and analyzed, the adolescents reported higher levels of SUD's during the VR exposure tasks and they gave lower SUD ratings after completing the exposure task. This may indicate that VR is a feasible method for adolescents, in line with a previous study on social anxious adolescents (Parrish et al., 2016). In the study by Parrish et al. (2016), the adolescents reported higher SUD ratings during public speaking tasks compared to neutral VR environments. In addition, the socially anxious adolescents reported higher anxiety levels compared to non-anxious adolescents. Together, the studies suggest that virtual public speaking environments are relevant social cues and elicit anxiety and are relatable to real-world public speaking settings. Thus, the development of tailored VR stimuli within a Norwegian classroom context and culture shows promising results for future development.

Pilot results

The pilot results included primary and secondary outcomes, including PSA symptoms from pre, post and one- and three-month follow-up, and generalized social anxiety symptoms at pre-measurement. This study showed that the adolescents had a reduction in PSA symptoms from pre to post, measured one week after the training session. The reduction in symptoms was maintained from post training to one-month

and three-month follow-up. The results from the study is in line with the original VRET study on adults (Lindner et al., 2019), although our study demonstrated even larger reduction in PSA symptoms one week after the training session; with 12.23 points (d = 1.53) reduction compared to 6.90 points (d = 0.77) reduction (Lindner et al., 2019). The results indicate that the adult version of the protocol was successfully adapted to adolescents before and during the trial. As the current study used a tailored VR scenario, this may have increased the ecological validity of the VR intervention, resulting in a larger symptom reduction on the same self-report assessment tool with larger effect sizes.

The study also supports the findings in a recent meta-analysis showing that VRET for PSA is efficacious (Reeves et al., 2021). However, the meta-analysis is restricted to an adult population due to the lack of evidence on adolescents (Kothgassner & Felnhofer, 2020). Only two studies have investigated VRET for PSA for children (Sülter et al., 2021) and adolescents (Gutiérrez-Maldonado et al., 2009). Although the evidence is still very limited, the findings suggest that VR is a promising tool for adolescents.

Moderators of treatment effects

Presence in the virtual environment was not associated with treatment outcome. While previous research show an association between presence and anxiety levels (Ling et al., 2014), it is still unclear how the role of presence impacts treatment outcome in VR interventions (Gromer et al., 2019; Price & Anderson, 2007). For instance, in one study non-anxious adolescents reported higher presence in the virtual environment compared to socially anxious youth (Parrish et al., 2016). Others have suggested that only a certain level of presence is needed in order to gain treatment improvement (Diemer et al., 2015). Thus, more research is still needed in order to understand the association between presence and anxiety levels and the psychological mechanisms of VRET.

Adolescents with high baseline generalized social anxiety symptoms did not differ from those with low baseline generalized social anxiety symptoms in terms of

treatment outcome. This could indicate that even adolescents with high baseline generalized social anxiety symptoms may benefit from a VR intervention specifically targeting PSA. Moreover, studies have shown that treating PSA symptoms may reduce generalized social anxiety symptoms (Hindo & González-Prendes, 2011; Hofmann, 2004; Hofmann et al., 2006). If a VR intervention for PSA is efficacious for both PSA symptoms as well as generalized social anxiety symptoms, one may be able to prevent the personal and societal costs of the disorder. However, the study in Paper I only assessed generalized social anxiety symptoms at pre-measurement. Future studies should investigate this further by including both pre and post-measurement.

Physiological symptoms in VR

The physiological data showed a small increase in physiological symptoms when they were exposed to the virtual scenarios in the 90-minutes training session compared to the non-exposure period. Thus, this may support the notion that the adolescents experienced anxiety during the VR exposure tasks. However, the difference from non-exposure to exposure differed substantially as some exposure tasks led to a greater increase in heart rate than others. Yet, the participants had a larger decrease in subjective symptoms measured through self-report assessments. The findings from the study is congruent with other studies showing a lack of correlation between self-report assessments and physiological arousal measured during an exposure task (Plaisted et al., 2022). For instance, one study targeting adolescents with PSA with a CBT intervention found that although SUD's decrease over time, physiological rating did not (Plaisted et al., 2022). This may indicate that objective measures such as physiological arousal are unrelated and different from the subjective experience of PSA (Behnke & Beatty, 1981). Although the reason for this is somewhat unclear, one possible explanation might be that the individual's subjective experience of the anxiety is based on the label they choose to put on the physiological arousal. The label may be a reflection based on previous experience. For instance, a person who defines the physiological arousal as "thrilling" would have a lower subjective level of PSA than a person who defines the arousal as

"frightening" (Behnke & Beatty, 1981). If the labeling changes throughout the intervention based on new, less frightening, experiences of public speaking situations, this may lead to a lower subjective level of PSA. However, the physiological symptoms may still remain the same. This also supports the theoretical rationale from the inhibitory learning theory (Craske et al., 2008) emphasizing new learning as the central mechanism and not the habituation of the physiological symptoms (Foa & Kozak, 1991) as formerly believed. It is therefore recommended to not solely rely on physiological measures when assessing PSA.

Barriers of the feasibility and pilot study

Experiences from the non-randomized feasibility and pilot study identified three barriers to the scalability of the intervention. First, as a therapist-guided intervention, it required great resources. The training had to be conducted after working/school hours so the participants did not have to take time off from school. This caused long working hours for the therapist and the adolescents, as well as the intervention itself was intensive for the adolescent. Second, the recruitment was difficult and long-lasting, possibly because adolescents were hesitant of seeking help from a clinician at the clinic. Third, the exposure sessions and the clinical effects may have been influenced by the presence of a therapist, although the original study on adults showed that the participants randomized to a self-guided version also had a reduction in PSA symptoms (Lindner et al., 2019). Nevertheless, it was of importance to investigate the intervention as a self-guided format in an adolescent sample.

4.2 Paper II: Clinical efficacy of a self-guided Virtual Reality intervention

The main research questions for Paper II were: "What is the clinical efficacy of self-guided Virtual Reality Exposure Therapy for adolescents with PSA when compared with waitlist and self-guided online programs? And, does VR + online exposure program facilitate more in-vivo exposure tasks compared to those who receive the online psychoeducation + online exposure program?

We answered the research questions through a two-phased, four-armed randomized controlled study, with a self-guided, and automated VR intervention compared with active and passive control groups. A total of 100 adolescents participated in the study. First we compared the clinical efficacy of a self-guided VR intervention (group 1 and 2, n = 40) with waitlist group (n = 20) and online psychoeducation (online PE, n = 40) in phase one. Second, we compared the clinical efficacy of the VR + online exposure program (VR + online EXP, n=20) with the active comparison online psychoeducation + exposure program (online PE + EXP, n=20), and VR only (n=20) in phase two. Finally, we investigated whether VR + online exposure program facilitated more in-vivo exposure tasks when compared to online psychoeducation + exposure program (online PE + EXP).

The results showed that the adolescents allocated to the VR groups had a significant decrease in PSA symptoms when compared with waitlist ($d_{between} = 0.61$) in phase one. The findings from the RCT study is congruent with a recent review that concludes VR interventions as more effective when compared with waiting list (Reeves et al., 2021). Additionally, this study is in line with a recent study on children between the ages of 9 and 12 that examined the clinical effects of VR intervention and showed that those in the VR group had larger decreases in PSA symptoms than those in the control group (Sülter et al., 2021). However, a limitation with the study by Sülter et al. (2021) was that they were not able to randomize the children to the VR intervention or the control group due to school organization, and whole classes were therefore allocated to one of the groups. Moreover, the control group and the intervention group received different presentation tasks. The lack of randomizing across classes with different teachers and different presentation tasks may have confounded the results. Furthermore, no active control group was included in the study. The study also reports data on children, which is different from adolescent samples due to developmental peaks during this period (Haller et al., 2015).

The results from this study further showed that the comparison between the VR intervention and online psychoeducation in the first phase of the intervention period

was not significant. However, post-hoc analysis was not statistically significant when comparing online psychoeducation with waitlist. This may indicate that the VR intervention was preferable to online psychoeducation. Moreover, within group analysis showed that only the adolescents allocated to the VR groups had a significant reduction in social phobia symptoms. This could suggest that the VR intervention has additional benefits.

There was a significant decrease in PSA symptoms over time for the group as a whole in phase two, however, there were no significant group differences. The results are congruent with review studies that conclude VR interventions as equally effective when compared with in-vivo exposure therapy (Ebrahimi et al., 2019). One review study found that in-vivo exposure therapy was marginally superior to VR interventions, however, the review study did not include adolescent samples (Reeves et al., 2021). VR interventions may be more beneficial than in-vivo exposure therapy, or at least equally effective, as it has a high acceptability rate, and can provide a safe environment for adolescents with PSA (Joshua N. Kelson et al., 2021), as well as being less time consuming and more cost effective (Daniels et al., 2020). There is therefore a need for more randomized controlled trials on adolescents with both active and passive control groups in order to conclude.

The clinical effects remained stable from post to three-month follow-up, and no significant differences were found at follow-up between the reference group VR + online EXP compared with the three other groups. In one review study (Horigome et al., 2020), they found that the efficacy of VR interventions continued at three-month and six-month follow-up and was more effective than in-vivo exposure therapy. As there is a lack of research on VRET in adolescents, more research is still needed in order to conclude on the long-term effects of VRET for this age group and whether it is inferior or superior compared to other treatment modalities.

There were no group differences in the number of completed in-vivo exposure tasks between those who received VR + online exposure program compared to those who received online psychoeducation + exposure program. It was hypothesized that

adolescents receiving a VR intervention in phase one would conduct more exposure tasks in the next phase due to a lowered threshold as a result from the VR training. However, the VR intervention did not facilitate more subsequent exposure tasks in the next phase compared with online psychoeducation. This may have been a result of the pandemic. Many were isolated during the intervention period as leisure activities were set on hold, and homeschooling was in effect for some of the adolescents. This resulted in minimal exposure opportunities during the training period. The results therefore need to be interpreted with caution. As only two studies (Lindner et al., 2021), including this study, have explicitly investigated the lowered threshold hypothesis, more research is still needed.

None of the groups had a reduction on the secondary outcome measure measuring social interaction anxiety symptoms. Thus, the results did not find that treating PSA symptoms may reduce generalized social anxiety symptoms at post nor three-month follow-up, unlike other studies (Hindo & González-Prendes, 2011; Hofmann, 2004; Hofmann et al., 2006). However, this may also be the result of a pandemic life as social interaction situations may have been limited. Future studies should continue to investigate whether a reduction in PSA symptoms may lead to an overall reduction of generalized social anxiety symptoms in adolescents.

4.3 Paper III: Perfectionism as a predictor of change in treatment outcome

The main research question in Paper III was: “Does an intervention targeting PSA also decrease symptoms of perfectionism? Does perfectionism moderate the clinical efficacy of digital self-guided interventions for PSA?”

Paper III investigated this through two aims. The first aim was to investigate whether digital self-guided interventions for PSA also cause a reduction in perfectionism. The second aim was to investigate whether changes and pre measurement levels of perfectionism moderated treatment effects.

We answered the research questions by analyzing the data material collected from the four-armed randomized controlled study, which included 100 adolescents allocated to four groups; 1) VR only, 2) VR + online exposure program, 3) Online psychoeducation + exposure program, and 4) Waitlist + online psychoeducation program.

The results showed that PSA interventions did not lead to a reduction in symptoms of perfectionism at a mean level, although the results indicated statistically significant individual differences in changes. One reason for the non-significant reduction may be that perfectionism was not targeted directly. Previous research suggests that in order to reduce symptoms of perfectionism, the interventions need to have an explicit focus on reducing perfectionism, and intervention programs where perfectionism is not targeted directly are less effective (Flett & Hewitt, 2014).

Adolescents with a reduction in perfectionism had a larger reduction in all outcome measures. The findings from the study support the conclusion from a review study that by reducing levels of perfectionism one might be able to reduce anxiety symptoms (Lloyd et al., 2015). The positive association between perfectionism and outcome measures only appeared during the follow-up period and not during the intervention period. This is also reported in another study, where they only found long-term effects on perfectionism in older children aged 10-11 years, whereas on younger children aged 9-10 years the effects were identified immediately after the intervention (Essau et al., 2012). One possible explanation to this may be that adolescents need real-life experience in order to change their cognitive attitudes. Although adolescence is a sensitive period for developing anxiety disorders such as PSA and SAD (Beidel & Turner, 2007), it is also considered as a period where their development is under increased plasticity and sensitive to positive experiences. Thus, perfectionistic standards may be more susceptible for change at this stage (Haller et al., 2015). However, as there is limited evidence on this age group, more research is still needed.

No interaction effects were identified between pre-treatment levels of perfectionism and public speaking anxiety symptoms. Thus, the level of perfectionism at pre-treatment did not seem to moderate symptoms of public speaking anxiety from pre to post, nor from post to follow-up. Although there is scarce evidence suggesting on how perfectionism predicts treatment outcome in adolescence, research do suggest that there is an association between high level of perfectionism and increased test anxiety (Abdollahi et al., 2018). More research is still needed on the role of perfectionism on interventions targeting public speaking anxiety in order to draw conclusions.

Adolescents allocated to the VR only group had a significantly weaker reduction in social phobia symptoms if pre-treatment levels of perfectionism were high compared to low. This has also been reported in a previous study on children aged 6-13 years with anxiety disorders (Mitchell et al., 2013). Following a CBT intervention, they found that self-oriented perfectionism was associated with poorer treatment outcomes as these children had higher anxiety symptoms at post-treatment. However, as the study by Mitchell et al. (2013) is restricted to children, more studies are still needed on adolescents due to the developmental peaks (Beidel & Turner, 2007). Nevertheless, the studies combine may indicate that high levels of perfectionism is negatively associated with treatment outcome (Egan et al., 2016).

Adolescents receiving the online exposure program had a stronger reduction in social phobia symptoms when pre-treatment perfectionism levels were high compared to low. This may indicate that the online exposure program included intervention elements which successfully targeted those with high perfectionistic standards. However, at long-term they had a significantly weaker reduction from post to follow-up compared to adolescents with low levels of perfectionism. This could indicate that high perfectionistic standards are persistent and a change in symptoms is only temporary (Egan et al., 2016). Interventions targeting adolescents should therefore first investigate the level of perfectionism and introduce tailored interventions targeting the perfectionism trait directly (Ashbaugh et al., 2007).

4.4 Contribution to the existing literature

The studies included in the thesis presents evidence on both therapist-guided as well as self-guided VR interventions targeting adolescents, and is a large contribution to the existing literature. Both studies included in the thesis address key gaps in the literature, as there is limited research on the clinical efficacy of VRET in adolescents (Kothgassner & Felnhofer, 2020).

The study in Paper I is the first to investigate the feasibility as well as to pilot the clinical effects of a VR intervention targeting adolescents with PSA. The study presents new evidence on the feasibility of VR interventions in general for this age group, as requested by several researchers (Kothgassner & Felnhofer, 2020; Reeves et al., 2021). Studies on VR and adolescents has a high potential as an intervention method for this age group, however, there has been a lack of evidence supporting the use of VR in a younger population (Kothgassner & Felnhofer, 2020).

The randomized controlled study in Paper II is the first study to explore the clinical efficacy of a self-guided VR intervention for adolescents aged 13-16 years with PSA, with both active and passive control groups. The study presents new evidence on adolescents, as existing high-quality randomized controlled trials of VR interventions targeting PSA are conducted on adults only (Reeves et al., 2021), whereas only one RCT study has been published on children aged 9-12 years with PSA (Sülter et al., 2021). The study fills a gap which has been asked to be prioritized by researchers due to the high burden of PSA (Reeves et al., 2021). As PSA may cause severe impairment in educational life, research on VR interventions for PSA for this age group has been warranted in order to intervene at an early stage.

The RCT study also presents new evidence on the utilization of self-guided, automated and gamified VR interventions for adolescents with PSA, in addition to adding to the already existing, yet, limited literature on self-guided, and automated VR interventions (Lindner et al., 2019; Zainal et al., 2021). Only two previous studies have examined the use of self-guided VR applications for PSA (Lindner et al., 2019; Zainal et al., 2021), however, the studies were conducted on adults. By developing an

evidence base for self-guided VR interventions, this may reduce waiting list, treatment costs and increase the accessibility of VR interventions for both clinical, as well as non-clinical purposes.

Moreover, Paper III presents new evidence on the role of perfectionism as a moderator for treatment outcome in young adolescents aged 13-16 years, as most studies investigating perfectionism as a moderator of treatment effects are conducted on children or late adolescence to adulthood. It is important to investigate for whom the intervention works for and what moderates treatment effects, as this remains unclear for this age group (Baker et al., 2021). By doing so, interventions can be optimized, thus leading to higher treatment improvement. In addition to improving the interventions, identifying the primary mediators and moderators of change would provide a much greater understanding of the psychopathology of PSA.

4.5 Developing VRET interventions for adolescents in a cross-disciplinary team

Although we could have used one of the already existing VR applications developed for PSA, we decided not do. Many of the applications are designed for an adult population, with scenarios such as wedding ceremonies, conference settings, and job interviews, and the virtual avatars being adults. As the context did not seem fit for adolescents, we decided to develop a typical Norwegian classroom environment with adolescents of similar age as an audience.

The VR interventions were designed in a collaboration between health researchers, IT researchers and industry partners, and included user involvement from the very beginning. This may have resulted in the large effect sizes of the interventions. The VR exposure therapy was based on evidence-based research including components from traditional in-vivo exposure therapy and the inhibitory learning model. The VR interventions involved scenarios commonly reported by adolescents as fearful, such as talking out loud while sitting in the middle of the classroom or standing in front of the classroom.

During the development of the interventions there was an ongoing debate in the team on whether an animated audience and simple scenarios were sufficient in order to provoke anxiety and create presence in the virtual environment. Efforts were therefore made by developing 360º videos. One of the IT researchers in the INTROMAT project developed four different 360º VR prototype scenarios through a participatory design with adolescents (Flobak et al., 2019). Although the expert evaluation phase from psychologists resulted in positive feedback and found the 360º as feasible, they are still limited by not being interactive. Moreover, animated VR and 360º have shown to induce comparable levels of anxiety and presence (Brivio et al., 2021), which suggests that a realistic audience is not necessary in order to gain treatment improvement.

4.6 Methodological considerations

Design

The overall aim of the thesis was to explore the effects of a new generation of automated Virtual Reality interventions as a self-help tool for adolescents with PSA, which was conducted in two steps; the development and feasibility testing of a therapist-guided VR intervention before initiating the development of a self-guided VR intervention. The studies included in the thesis were compatible with the MRC framework on how to develop complex interventions (Skivington et al., 2021). The framework recommends a feasibility and a pilot study as a first step (Paper I), before investigating the clinical efficacy through a randomized controlled study (Paper II). Moreover, Paper III evaluated how perfectionism predicts treatment outcomes in order to optimize future interventions targeting PSA. Long-term results were collected at one- and three-month follow-up. In addition, there is an ongoing collection of the one year follow-up data.

Feasibility and piloting

Paper I consisted of an open non-randomized feasibility and pilot study and assessed whether future studies could be conducted and acted as a preparation to a larger

study. Feasibility and pilot studies are considered as the first step in developing complex intervention (Skivington et al., 2021), and is recommended in order to assess whether a future intervention needs further adaptation. However, many studies mix these two concepts, causing difficulties for those conducting electronic search and reviewing the literature (Eldridge et al., 2016). Thus, the current study follows the guidelines and recommendations when defining these two terms; the feasibility part of the study provided guidance in case there were any uncertainties or refinement that needed to be done before progressing to the next evaluation phase. The piloting part of the study investigated the clinical effects of the VR intervention, and whether the VR scenario provoked anxiety in adolescents.

Randomized controlled studies

Paper II consisted of a randomized controlled study and evaluated the clinical effects of the VR intervention. While a majority of preventive programs for adolescents are not evaluated in high quality randomized controlled trials (Moreno-Peral et al., 2017), this trial used a strong design, with a large sample with both active and passive control groups. Randomized controlled studies are considered as the most powerful way to investigate a cause-effect relationship, as the allocation procedure makes the groups as similar as possible (Skivington et al., 2021). One of the advantages of a RCT study is that it can control the potential confounding variables. However, several biases might have occurred in the current RCT study, which may have affected the results from the study.

The RCT study was not blinded, which may have affected the expectancies from the researchers involved, as well as the participants receiving the intervention, resulting in a selection bias. Selection bias arises when there is a difference among the groups, e.g. key demographic measurements, baseline clinical outcome measures (Jadad, 1998). In the current RCT study the allocation was made through a predefined list from randomization.org, however, the actual allocation was conducted by the research group. The research group had a special interest in the study outcome, and a

bias might have occurred if the researchers presented the information about the study to potential participants, or i.e. formulated the information in a certain manner.

Moreover, selection bias may have occurred as the adolescents were informed about the group allocation before they entered the trial and completed the pre-assessment. Thus, participants knew what type of intervention they would receive and had an expectation on whether or not it would improve their mental health (Boot et al., 2013). A few participants even declined or expressed disapproval if they were assigned to one of the control groups. However, allocation concealment could have led to a higher attrition in this case, as the user testing resulted in confusion due to restraints with the internet-delivered platform. Although pre-measurement analysis did not identify any group differences, in retrospect, a potential selection bias could have been reduced to a minimum by concealing the allocation sequence from the research group and having an unbiased person responsible for this, as well as having more time to develop a better solution for the technicality issues.

Other biases might have appeared in the RCT study. Performance bias arises when there are differences in behavior between groups (Jadad, 1998). For instance, if participants know that they are in the VR intervention group, they will expect a greater outcome and have a greater adherence compared to those in the control group. Whereas the participants assigned to the control groups may have been less motivated as the VR intervention was considered to be a more attractive group. Moreover, the VR groups were instructed to complete the pre-assessment prior to receiving the VR equipment, which could have increased their adherence compared to the control group. Hence, attrition bias may have resulted in higher dropout rates among the control groups. However, differences in attrition and adherence to the interventions were not analyzed as it was not within the scope of this thesis. In order to avoid attrition bias and selection bias, the study followed the recommendation and used intention to treat analysis. Intention to treat analysis includes all those who participated in the study, not only those who have completed the intervention (Jadad, 1998).

Measuring PSA

In this thesis, the primary and secondary outcomes were based on self-reported questionnaires. Self-reported questionnaires are most widely used in psychology (Paulhus & Vazire, 2007), due to the many advantages; they are easy to administer, have low cost and several variables can be collected at once (Gallego et al., 2021). However, there are disadvantages and biases related to self-report measures that may have affected the validity of the studies. First, adolescents may present themselves in a socially desired way. Second, while some tend to use the middle response, others might have an extreme response, thus creating individual differences in the reporting style (Paulhus & Vazire, 2007). Third, adolescents can have difficulties to interpret and understand the wording of the questionnaire, as many of the well-documented assessments included in the thesis are originally developed for adults (Bartholomay & Houlihan, 2016). For instance, PSAS has been only validated for the adult population (Bartholomay & Houlihan, 2016). SPS-6 and SIAS-6 have been tested in a few studies on an adolescent population and have shown good psychometric properties, although more studies are warranted in order to set an appropriate cut-off score (Zsido et al., 2021).

Self-report measurements are most commonly used in PSA research (Paulhus & Vazire, 2007), however, several studies include other types of measurements. Behavioral assessment tasks (BAT's) are often used to measure their distress tolerance/avoidance level to public speaking challenges before and after an intervention (Beidel et al., 1989). Physiological measurements assess physiological reactivity during public speaking tasks (Sawyer & Behnke, 1999). Self-report measurements (cognitive), BAT's and physiological measures all seem to have high reliability, but they do not seem to be correlated with each other (Gallego et al., 2021). For instance, studies report higher effectiveness of an intervention when using self-report measurements compared to physiological and behavioral measures (Gallego et al., 2021; Heimberg et al., 1990), which was also apparent in Paper I. The mismatch in the findings from self-report measurements and physiological and

behavioral measures may mislead researchers when interpreting the findings, thus, resulting in wrongful conclusions (Gallego et al., 2021).

Although the self-report measurements assessing PSA and generalized SAD symptoms measure the subjective experience during public speaking situations and in social interaction situations, it gives little information regarding how it impairs their daily life. In retrospect, it would have been useful to include measurements that assess daily life functioning related to school attendance, interpersonal relationships and leisure activities.

Patient sample

The studies in this thesis were conducted in only one municipality in a high-income country. The sample consisted of adolescents at junior high school, with PSA. The studies did not include any cut-off on PSA symptom levels in order to be eligible, neither did the study set a diagnosis. However, in order to be included, PSA had to cause some interference in their daily life, and adolescents who received ongoing treatment for SAD were excluded. The sample was limited to adolescents with sufficient Norwegian reading and writing skills, thus excluding adolescents with a minority background and lack of Norwegian language skills. Furthermore, adolescents with difficulties in reading or writing, i.e. dyslexia, were also excluded. When inclusion and exclusion criteria are strict, the groups will be as similar as possible, reducing the likelihood of low internal validity, thus providing strong evidence of the causal relationship (Bhandari & Schemitsch, 2004). However, this may have led to a decrease in external validity (Jadad, 1998). Although few inclusion and exclusion criteria were used, the generalizability of the findings may still be limited to a homogeneity sample.

The majority of the sample in both studies were girls. However, girls in general have higher prevalence for anxiety disorders compared to boys (Wittchen et al., 1999). Moreover, girls more often seek mental health advice (Santor et al., 2007). Thus, compared to other studies this may not limit the generalizability of the findings. However, boys are still underrepresented in mental health (Granrud et al., 2020).

Boys may be more uncomfortable with talking about their feelings to a stranger, and are more concerned about stigma and lack of confidentiality if they eventually seek mental health advice (Granrud et al., 2020). Interventions should therefore seek to target specifically males, and investigate how interventions can be developed and disseminated in order to reach out to those who do not seek help.

Additionally, the sample may be biased due to the fact that the adolescents who showed interest in participating in the study may have a special interest in the VR technology. As some of the participants declined to participate when being told that they were allocated to the control groups, this proves that the adolescents showing interest in the study were more motivated by the VR intervention. Thus, this may affect the generalizability of the findings.

Power issues

The study in Paper I did not find any significant differences in symptom reduction based on high or low levels of baseline generalized social anxiety symptoms or level of presence in the VR scenario. Important to note, the moderation analysis were low-powered, and the results should therefore be interpreted with caution.

Randomized controlled studies with active control groups require a larger sample size in order to get a significant difference, as there is a chance of getting false results (Möller, 2011). Paper II did not identify a difference in the number of subsequent in-vivo exposure when comparing the groups VR + online EXP (n=20) with online PE + EXP (n=20). The non-significant findings may reflect a power issue, as a sample size n= 20+20 with 80 % power requires an effect size of d>0.9. Thus, a larger sample would have been preferable. Noteworthy, it was originally planned to have a different study design with a larger sample. However, due to recruitment postponement, a simplified study design with a smaller sample was conducted in order to complete the recruitment in time.

4.7 Ethical considerations

Training vs treatment

With young adolescents as a target group for the intervention, one ethical dilemma was how to label the treatment. The word "treatment" is often negatively associated, and adolescents may be reluctant and concerned about how their surroundings will react if they seek mental health advice (Chandra & Minkovitz, 2007). Moreover, as the studies aimed for including adolescents with PSA as their main problem with no clinical cut-off score and diagnosis, we found it unethical to call it a treatment and thereby label a normal fear most of the adolescents experience in different settings as pathological. Hence, the studies in the thesis explicitly decided not to use the word "treatment" during the recruitment process in order to reach out to as many as possible. By introducing the intervention as a "training program" it reduces the stigma and embarrassment related to seeking help, and may lower their threshold and make the interventions more attractive. This has also been reported in a study on how to reach out to boys (Robertson et al., 2015), where they found that using language which is more familiar to the adolescents makes the interventions less off-putting, and could increase the engagement to the interventions.

Parental consent

In order to participate in the study, research ethics states that parents of adolescents younger than 16 years/ adolescents aged 16 years have to give their informed consent in order to participate. Adolescents and parents also need to be informed about the possibility of withdrawing from the study without any explanations (Befring, 2007). In the first study, informed consent was obtained at the beginning of the training session. In the second study, informed consent was obtained by using the digital platform YouWell. Although the study was able to obtain informed consent from all parents involved, digital health platforms were not optimalized for adolescents younger than 16 years old as there was no direct link between the parent and the adolescent in the digital platform. Thus, more technological development is warranted in order to ease the process of obtaining parental consent.

Harmful effects

A common reported negative effect in exposure therapy is increased anxiety (Rozental et al., 2016). One of the main principles in research ethics is that research should be beneficial and not harm the participant (American Psychological Association, 2017). Although evidence shows that exposure therapy is efficacious, safe and tolerable when implemented correctly, some therapists believe that exposure therapy is a harsh approach, and fear the negative consequences of it (Deacon & Farrell, 2013). Moreover, adolescents may also regard increased anxiety during the exposure sessions as harmful and negative, although it is expected and regarded as beneficial for an experienced CBT therapist (Rozental et al., 2016). Thus, it was important to inform the adolescents about the anxiety they may experience during the session. Importantly, none of the participants reported a significant deterioration following the interventions in the RCT study measured by the reliable change index. This is also in line with a meta-analysis that found low deterioration rates in VRET, and similar to other intervention modalities (Fernández-Álvarez et al., 2019).

Lack of exposure opportunities

At the end of phase two in the RCT study, around 33 % of the respondents in the VR + online exposure program and 18 % from the online psychoeducation + online exposure program reported a significant reliable change. Although the remission rates were low for the online psychoeducation + online exposure program, the remission rates were similar for those in the VR + online exposure program compared to prior research (Baker et al., 2021). Importantly, Covid-19 pandemic restrictions were in effect during the recruitment period. Many adolescents had homeschooling and/or quarantine periods which varied across time. They also had fewer social arenas. This may have limited their opportunities in conducting in-vivo exposure and practice on skills they have learned throughout the intervention program. Those who had lack of opportunities in conducting in-vivo exposure, may therefore have experienced less improvement of the intervention program, as exposure training is the most central

component in CBT (Sewart & Craske, 2020). The clinical effects of the interventions should therefore be interpreted with caution.

At the very beginning of the pandemic and while the country was in complete lockdown, we put a stop to the recruitment process and postponed it to the next semester. Ideally, the recruitment process should have been postponed even more in order to provide the adolescents with the full benefits of participating in the intervention program. However, due to the limited time of the Ph.D. project, it was not possible to postpone the recruitment further.

Waitlist condition

One ethical dilemma that arose when planning the design of the randomized controlled study was whether or not to include a passive condition that receives no intervention. Including a control group with no intervention means that the participants complete a questionnaire, and are required to complete a new questionnaire when the intervention group completes its training program (Carroll, 2001). This type of control group measures natural recovery and is considered as the most basic in terms of evaluating the effectiveness of an intervention and requires smaller sample size in order to get large effect sizes (Carroll, 2001). However, as clinicians, we found it difficult to deny motivated adolescents a training program that could make them understand more of the processes involved in PSA and normalize the symptoms. In the absence of any intervention, people are also likely to be severely disappointed. The attrition rate is often very high, as many drop out or seek other therapies (Carroll, 2001). This resulted in a waitlist condition receiving the additional Online PE program, with non-active ingredients of a CBT intervention with only psychoeducative text. However, waitlist groups could result in a higher attrition and affect the motivation to participate in the study. This could lead to an overestimation of the clinical effects (Carroll, 2001). In retrospect, in order to reduce the “disappointment” related to the allocation to a waitlist group, a non-effective VR game could be more motivating. However, this would have been more time

consuming due to the limited availability of VR headsets, and led to a higher cost if the study had distributed VR headsets to all participants.

Level of therapist guidance

Another ethical dilemma was whether or not to include therapist guidance. Evidence on digital mental health interventions have concluded that therapist-guided internet-delivered interventions have higher adherence rates, greater effectiveness and lower dropout rates compared to self-guided interventions (Lehtimaki et al., 2021). However, adolescents are reluctant to seek mental health advice (Lehtimaki et al., 2021), which was apparent in the recruitment process. While it took about one year to reach the sample size of 27 adolescents in the therapist-guided feasibility and pilot study, 100 adolescents were recruited in the same period in the self-guided RCT study. Thus, the recruitment difficulties experienced in the feasibility and pilot study supported the use of a self-guided version. Moreover, although previous research is limited to university students (Zainal et al., 2021) and adults (Lindner et al., 2019), the results from the RCT study supports the use of VR intervention for PSA as a self-guided format.

4.8 Clinical implications

Given that state-of-the-art in-vivo exposure therapy for PSA has been time-consuming and presents some logistical challenges, VR technology can overcome some of these challenges by providing a readily available exposure situation. As it is easy to administer and only requires a maximum 4 hours workshop for an experienced CBT therapist, this might also lower the threshold for a therapist in order to utilize the intervention method. As the studies indicate that the self-guided VR intervention is equally effective as the internet-delivered intervention, VR should be considered as a treatment option or as a supplement. A therapist-guided version can give the therapist a tool within a session, while the self-guided version can be used in between sessions.

There are however some issues regarding VR and clinical practice. Patients, as well as clinicians may have concerns about the use of VR technology in treatment. Safety strategies such as “this is not real” may occur in VRET (Lindner, 2020), and clinicians may fear that patients will drop out of the VR treatment and experience it as unrealistic and irrelevant. The age of the clinician and the user is also of relevance. Most clinicians may be older and experience VR as frustrating as they are not accustomed to the technology, and older users might display more resilience towards VR interventions. On the other hand, the younger generation are more familiar with computer games, and will be able to understand the nature of VR technology more rapidly and have a higher acceptability rate. This is also evident as the VR market is dominated by the younger generation (Garrett et al., 2018).

The interventions have the potential of being delivered as an indicated prevention program at Norwegian junior high schools, with a goal of reducing PSA symptoms and prevent the long-term negative consequences related to PSA. They can also be disseminated through other services, such as the regular marketplace. However, one concern related to the dissemination of VR is the cost of the VR device. Although VR devices are becoming readily available and cheaper, there is still a high cost related to this. This may present as a barrier, especially for the users if the VR applications are presented as self-guided and they have to cover the cost of the VR device. In addition, creating a computer generated VR environment presents a considerable amount of expenses. As an alternative, one might use one of the several VR applications on the regular marketplace (Emmelkamp & Meyerbröker, 2021). However, this still depends on whether the users and/or the clinicians can buy the VR devices.

Paper III shows the importance of targeting perfectionism at an early stage of the intervention, as high levels of pre-treatment perfectionism may result in lack of improvement on generalized social anxiety symptoms. Early identification of high levels of perfectionism should therefore be addressed explicitly before initiating PSA intervention. Strategies in order to optimize interventions may include targeting cognitive biases, selective attention, self-criticism and a restrictive self-evaluation

(Shafran et al., 2018). This may be done through dichotomous thinking, thought records and behavioural experiments, thought diaries, utilizing a compassionate voice rather than a critical voice and broadening their self-evaluation through pie charts and consider other aspect where they can evaluate their self-worth which is not dominated by achievements (Shafran et al., 2018).

4.9 Innovation and exploitation

Even though there were several available VR scenarios for PSA in the international commercial market, there was a need to develop a Nordic classroom for adolescents as the existing ones with scenarios such as wedding ceremonies, auditorium and an adult audience did not seem appropriate for these studies. Moreover, many VR environments and applications that are being developed for health-related aspects are developed by technicians only. Many of these lack the essential functionality that is needed to trigger anxiety or being able to put it to use in clinical practice (Meyerbröker & Morina, 2021). Internet-delivered interventions can be a subject to low adherence, which could be related to the usability issues, lack of universal design and an outdated technology compared to other technology (Yogarajah et al., 2020).

Collaboration between health services and the industry partners, as well as user involvement has been crucial in order to develop efficacious and usable interventions (Nordgreen et al., 2021). The cross-disciplinary team identified six central themes in order to gain a productive collaboration during the research process: establishing a joint understanding of the domain; understanding key concepts among project participants; engaging end-users in the research and developmental process; collaborating across sectors; ensuring the privacy and security of health-related data and ensuring right timing of activities based on the project dependencies (Nordgreen et al., 2021)

One important part of the successful collaboration has been the proximity to the industry partners. In the INTROMAT project we have been working side by side with the industry, which has had a great impact on the elements in both the VR stimuli as

well as the internet-delivered platform. For instance, in the developmental process of the internet-delivered platform, a colleague from YouWell had regular attendance at our workplace. In addition, weekly meetings with the VR industry partners ensured that the developmental process was heading in the right direction. This created a dynamic process during the development of the platform, and therapist's and the users' viewpoints were central from the very beginning. In another case in the INTROMAT project, they conducted usability testing with both patients and therapists when developing a prototype of an internet-delivered intervention for residual cognitive symptoms after depression. Feedback from the usability testing contributed to further adaptation of the platform (Myklebost et al., 2022).

By collaborating with the industry, it also ensures a successful future exploitation and implementation of the interventions, which has been a common goal in the INTROMAT project. The industry partners' economical motivation, as well as their expertise, has probably been one of the main reasons for successful exploitation. As a result, the YoungSpotlight internet-delivered intervention is now publicly available through "Helsedirektoratet " with YouWell in lead of the process. Attensi AS is further working on making the self-guided VR application available at Oculus Store.

4.10 Future directions

Future studies should continue to investigate the clinical effects of available and scalable PSA interventions and focus more on digital self-guided interventions targeting adolescents. Due to the burden of the COVID-19 pandemic, there has been an increase in mental health problems among adolescents, and adolescents are at higher risk of experiencing anxiety, as well as depression problems after a pandemic (Meherali et al., 2021). Future studies should therefore aim to explore how interventions may be delivered to the adolescents in an efficient way in order to prevent long-term negative consequences.

VRET literature on adolescents is still scarce and limited and more randomized controlled trials are needed. There is also a need to further investigate on the

psychological mechanisms involved in VRET, as the role of presence in PSA is unclear. One recent review study suggests that treatment effects are not predicted by expectancy violation as the inhibitory learning model propose, and suggests self-efficacy as the underlying mechanism in VRET (Meyerbröker & Morina, 2021). Self-efficacy refers to the ability to trust one's capacity to conduct relevant behavior (Bandura, 1977). By breaking the avoidant pattern and exposing themselves to the fear they may gain more trust in their own abilities and be motivated to continue with the exposure tasks. Studies on specific phobias (Meyerbroker & Emmelkamp, 2008) and SAD (Kampmann et al., 2019) found that self-efficacy increases in VRET and is associated with treatment outcome. Future studies should investigate the role of expectancy violation and include self-efficacy measurements in order to understand more of the underlying psychological mechanisms related to VRET.

Studies on adults have reported that anxiety symptoms continue to decrease years after a VRET session, which may be due to the generalization from a VR phobic stimuli to in-vivo exposure situations and that they continue with the practice in real life (Lindner et al., 2021). Future studies should further include long-term follow-up for minimum a year, preferably longer in order to investigate the treatment improvement after the discontinuation of VR. Additionally, more studies are needed in order to investigate whether VR interventions targeting PSA in adolescence also lead to a reduction in generalized social anxiety symptoms as this remains unclear.

The RCT study excluded adolescents who reported having dyslexia as the text format in the online programs might have caused difficulties. However, those with dyslexia may experience stronger PSA symptoms compared to others. One study found that adolescents with dyslexia reported lower self-esteem and higher anxiety levels in academic and social situations compared to control groups, and the highest reported fear was performance related situations (Zuppardo et al., 2021). There is a need to investigate whether VRET may be suitable for this group and future studies should therefore introduce VR interventions for adolescents with dyslexia compared with adolescents with no learning disabilities.

Computer-generated audience provides more opportunities with regards to manipulating the scenarios, and has the potential of being individually tailored through algorithms based on the user's performance. This can enhance the user's experience, thus, increasing their anxiety level. Future studies should therefore aim to investigate how VR interventions may be optimized through interactive elements.

4.11 Concluding remarks

The present thesis contributes to the growing evidence base for VR exposure therapy. The studies in this thesis are among the first to demonstrate the potential of VR as an intervention method for adolescents with PSA, with its clinical effects evaluated for the first time through a high quality randomized controlled trial with both active and passive groups. The thesis also presents new evidence on moderators of treatment, and hightlights the importance of assessing and addressing high pre-treatment levels of perfectionism prior to a PSA intervention. Contrary to prior studies, the thesis did not find that targeting PSA symptoms may reduce generalized social anxiety symptoms. However, COVID-19 pandemic may have limited their exposure opportunities and the results need to be interpreted with caution. Future studies should continue to explore the preventive long-term effects of targeting adolescents with PSA and more randomized controlled trials are needed in order to conclude on the clinical effects on adolescents. VR benefits as it can be implemented as both therapist-guided as well as self-guided intervention, and has the potential to serve as an indicated prevention program for adolescents in order to reduce the PSA symptoms. However, although VR has high acceptability among adolescents, it is still limited by its costs, which may hinder its scalability.

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RESEARCH ARTICLE

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Virtual reality exposure therapy for adolescents with fear of public speaking: a non-randomized feasibility and pilot study

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Abstract

Background: Public Speaking Anxiety (PSA) is a common anxiety with onset in adolescence and early adulthood. With the advent of consumer virtual reality (VR) technology, VR-delivered exposure therapy is now a scalable and practical treatment option and has previously been shown to be efficacious with adults. In this non-randomized feasibility and pilot trial, we explore the effect of one-session (90 min) VR-delivered exposure therapy for adolescents (aged 13–16) with PSA.

Methods: A total of 27 adolescents were recruited from Norwegian high schools and completed self-report measures of PSA twice prior to treatment, 1 week after treatment, and at 1 and 3 month follow-up. Heart rate was recorded during the treatment session. A low-cost head-mounted VR display with a custom-built VR stimuli material depicting a cultural and age appropriate classroom and audience were used when a series of speech (exposure exercises) were performed.

Results: Linear mixed effects model revealed a significant decrease in PSA symptoms (Cohen's $d = 1.53$) pre-post treatment, and improvements were maintained at follow-ups. Physiological data revealed a small increase in heart rate during exposure tasks. Based on feedback from the adolescents, the feasibility of the intervention was increased during the trial.

Conclusions: The results show that low-cost, consumer VR hardware can be used to deliver efficacious treatment for PSA in adolescents, in a feasible one-session format.

Keywords: Virtual reality, Virtual reality exposure therapy, Public Speaking Anxiety, Cognitive behavior therapy, Adolescents, Inhibitory learning

Background

One out of three report anxiety symptoms when giving a speech in front of others [1], referred to as Public Speaking Anxiety (PSA). The most common fears in performance situations among individuals with PSA include showing signs of anxiety symptoms like shaking or trembling, the mind going blank while presenting, saying something stupid or not being able to continue to talk [2]. PSA is a distinct subgroup of the wider clinical presentation of social anxiety disorder (SAD) [3]. SAD is defined as the fear of negative evaluation of others in social situations, followed by feeling embarrassed or humiliated [4]. SAD is one of the most common psychiatric disorders with a life time prevalence of 13.7% in the Norwegian general population [5] and 4.0% across all countries [6]. The majority of the individuals with SAD report anxiety in performance situations [2]. SAD has an onset in adolescence with a mean age onset at 15 years [2, 7]. Over 80% of the individuals with SAD do not receive

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any treatment, and the mean age of first treatment is at 27 years [2].

The literature describes two subgroups of adult SAD: those with both interaction and performance anxiety (generalized SAD) and those with only performance anxiety [3], with PSA as the most common symptom in both adolescents [8] and adults [9]. Congruently, the novel DSM-5 [4] revised its specifier of SAD to include a "performance only" subgroup, distinct in terms of etiology, age at onset, physiological response, and treatment response [10].

Untreated PSA may cause further impairment in adulthood and around 50% of adolescents [11] and adults [3] with PSA develop generalized social anxiety [7]. Studies have shown that treating the specific subtype of PSA reduce the overall level of generalized social anxiety [12–14] and by providing a treatment intervention targeting adolescents, one might be able to reduce the societal and personal costs of the disease.

There is strong evidence supporting cognitive behavioral therapy (CBT) with exposure as the treatment of choice in treating PSA and SAD [15, 16]. However, conducting in-session exposure exercises for PSA has historically been unpractical or outright infeasible since this would require access to and control over an audience. This is in contrast with treatments of other anxiety disorders that rely on in-session exposure therapy, e.g. animal phobias and other specific phobias that are highly efficacious [17–20]. Virtual reality (VR) technology can resolve this issue by creating the illusion of being present in front of a realistic virtual audience. This is achieved by wearing a headset with dual displays that cover the eyes and simulates depth perception, the displayed content of which is interactive to head movement to give the illusion of being able to look around the virtual world [21]. By creating an animated virtual audience and presenting the feared stimuli to the patient, VR Exposure Therapy (VRET) for PSA is an attractive treatment method since it provides a convenient way doing in-session exposure with immediate access to controllable fear stimuli. Importantly, virtual audiences are sufficient to elicit a fear response [22], the basis of exposure therapy, and several randomized controlled trials of VRET for PSA have shown good results [23–26].

Until recently however, VR equipment was expensive, inaccessible, and required a high degree of technical competence to develop for and use. Lindner et al. [26] was the first to investigate whether consumer VR hardware and software can be used to conduct in-session exposure therapy with a therapist. One study has showed that relevant VR-stimuli do provoke distress in socially anxious youth [27]. To our knowledge, there have been no intervention studies on VRET for adolescents with PSA. In the current, non-randomized feasibility and pilot study, we investigate the feasibility of adapting the 3-h single session VRET protocol for PSA examined in Lindner et al. [26] into a 90-min single session for use with adolescents, and examine whether the effect size is similar, explore possible moderators of treatment effects, and physiological response to the VR scenarios.

Methods

Design

This study is a non-randomized feasibility and pilot study with pre, post and 1- and 3-month follow-ups. Reporting follows the CONSORT guidelines for pilot/feasibility trials.

Ethics

The study received ethical approval from the Norwegian Regional Ethical Committee (REK 2017-1521). Written informed consent was obtained from the parents of adolescents at the training session.

Procedure

A total of $N=27$ adolescents were included in the feasibility and pilot study. Recruitment was done in two periods: spring 2018 and autumn 2018. Information about the study was given in classrooms at two high schools (8th to 10th grade). In addition, written information with a link to the study website was distributed to all students and parents through mail, as well as school health services and head masters at the schools in Bergen, Norway, and through Facebook. Interested participants accessed the study website and completed the online screening, including Public Speaking Anxiety Scale (PSAS; [28]) and Social Interaction Anxiety Scale (SIAS; [29]). In order to be included, the adolescents had to be between 13 and 16 years old, confirm that they were afraid of speaking in public, had to report symptoms of PSA on the PSAS (observed range: 46–73, possible range 17–85) and functional impairment due to PSA. Due to the lack of international established cut-offs, no threshold level for PSAS was applied. Exclusion criteria, assessed during the same phone call, were: ongoing psychotherapy, use of benzodiazepines, and lack of stereoscopic vision that would impair the VR experience. After the initial screening eligible participants were contacted by phone to schedule a date for the training session.

Participants met for a single 90-min training session approximately 1 week after completing the online pretreatment questionnaires. Informed consent from parents was obtained before the exposure session. Posttreatment questionnaires were distributed 1 week after the training session. In addition, follow-up questionnaires were distributed one and 3 months after completing the

treatment session, in order to evaluate the long-term effects of the treatment. See Fig. 1 for study flowchart. Participants who completed the training session and responded to the questionnaires received a gift certificate of 200 NOK (approximately 20 Euros) when completing the 1-month follow-up assessment.

Intervention

VR scenario

A custom-built VR stimuli material depicting a typical Norwegian classroom and an age-appropriate audience was developed by Attensi AS, a professional IT developer. The scenario was inspired by five culturally and age-appropriate actual Norwegian classrooms and adjusted after feedback from testing by four adolescents. The classroom featured ten virtual avatars, depicted to be in the age range of 13–16, sitting at their desks, with minor body animations and gaze directed at the user situated at the front of the class. An empty classroom and a lobby were also available, with each exposure exercise beginning with the participant selecting to enter the full classroom. See Fig. 2 for screenshots. An Apple iPhone 7 and a high-end Cardboard-type VR headset (costing the equivalent of 60 USD) was used for stimuli presentation. The application automatically logged all user behaviors (e.g. entering and exiting the full classroom) with timestamps.

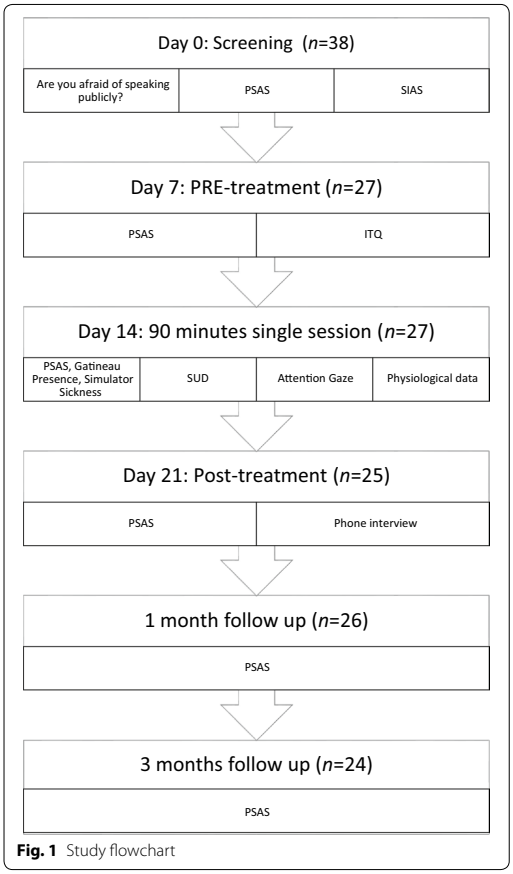

Fig. 1 Study flowchart

Treatment protocol

The treatment protocol was adapted from a recent VRET protocol for PSA [26], and tailored for use with adolescents. This protocol in turn was based on Öst's [20] one-session treatment for specific phobias, with speech (exposure) exercises (e.g. count down from 60, say words beginning with the letter P, improvised speeches about everyday matters), partly drawn from a one-session in vivo exposure protocol for PSA [12]. The session was therapist-led and consisted of three parts: brief psychoeducation (approx. 15 min), followed by exposure tasks (approx. 60 min) and ending with a summary and introduction to active maintenance (approx. 15 min). The therapeutic goal was to promote inhibitory learning [30] by exposing participants to speech scenarios designed to test their idiosyncratic catastrophic beliefs about speech performance and physiological reaction. The psychoeducation consisted of a short introduction to the CBT model of anxiety with some VR-adjustments. A simple functional analysis of their PSA was performed and the treatment rationale was explained.

The treatment protocol included seven tasks with varying levels of difficulty that lasted 1 to 2 min each with no or little preparation time. Adolescents wore the VR device only during the actual exposure tasks in order to avoid habituation to the virtual environment in itself, outside an exposure context. Participants were first instructed to enter a neutral empty classroom to make sure that the VR device was correctly configured. The adolescents were then exposed to a virtual classroom with an animated audience. Each task required entering and leaving the virtual classroom from a lobby, with discussions with the therapist between the tasks. Prior to each exposure task, the therapist would give instructions and noting their catastrophic beliefs and expectancy rating on a scale from 0 to 100. The therapist recorded maximum and minimum subjective units of distress (SUD; [31]) on a 0–100 scale, where 0 corresponds to no distress at all and 100 is the worst possible, as reported by the participant directly after each exposure task. SUDS [31] is a useful tool by showing the participants how their level of anxiety reduces throughout the exposure

Fig. 2 Screenshots from the VR application

tasks. Immediately after the exposure task, the adolescent would evaluate the performance together with the therapist and rate the subjective level of discomfort experienced. The therapist and adolescent then listened to an audio recording of the task, with the adolescent using mental imagery to cast themselves in the role of an audience member in the same scenario listening to the speech as played back. Participants were then asked to once again quality rate the performance after listening and discuss with the therapist about discrepancies before continuing to the next exposure task. This procedure was then repeated for each task.

After completing the exposure tasks, the adolescent and the therapist had a short summary discussion before introducing them how to practice exposure in real life. Main points were summed up in a folder, which was given to the adolescent at the end of the session. The duration of the session was reduced from an original 3 h [26] to approximately 90 min, thus making the session more age appropriate. All training sessions were conducted at a hospital location after school hours. In order to ensure further in vivo exposure, the participants were contacted by telephone 2 weeks after the training session. A short assessment was then made of the participant's experience in participating in the session. In addition, the participants were given prompts for data purposes.

Therapists

The sessions were conducted by two clinical psychologists with experience in CBT treatments of social anxiety disorder and received 4 h of protocol-specific training. The same therapist that conducted the session also contacted the participants by telephone after the training session. The therapists were supervised by a senior clinical psychologist throughout the treatment period.

Measurements

Primary outcome measure

The Public Speaking Anxiety Scale (PSAS; [28]) was administered at screening, at the beginning of the session, post-treatment and at 1 and 3-month follow-up. The PSAS covers cognitions, behaviors and physiological manifestations of Public Speaking Anxiety with 17-items, with a five-point Likert response format. Five of the items are reverse coded. The questionnaire was translated into Norwegian for this study according to scientific standard (including back-translation). Cronbach's alpha at pre-treatment was an acceptable 0.76.

Moderators of treatment effect

Two possible moderators of treatment effects were examined. The Social Interaction Anxiety Scale (SIAS; [29]) was administered at screening and measures the more

generalized type of SAD which includes interaction anxiety. SIAS is a 20-items scale on a scale from 1 "not at all characteristic or true of me" to 4 "extremely characteristic or true of me". Summary scores ranges from 20 to 80 with a higher score indicating more social interaction anxiety. SIAS show good psychometric properties, and discriminates patients with social phobia from patients with other anxiety disorders or no disorder at all. Cronbach's alpha at screening was calculated to 0.86. As the literature distinguishes between the two subgroups of SAD [3], we investigated whether performance-only social anxiety had better treatment outcome than adolescents with the more generalized type of social anxiety, which includes both performance and interaction anxiety. A binary variable corresponding to "low SIAS" (0, reference) and "high SIAS" (1) was created using median-split subsampling (median = 35), creating two groups ($n_{low} = \geq 35$, $n_{high} = \leq 36–100$). This binary variable was used to examine moderating effects, since interaction effects were unlikely to be linear.

Sense of presence in VR environment, the degree to which the experience feels real [32], was also explored as a possible moderator of treatment effects. Sense of presence is positively associated with emotional distress in VR [33], yet the causal, possibly bi-directional relationship between presence and emotional distress is complex [34]. In this study, the Gatineau Presence Questionnaire [35] was administered at the end of the session. The Gatineau Presence Questionnaire is a short measure with five items rated on a 0–100 scale resulting in an average score in percentage. The questionnaire assesses (1) the impression of being in the virtual environment, (2) the experience as being real, and the reversed items; (3) attentiveness of the virtual environment as being artificial, (4) the experience of being present in the office instead of the virtual environment and (5) the experience of discomfort. A presence score is calculated by averaging items 1–4. A binary variable "low presence" (0, reference) and "high presence" (1) was then created using median-split subsampling, creating two groups ($n_{low} = \geq 59$, $n_{high} = \leq 60$. This binary variable was used to examine moderating effects, since interaction effects were unlikely to be linear.

Physiological data

Heart rate data was collected continuously during the session using a wearable, wireless Empatica E4 wristband. Timestamped heart rate data were synchronized to the log files of the VR-running smartphone such that for each data point (temporal resolution: 1 s), the virtual scenario in which each data point was recorded was known. In total, $n = 147{,}322$ data points from $n = 21$ participants were available for analyses. Time spent in the lobby before entering the full classroom served as comparison period for each exposure period, with the first 60 s of data after each exposure period being discarded to allow heart rate normalization. Mean heart rate during each period and task were calculated. The median number of recorded transitions from lobby to full classroom was eight, with a maximum of 14. Since repetitions of and deviations from the seven per-protocol speech exercises was not systematically recorded, it is not possible to assert whether recoded exposure tasks are equivalent across participants. Only the initial eight exercises for each participant were included in analyses since these likely show the least variations across participants.

Analyses

SPSS Statistics version 24 was used to analyze data. Outcome data were analyzed using linear mixed effects models [36], modeling change on both individual and group level. The analysis included unstructured random effects covariance matrices, random slopes and intercept. All participants who began treatment were included in analyses, with missing data estimated using restricted maximum likelihood modeling of random effects. PSAS scores served as the dependent variable in all models, with a binary independent variable corresponding to before and after treatment (both screening and pre-measurement coded as zero and the post-measurement as one). Moderation analyses were performed using the same time variable, a binary moderator, and the interaction thereof. In the analysis of long-term effects, a separate mixed model was run using a new, numeric time variable corresponding to months since treatment (0 = post, 1 = 1-month follow-up, 3 = 3-months follow-up). Calculation of effect sizes was based on estimated means pre and post treatment: $Pre_m - Post_m/SD_{pre}$ where the calculation of standard deviation = standard error $\times \sqrt{N}$. Heart rate data were also analyzed using mixed models (random slopes and intercepts), with period-average heart rate as the dependent variable and period (lobby or full classroom) as independent variable.

Results

Attrition

A total of 38 participants completed the online screening, 32 participants (84.2%) were invited to participate in the study and to the training. Two participants cancelled the training session due to lack of time, one did not show up at the training session, one participant was referred to other health services and one participant was excluded due to missing consent from parents. This resulted in $N = 27$ participants: $n = 6$ male (22%) and $n = 21$ female (78%). Participants ranged from 13 to 16 years old, with an average age of 14.22 years ($SD = 0.64$). Observed mean

Table 1 Observed means, standard deviations and n missing for primary outcome measure (PSAS) at each measure point

Day	Assessment	*M*	*SD*	*n* missing
0	Screening	62.81	9.88	0
7	Pre-treatment	61.04	7.80	0
21	Post-treatment	49.28	10.23	2
42	One-month follow-up	50.00	12.73	1
97	Three-months follow-up	47.25	11.92	3

M mean, *SD* standard deviation, *n*: number of participants, *PSAS* Public Speaking Anxiety scale

pretreatment level and the mean change and standard deviations for the primary outcome variable PSAS are presented in Table 1.

Changes from pre-treatment to post-treatment

Table 1 shows observed means and standard deviations for all measure points. PSAS symptoms remained stable from screening to pre-treatment. The unconditional mixed model showed a significant decrease in their PSAS score from pre to post by an average of 12.23 points ($SE = 2.08$, $p < 0.001$). The effect size, calculated from estimated means pre and post treatment and standard error: $61.04 - 48.81/7.98 = 1.53$.

Changes from Post-treatment to Follow-ups

Modeling the follow-up period revealed a non-significant decrease in PSAS score of -0.44 ($SE = 0.41$, $p = 0.300$) per month after treatment. See Table 1 for observed scores.

Moderators of treatment effects

Mixed effects models were computed in order to investigate whether there was any difference between groups when exploring moderators of treatment effects, by using low generalized social anxiety and low experience of presence as a reference in the analyses. Moderators of treatment effects showed no difference between groups in treatment outcome from pre to post. See Table 2 for details.

Physiological response to exposure

Average heart rate during exposure was 85.89 ($SE = 1.59$), rising on average 3.66 ($SE = 1.03$, $p < 0.001$) from the non-exposure period immediately preceding it. Plotting the data over time revealed that this difference differed substantially between tasks, but because task-equivalence across participants cannot be assumed, it is not possible to draw conclusions as to whether some tasks led to greater increases of heart rate. See Fig. 3.

Table 2 Estimated treatment effects on primary outcome measures (PSAS)

	β	*SE*	*p*	95% CI
Unconditional pre-post				
(Intercept)	61.93	1.56	< 0.001	58.72 to 65.13
Time	− 12.23	2.08	< 0.001	− 16.52 to 7.94
Moderation pre-post by presence (median-split)				
(Intercept)	60.36	2.16	< 0.001	55.91 to 64.81
Presence	2.48	3.18	0.443	− 4.08 to 9.03
Time	− 10.99	3.19	< 0.01	− 17.57 to 4.40
Presence × time	− 4.04	4.60	0.389	− 13.54 to 5.46
Moderation pre-post by generalized SAD (median-split)				
(Intercept)	60.04	2.12	< 0.001	55.67 to 64.40
SIAS	3.93	3.05	0.21	− 2.36 to 10.21
Time	− 14.68	2.82	< 0.01	− 20.51 to − 8.85
SIAS × time	5.10	4.07	0.22	− 3.31 to 13.51

$N = 27$

B (unstandardized) parameter estimates, *SE* standard error, *CI* confidence interval

Feasibility outcomes

One main purpose of this study was to examine the feasibility of the protocol. Five elements were adjusted from the first (spring 2018) to the second period (autumn 2018) of the study.

Parent involvement

Parents were more involved in the second period compared to the first period through e-mail distribution and telephone contact. They were given more detailed information at the beginning of the exposure session, and were asked to ensure that the adolescents fill out the follow- up assessments.

Attrition

During the first period, the gift card was distributed to the adolescents after completion of 1-month follow-up, which resulted in difficulties in collecting the 3-month follow-up questionnaire. By adjusting the value of the gift card and distributing them to the adolescents after having completed the 3-month questionnaires, the study did not have any missing data during the second period.

Compensation

Due to the workload for the adolescents, we increased the value of the gift card from 200 to 300 NOK (30 euros).

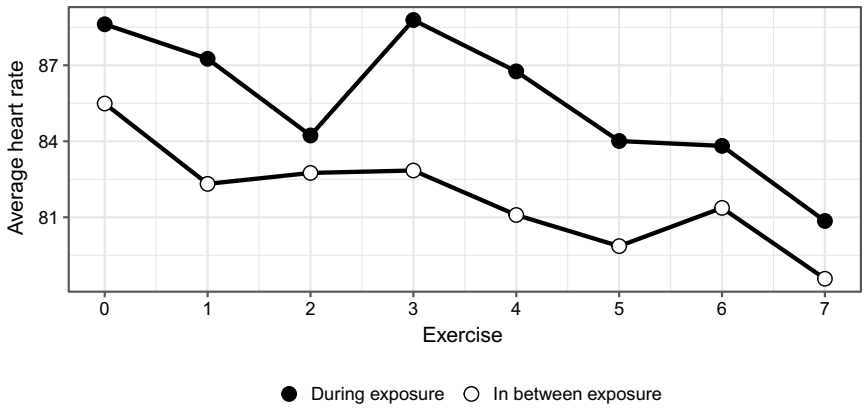

Fig. 3 Heart rate

Break

Due to the long duration after school hours, a short break was included halfway through the intervention and before starting on the relapse prevention part.

Duration of training session

According to the protocol, the intervention was supposed to be 90 min. However, this was not applicable and time spent on each training session was between 2 and 2.5 h.

Discussion

The present study is the first to examine the feasibility, to pilot the effects of a VRET intervention for adolescents with fear of public speaking. In addition, the aim was to examine moderators of treatment and heart rate during the intervention.

A total of $N=27$ eligible adolescents between 13 and 16 years participated in the study, the majority being female. The original protocol was developed for adults, and adjusted for this age group. Through feedback from the participating adolescents and the therapists, a further adaption to the target group was conducted during the study period. This included increasing the training session from 90 to 120–150 min with a short break, increasing parent involvement, increasing gift card value and introducing prompts after the treatment session for in vivo exposure and data-collection purposes.

The one-session treatment showed large effects on the primary outcome measure (PSAS, $ES=1.53$) 1 week after treatment. This result remained stable during the one and three follow-up period. This result is comparable to the findings from previous studies on VRET for PSA for adults [23, 25, 26, 37]. The present study showed a large effect size and a reduction in PSAS scores of 12.23 points, whereas the Lindner et al. [26] study showed a 6.90 point reduction. This difference indicate that the original protocol was successfully adapted before and during the trial to our target group. This includes the development of a VR stimuli tailored specifically to illustrate a cultural and age appropriate classroom and audience.

With regards to treatment moderators, the results revealed no significant differences in symptom reduction on the basis of a high general social anxiety symptoms (SIAS scores). Neither did our results show a moderating effect of high sense of presence. While previous research has shown robust associations between presence and emotional distress during the VR exposure, the role of presence in explaining treatment outcome remains unclear [34, 38]. Of note, both these moderation analyses were low–powered, and should therefore be interpreted with caution.

Results from analyses on physiological data revealed that the exposure scenarios were successful in eliciting a physiological response in the form of increase heart rate, yet the increase was small. This is in line with clinical experience from the Lindner et al. [26] trial, finding that VR public speaking scenarios elicit a weaker fear response compared to e.g. VR spider scenarios [39]. The combination of a relative weak physiological response during treatment and a large decrease in the psychological symptoms is congruent with the theoretical foundation for the treatment protocol, emphasizing inhibitory learning over a strong fear response and subsequent habituation rationale [30]. This is

also consistent with empirical findings showing that a strong fear response is not necessary for fear extinction [40].

PSA has been until now difficult to treat in a traditional therapeutic setting, due to the stimuli required. VRET is not a common method in the healthcare services, as VR-devices has not been easily available, and has a high cost. With innovative and accessible consumer technology, VRET for PSA may now be offered as a tool for therapists, and VRET can be easily conducted in any clinical setting. The therapists involved in the feasibility and pilot study had a CBT background with no prior experience with VRET, and were able to conduct the treatment after only a 4-h workshop. This shows how any CBT clinician can use the treatment method after only a small amount of training. Also, studies conducted both before and after the advent of available consumer VR technology, have shown that clinicians see benefits of using VR to conduct exposure therapy and that they are willing to adopt the technology in clinical practice [26, 41, 42].

Importantly, we also replicate the finding that modern, low-cost consumer VR hardware can be used to administer efficacious treatment [26]. Findings from this study shows how low-cost VR can be used in treatment and by using a mobile app the potential for the scalability of the treatment method.

Strengths and limitations

One major strength of this study is low attrition among adolescents as the study had few missing data. Another major strength of this study is the investigation of physiological data using heart rate as well as collecting the PSAS symptom scores, which gives valuable information on both their subjective and their objective level of discomfort experienced when talking to an audience.

There are also some limitations of this study, which needs to be addressed. No control or comparison groups were included in this feasibility and pilot study. Consequently, we cannot conclude on cause for change during the intervention. For example, a decrease in PSA symptoms can be attributed to less oral presentations at school during the treatment and follow-up period. Moreover, the current design cannot isolate the therapist effect from the VRET effect, as the participants conducted the VRET intervention with guidance from a therapist. Being adjacent to a therapist when doing the exposure tasks might have contributed to the clinical efficacy of the VR intervention. However, the recent randomized controlled trial conducted by Lindner et al. [26] showed a reduction in anxiety symptoms when doing the intervention at home without therapist-guidance. Miloff et al. [39] showed that limited therapeutic guidance in VRET for spider phobia led to reduction in anxiety symptoms, and the results maintained the same at follow-up. This indicates that the VR intervention itself is contributing to the reduction in PSA symptoms. Moreover, the study did not collect data on generalized social anxiety disorder (SAD) after treatment; in retrospect, it would have been valuable to include such data at post and follow-up and explore whether VRET for PSA also has a treatment effect on SAD, as indicated by previous studies [12–14]. Another limitation is the small sample (although well-powered for the expected effect size), and as is typical of clinical trials, it is unknown to what degree findings generalize to non-treatment seekers. Further, it consists of a higher group of female.

Future studies should examine the effectiveness of the VR intervention in a randomized controlled trial, with a larger population for the generalizability of the study, in addition to providing the intervention as self-guided for scalability purposes. There is also a need to explore the limitations and benefits of VR-delivered exposure in a head-to-head comparison of in vivo and VR-delivered exposure for FoPS. Data on real-world public speaking behavior during the follow-up intervention would be an interesting outcome measure in future studies, in order to investigate the transition from the VR-scenario to the real world context. In this regard, a longer follow-up period (e.g. 12 months) would have been useful.

Conclusion

The feasibility and pilot study shows that one-session VRET is an effective tool for treating adolescents with PSA. By using a mobile application platform and an affordable VR platform, the study shows the great potential of VRET as scalable option for treating PSA in adolescents.

Abbreviations

PSA: Public Speaking Anxiety; SAD: social anxiety disorder; VR: virtual reality; VRET: virtual reality exposure therapy; CBT: cognitive behavioral therapy.

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Authors' contributions

Designed the study: SK, PL and TN. Treated participants and collected data: SK. Analyzed data: SK, PL and TN. Drafted the manuscript SK. Made significant contributions to writing: PL and TN. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The study has received ethics approval from the Regional Ethics Committee (2017/1521). Informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
Author PL reports having received consulting fees from Mimerse. The other authors declare that they have no competing interests.

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	Hestad, Knut, Dr. philos.	Neuropsychological deficits in HIV-1 infection.
	Lugoe, L.Wycliffe, Dr. philos.	Prediction of Tanzanian students' HIV risk and preventive behaviours
	Sandvik, B. Gunnhild, Dr. philos.	Fra distriktsjordmor til institusjonsjordmor. Fremveksten av en profesjon og en profesjonsutdanning
	Lie, Gro Therese, Dr. psychol.	The disease that dares not speak its name: Studies on factors of importance for coping with HIV/AIDS in Northern Tanzania
	Øygard, Lisbet, Dr. philos.	Health behaviors among young adults. A psychological and sociological approach
	Stormark, Kjell Morten, Dr. psychol.	Emotional modulation of selective attention: Experimental and clinical evidence.
	Einarsen, Ståle, Dr. psychol.	Bullying and harassment at work: epidemiological and psychosocial aspects.

1997	Knivsberg, Ann-Mari, Dr. philos.	Behavioural abnormalities and childhood psychopathology: Urinary peptide patterns as a potential tool in diagnosis and remediation.
	Eide, Arne H., Dr. philos.	Adolescent drug use in Zimbabwe. Cultural orientation in a global-local perspective and use of psychoactive substances among secondary school students.
	Sørensen, Marit, Dr. philos.	The psychology of initiating and maintaining exercise and diet behaviour.
	Skjæveland, Oddvar, Dr. psychol.	Relationships between spatial-physical neighborhood attributes and social relations among neighbors.
	Zewdie, Teka, Dr. philos.	Mother-child relational patterns in Ethiopia. Issues of developmental theories and intervention programs.
	Wilhelmsen, Britt Unni, Dr. philos.	Development and evaluation of two educational programmes designed to prevent alcohol use among adolescents.
	Manger, Terje, Dr. philos.	Gender differences in mathematical achievement among Norwegian elementary school students.
1998 **V**	Lindstrøm, Torill Christine, Dr. philos.	«Good Grief»: Adapting to Bereavement.
	Skogstad, Anders, Dr. philos.	Effects of leadership behaviour on job satisfaction, health and efficiency.
	Haldorsen, Ellen M. Håland, Dr. psychol.	Return to work in low back pain patients.
	Besemer, Susan P., Dr. philos.	Creative Product Analysis: The Search for a Valid Model for Understanding Creativity in Products.
H	Winje, Dagfinn, Dr. psychol.	Psychological adjustment after severe trauma. A longitudinal study of adults' and children's posttraumatic reactions and coping after the bus accident in Måbødalen, Norway 1988.
	Vosburg, Suzanne K., Dr. philos.	The effects of mood on creative problem solving.
	Eriksen, Hege R., Dr. philos.	Stress and coping: Does it really matter for subjective health complaints?
	Jakobsen, Reidar, Dr. psychol.	Empiriske studier av kunnskap og holdninger om hiv/aids og den normative seksuelle utvikling i ungdomsårene.
1999 **V**	Mikkelsen, Aslaug, Dr. philos.	Effects of learning opportunities and learning climate on occupational health.
	Samdal, Oddrun, Dr. philos.	The school environment as a risk or resource for students' health-related behaviours and subjective well-being.
	Friestad, Christine, Dr. philos.	Social psychological approaches to smoking.
	Ekeland, Tor-Johan, Dr. philos.	Meining som medisin. Ein analyse av placebofenomenet og implikasjoner for terapi og terapeutiske teoriar.
H	Saban, Sara, Dr. psychol.	Brain Asymmetry and Attention: Classical Conditioning Experiments.

	Carlsten, Carl Thomas, Dr. philos.	God lesing – God læring. En aksjonsrettet studie av undervisning i fagtekstlesing.
	Dundas, Ingrid, Dr. psychol.	Functional and dysfunctional closeness. Family interaction and children's adjustment.
	Engen, Liv, Dr. philos.	Kartlegging av leseferdighet på småskoletrinnet og vurdering av faktorer som kan være av betydning for optimal leseutvikling.
2000 V	Hovland, Ole Johan, Dr. philos.	Transforming a self-preserving "alarm" reaction into a self-defeating emotional response: Toward an integrative approach to anxiety as a human phenomenon.
	Lillejord, Sølvi, Dr. philos.	Handlingsrasjonalitet og spesialundervisning. En analyse av aktørperspektiver.
	Sandell, Ove, Dr. philos.	Den varme kunnskapen.
	Oftedal, Marit Petersen, Dr. philos.	Diagnostisering av ordavkodingsvansker: En prosessanalytisk tilnærmingsmåte.
H	Sandbak, Tone, Dr. psychol.	Alcohol consumption and preference in the rat: The significance of individual differences and relationships to stress pathology
	Eid, Jarle, Dr. psychol.	Early predictors of PTSD symptom reporting; The significance of contextual and individual factors.
2001 V	Skinstad, Anne Helene, Dr. philos.	Substance dependence and borderline personality disorders.
	Binder, Per-Einar, Dr. psychol.	Individet og den meningsbærende andre. En teoretisk undersøkelse av de mellommenneskelige forutsetningene for psykisk liv og utvikling med utgangspunkt i Donald Winnicotts teori.
	Roald, Ingvild K., Dr. philos.	Building of concepts. A study of Physics concepts of Norwegian deaf students.
H	Fekadu, Zelalem W., Dr. philos.	Predicting contraceptive use and intention among a sample of adolescent girls. An application of the theory of planned behaviour in Ethiopian context.
	Melesse, Fantu, Dr. philos.	The more intelligent and sensitive child (MISC) mediational intervention in an Ethiopian context: An evaluation study.
	Råheim, Målfrid, Dr. philos.	Kvinners kroppserfaring og livssammenheng. En fenomenologisk – hermeneutisk studie av friske kvinner og kvinner med kroniske muskelsmerter.
	Engelsen, Birthe Kari, Dr. psychol.	Measurement of the eating problem construct.
	Lau, Bjørn, Dr. philos.	Weight and eating concerns in adolescence.
2002 V	Ihlebæk, Camilla, Dr. philos.	Epidemiological studies of subjective health complaints.
	Rosén, Gunnar O. R., Dr. philos.	The phantom limb experience. Models for understanding and treatment of pain with hypnosis.

	Høines, Marit Johnsen, Dr. philos.	Fleksible språkrom. Matematikklæring som tekstutvikling.
	Anthun, Roald Andor, Dr. philos.	School psychology service quality. Consumer appraisal, quality dimensions, and collaborative improvement potential
	Pallesen, Ståle, Dr. psychol.	Insomnia in the elderly. Epidemiology, psychological characteristics and treatment.
	Midthassel, Unni Vere, Dr. philos.	Teacher involvement in school development activity. A study of teachers in Norwegian compulsory schools
	Kallestad, Jan Helge, Dr. philos.	Teachers, schools and implementation of the Olweus Bullying Prevention Program.
H	Ofte, Sonja Helgesen, Dr. psychol.	Right-left discrimination in adults and children.
	Netland, Marit, Dr. psychol.	Exposure to political violence. The need to estimate our estimations.
	Diseth, Åge, Dr. psychol.	Approaches to learning: Validity and prediction of academic performance.
	Bjuland, Raymond, Dr. philos.	Problem solving in geometry. Reasoning processes of student teachers working in small groups: A dialogical approach.
2003 **V**	Arefjord, Kjersti, Dr. psychol.	After the myocardial infarction – the wives' view. Short- and long-term adjustment in wives of myocardial infarction patients.
	Ingjaldsson, Jón Þorvaldur, Dr. psychol.	Unconscious Processes and Vagal Activity in Alcohol Dependency.
	Holden, Børge, Dr. philos.	Følger av atferdsanalytiske forklaringer for atferdsanalysens tilnærming til utforming av behandling.
	Holsen, Ingrid, Dr. philos.	Depressed mood from adolescence to 'emerging adulthood'. Course and longitudinal influences of body image and parent-adolescent relationship.
	Hammar, Åsa Karin, Dr. psychol.	Major depression and cognitive dysfunction- An experimental study of the cognitive effort hypothesis.
	Sprugevica, Ieva, Dr. philos.	The impact of enabling skills on early reading acquisition.
	Gabrielsen, Egil, Dr. philos.	LESE FOR LIVET. Lesekompetansen i den norske voksenbefolkningen sett i lys av visjonen om en enhetsskole.
H	Hansen, Anita Lill, Dr. psychol.	The influence of heart rate variability in the regulation of attentional and memory processes.
	Dyregrov, Kari, Dr. philos.	The loss of child by suicide, SIDS, and accidents: Consequences, needs and provisions of help.
2004 **V**	Torsheim, Torbjørn, Dr. psychol.	Student role strain and subjective health complaints: Individual, contextual, and longitudinal perspectives.
	Haugland, Bente Storm Mowatt Dr. psychol.	Parental alcohol abuse. Family functioning and child adjustment.

	Milde, Anne Marita, Dr. psychol.	Ulcerative colitis and the role of stress. Animal studies of psychobiological factors in relationship to experimentally induced colitis.
	Stornes, Tor, Dr. philos.	Socio-moral behaviour in sport. An investigation of perceptions of sportspersonship in handball related to important factors of socio-moral influence.
	Mæhle, Magne, Dr. philos.	Re-inventing the child in family therapy: An investigation of the relevance and applicability of theory and research in child development for family therapy involving children.
	Kobbeltvedt, Therese, Dr. psychol.	Risk and feelings: A field approach.
2004 H	Thomsen, Tormod, Dr. psychol.	Localization of attention in the brain.
	Løberg, Else-Marie, Dr. psychol.	Functional laterality and attention modulation in schizophrenia: Effects of clinical variables.
	Kyrkjebø, Jane Mikkelsen, Dr. philos.	Learning to improve: Integrating continuous quality improvement learning into nursing education.
	Laumann, Karin, Dr. psychol.	Restorative and stress-reducing effects of natural environments: Experiencal, behavioural and cardiovascular indices.
	Holgersen, Helge, PhD	Mellom oss - Essay i relasjonell psykoanalyse.
2005 V	Hetland, Hilde, Dr. psychol.	Leading to the extraordinary? Antecedents and outcomes of transformational leadership.
	Iversen, Anette Christine, Dr. philos.	Social differences in health behaviour: the motivational role of perceived control and coping.
2005 H	Mathisen, Gro Ellen, PhD	Climates for creativity and innovation: Definitions, measurement, predictors and consequences.
	Sævi, Tone, Dr. philos.	Seeing disability pedagogically – The lived experience of disability in the pedagogical encounter.
	Wiium, Nora, PhD	Intrapersonal factors, family and school norms: combined and interactive influence on adolescent smoking behaviour.
	Kanagaratnam, Pushpa, PhD	Subjective and objective correlates of Posttraumatic Stress in immigrants/refugees exposed to political violence.
	Larsen, Torill M. B. , PhD	Evaluating principals` and teachers` implementation of Second Step. A case study of four Norwegian primary schools.
	Bancila, Delia, PhD	Psychosocial stress and distress among Romanian adolescents and adults.
2006 V	Hillestad, Torgeir Martin, Dr. philos.	Normalitet og avvik. Forutsetninger for et objektivt psykopatologisk avviksbegrep. En psykologisk, sosial, erkjennelsesteoretisk og teorihistorisk framstilling.
	Nordanger, Dag Øystein, Dr. psychol.	Psychosocial discourses and responses to political violence in post-war Tigray, Ethiopia.

	Rimol, Lars Morten, PhD	Behavioral and fMRI studies of auditory laterality and speech sound processing.
	Krumsvik, Rune Johan, Dr. philos.	ICT in the school. ICT-initiated school development in lower secondary school.
	Norman, Elisabeth, Dr. psychol.	Gut feelings and unconscious thought: An exploration of fringe consiousness in implicit cognition.
	Israel, K Pravin, Dr. psychol.	Parent involvement in the mental health care of children and adolescents. Emperical studies from clinical care setting.
	Glasø, Lars, PhD	Affects and emotional regulation in leader-subordinate relationships.
	Knutsen, Ketil, Dr. philos.	HISTORIER UNGDOM LEVER – En studie av hvordan ungdommer bruker historie for å gjøre livet meningsfullt.
	Matthiesen, Stig Berge, PhD	Bullying at work. Antecedents and outcomes.
2006 H	Gramstad, Arne, PhD	Neuropsychological assessment of cognitive and emotional functioning in patients with epilepsy.
	Bendixen, Mons, PhD	Antisocial behaviour in early adolescence: Methodological and substantive issues.
	Mrumbi, Khalifa Maulid, PhD	Parental illness and loss to HIV/AIDS as experienced by AIDS orphans aged between 12-17 years from Temeke District, Dar es Salaam, Tanzania: A study of the children's psychosocial health and coping responses.
	Hetland, Jørn, Dr. psychol.	The nature of subjective health complaints in adolescence: Dimensionality, stability, and psychosocial predictors
	Kakoko, Deodatus Conatus Vitalis, PhD	Voluntary HIV counselling and testing service uptake among primary school teachers in Mwanza, Tanzania: assessment of socio-demographic, psychosocial and socio-cognitive aspects
	Mykletun, Arnstein, Dr. psychol.	Mortality and work-related disability as long-term consequences of anxiety and depression: Historical cohort designs based on the HUNT-2 study
	Sivertsen, Børge, PhD	Insomnia in older adults. Consequences, assessment and treatment.
2007 V	Singhammer, John, Dr. philos.	Social conditions from before birth to early adulthood – the influence on health and health behaviour
	Janvin, Carmen Ani Cristea, PhD	Cognitive impairment in patients with Parkinson's disease: profiles and implications for prognosis
	Braarud, Hanne Cecilie, Dr.psychol.	Infant regulation of distress: A longitudinal study of transactions between mothers and infants
	Tveito, Torill Helene, PhD	Sick Leave and Subjective Health Complaints
	Magnussen, Liv Heide, PhD	Returning disability pensioners with back pain to work

	Thuen, Elin Marie, Dr.philos.	Learning environment, students' coping styles and emotional and behavioural problems. A study of Norwegian secondary school students.
	Solberg, Ole Asbjørn, PhD	Peacekeeping warriors – A longitudinal study of Norwegian peacekeepers in Kosovo
2007 H	Søreide, Gunn Elisabeth, Dr.philos.	Narrative construction of teacher identity
	Svensen, Erling, PhD	WORK & HEALTH. Cognitive Activation Theory of Stress applied in an organisational setting.
	Øverland, Simon Nygaard, PhD	Mental health and impairment in disability benefits. Studies applying linkages between health surveys and administrative registries.
	Eichele, Tom, PhD	Electrophysiological and Hemodynamic Correlates of Expectancy in Target Processing
	Børhaug, Kjetil, Dr.philos.	Oppseding til demokrati. Ein studie av politisk oppseding i norsk skule.
	Eikeland, Thorleif, Dr.philos.	Om å vokse opp på barnehjem og på sykehus. En undersøkelse av barnehjemsbarns opplevelser på barnehjem sammenholdt med sanatoriebarns beskrivelse av langvarige sykehusopphold – og et forsøk på forklaring.
	Wadel, Carl Cato, Dr.philos.	Medarbeidersamhandling og medarbeiderledelse i en lagbasert organisasjon
	Vinje, Hege Forbech, PhD	Thriving despite adversity: Job engagement and self-care among community nurses
	Noort, Maurits van den, PhD	Working memory capacity and foreign language acquisition
2008 V	Breivik, Kyrre, Dr.psychol.	The Adjustment of Children and Adolescents in Different Post-Divorce Family Structures. A Norwegian Study of Risks and Mechanisms.
	Johnsen, Grethe E., PhD	Memory impairment in patients with posttraumatic stress disorder
	Sætrevik, Bjørn, PhD	Cognitive Control in Auditory Processing
	Carvalhosa, Susana Fonseca, PhD	Prevention of bullying in schools: an ecological model
2008 H	Brønnick, Kolbjørn Selvåg	Attentional dysfunction in dementia associated with Parkinson's disease.
	Posserud, Maj-Britt Rocio	Epidemiology of autism spectrum disorders
	Haug, Ellen	Multilevel correlates of physical activity in the school setting
	Skjerve, Arvid	Assessing mild dementia – a study of brief cognitive tests.

	Kjønniksen, Lise	The association between adolescent experiences in physical activity and leisure time physical activity in adulthood: a ten year longitudinal study
	Gundersen, Hilde	The effects of alcohol and expectancy on brain function
	Omvik, Siri	Insomnia – a night and day problem
2009 V	Molde, Helge	Pathological gambling: prevalence, mechanisms and treatment outcome.
	Foss, Else	Den omsorgsfulle væremåte. En studie av voksnes væremåte i forhold til barn i barnehagen.
	Westrheim, Kariane	Education in a Political Context: A study of Konwledge Processes and Learning Sites in the PKK.
	Wehling, Eike	Cognitive and olfactory changes in aging
	Wangberg, Silje C.	Internet based interventions to support health behaviours: The role of self-efficacy.
	Nielsen, Morten B.	Methodological issues in research on workplace bullying. Operationalisations, measurements and samples.
	Sandu, Anca Larisa	MRI measures of brain volume and cortical complexity in clinical groups and during development.
	Guribye, Eugene	Refugees and mental health interventions
	Sørensen, Lin	Emotional problems in inattentive children – effects on cognitive control functions.
	Tjomsland, Hege E.	Health promotion with teachers. Evaluation of the Norwegian Network of Health Promoting Schools: Quantitative and qualitative analyses of predisposing, reinforcing and enabling conditions related to teacher participation and program sustainability.
	Helleve, Ingrid	Productive interactions in ICT supported communities of learners
2009 H	Skorpen, Aina Øye, Christine	Dagliglivet i en psykiatrisk institusjon: En analyse av miljøterapeutiske praksiser
	Andreassen, Cecilie Schou	WORKAHOLISM – Antecedents and Outcomes
	Stang, Ingun	Being in the same boat: An empowerment intervention in breast cancer self-help groups
	Sequeira, Sarah Dorothee Dos Santos	The effects of background noise on asymmetrical speech perception
	Kleiven, Jo, dr.philos.	The Lillehammer scales: Measuring common motives for vacation and leisure behavior
	Jónsdóttir, Guðrún	Dubito ergo sum? Ni jenter møter naturfaglig kunnskap.
	Hove, Oddbjørn	Mental health disorders in adults with intellectual disabilities - Methods of assessment and prevalence of mental health disorders and problem behaviour
	Wageningen, Heidi Karin van	The role of glutamate on brain function

	Bjørkvik, Jofrid	God nok? Selvaktelse og interpersonlig fungering hos pasienter innen psykisk helsevern: Forholdet til diagnoser, symptomer og behandlingsutbytte
	Andersson, Martin	A study of attention control in children and elderly using a forced-attention dichotic listening paradigm
	Almås, Aslaug Grov	Teachers in the Digital Network Society: Visions and Realities. A study of teachers' experiences with the use of ICT in teaching and learning.
	Ulvik, Marit	Lærerutdanning som danning? Tre stemmer i diskusjonen
2010 V	Skår, Randi	Læringsprosesser i sykepleieres profesjonsutøvelse. En studie av sykepleieres læringserfaringer.
	Roald, Knut	Kvalitetsvurdering som organisasjonslæring mellom skole og skoleeigar
	Lunde, Linn-Heidi	Chronic pain in older adults. Consequences, assessment and treatment.
	Danielsen, Anne Grete	Perceived psychosocial support, students' self-reported academic initiative and perceived life satisfaction
	Hysing, Mari	Mental health in children with chronic illness
	Olsen, Olav Kjellevold	Are good leaders moral leaders? The relationship between effective military operational leadership and morals
	Riese, Hanne	Friendship and learning. Entrepreneurship education through mini-enterprises.
	Holthe, Asle	Evaluating the implementation of the Norwegian guidelines for healthy school meals: A case study involving three secondary schools
H	Hauge, Lars Johan	Environmental antecedents of workplace bullying: A multi-design approach
	Bjørkelo, Brita	Whistleblowing at work: Antecedents and consequences
	Reme, Silje Endresen	Common Complaints – Common Cure? Psychiatric comorbidity and predictors of treatment outcome in low back pain and irritable bowel syndrome
	Helland, Wenche Andersen	Communication difficulties in children identified with psychiatric problems
	Beneventi, Harald	Neuronal correlates of working memory in dyslexia
	Thygesen, Elin	Subjective health and coping in care-dependent old persons living at home
	Aanes, Mette Marthinussen	Poor social relationships as a threat to belongingness needs. Interpersonal stress and subjective health complaints: Mediating and moderating factors.
	Anker, Morten Gustav	Client directed outcome informed couple therapy

	Bull, Torill	Combining employment and child care: The subjective well-being of single women in Scandinavia and in Southern Europe
	Viig, Nina Grieg	Tilrettelegging for læreres deltakelse i helsefremmende arbeid. En kvalitativ og kvantitativ analyse av sammenhengen mellom organisatoriske forhold og læreres deltakelse i utvikling og implementering av Europeisk Nettverk av Helsefremmende Skoler i Norge
	Wolff, Katharina	To know or not to know? Attitudes towards receiving genetic information among patients and the general public.
	Ogden, Terje, dr.philos.	Familiebasert behandling av alvorlige atferdsproblemer blant barn og ungdom. Evaluering og implementering av evidensbaserte behandlingsprogrammer i Norge.
	Solberg, Mona Elin	Self-reported bullying and victimisation at school: Prevalence, overlap and psychosocial adjustment.
2011 V	Bye, Hege Høivik	Self-presentation in job interviews. Individual and cultural differences in applicant self-presentation during job interviews and hiring managers' evaluation
	Notelaers, Guy	Workplace bullying. A risk control perspective.
	Moltu, Christian	Being a therapist in difficult therapeutic impasses. A hermeneutic phenomenological analysis of skilled psychotherapists' experiences, needs, and strategies in difficult therapies ending well.
	Myrseth, Helga	Pathological Gambling - Treatment and Personality Factors
	Schanche, Elisabeth	From self-criticism to self-compassion. An empirical investigation of hypothesized change prosesses in the Affect Phobia Treatment Model of short-term dynamic psychotherapy for patients with Cluster C personality disorders.
	Våpenstad, Eystein Victor, dr.philos.	Det tempererte nærvær. En teoretisk undersøkelse av psykoterapautens subjektivitet i psykoanalyse og psykoanalytisk psykoterapi.
	Haukebø, Kristin	Cognitive, behavioral and neural correlates of dental and intra-oral injection phobia. Results from one treatment and one fMRI study of randomized, controlled design.
	Harris, Anette	Adaptation and health in extreme and isolated environments. From 78°N to 75°S.
	Bjørknes, Ragnhild	Parent Management Training-Oregon Model: intervention effects on maternal practice and child behavior in ethnic minority families
	Mamen, Asgeir	Aspects of using physical training in patients with substance dependence and additional mental distress
	Espevik, Roar	Expert teams: Do shared mental models of team members make a difference
	Haara, Frode Olav	Unveiling teachers' reasons for choosing practical activities in mathematics teaching

2011 H	Hauge, Hans Abraham	How can employee empowerment be made conducive to both employee health and organisation performance? An empirical investigation of a tailor-made approach to organisation learning in a municipal public service organisation.
	Melkevik, Ole Rogstad	Screen-based sedentary behaviours: pastimes for the poor, inactive and overweight? A cross-national survey of children and adolescents in 39 countries.
	Vøllestad, Jon	Mindfulness-based treatment for anxiety disorders. A quantitative review of the evidence, results from a randomized controlled trial, and a qualitative exploration of patient experiences.
	Tolo, Astrid	Hvordan blir lærerkompetanse konstruert? En kvalitativ studie av PPU-studenters kunnskapsutvikling.
	Saus, Evelyn-Rose	Training effectiveness: Situation awareness training in simulators
	Nordgreen, Tine	Internet-based self-help for social anxiety disorder and panic disorder. Factors associated with effect and use of self-help.
	Munkvold, Linda Helen	Oppositional Defiant Disorder: Informant discrepancies, gender differences, co-occuring mental health problems and neurocognitive function.
	Christiansen, Øivin	Når barn plasseres utenfor hjemmet: beslutninger, forløp og relasjoner. Under barnevernets (ved)tak.
	Brunborg, Geir Scott	Conditionability and Reinforcement Sensitivity in Gambling Behaviour
	Hystad, Sigurd William	Measuring Psychological Resiliency: Validation of an Adapted Norwegian Hardiness Scale
2012 V	Roness, Dag	Hvorfor bli lærer? Motivasjon for utdanning og utøving.
	Fjermestad, Krister Westlye	The therapeutic alliance in cognitive behavioural therapy for youth anxiety disorders
	Jenssen, Eirik Sørnes	Tilpasset opplæring i norsk skole: politikeres, skoleledereres og læreres handlingsvalg
	Saksvik-Lehouillier, Ingvild	Shift work tolerance and adaptation to shift work among offshore workers and nurses
	Johansen, Venke Frederike	Når det intime blir offentlig. Om kvinners åpenhet om brystkreft og om markedsføring av brystkreftsaken.
	Herheim, Rune	Pupils collaborating in pairs at a computer in mathematics learning: investigating verbal communication patterns and qualities
	Vie, Tina Løkke	Cognitive appraisal, emotions and subjective health complaints among victims of workplace bullying: A stress-theoretical approach
	Jones, Lise Øen	Effects of reading skills, spelling skills and accompanying efficacy beliefs on participation in education. A study in Norwegian prisons.

2012 H	Danielsen, Yngvild Sørebø	Childhood obesity – characteristics and treatment. Psychological perspectives.
	Horverak, Jøri Gytre	Sense or sensibility in hiring processes. Interviewee and interviewer characteristics as antecedents of immigrant applicants' employment probabilities. An experimental approach.
	Jøsendal, Ola	Development and evaluation of BE smokeFREE, a school-based smoking prevention program
	Osnes, Berge	Temporal and Posterior Frontal Involvement in Auditory Speech Perception
	Drageset, Sigrunn	Psychological distress, coping and social support in the diagnostic and preoperative phase of breast cancer
	Aasland, Merethe Schanke	Destructive leadership: Conceptualization, measurement, prevalence and outcomes
	Bakibinga, Pauline	The experience of job engagement and self-care among Ugandan nurses and midwives
	Skogen, Jens Christoffer	Foetal and early origins of old age health. Linkage between birth records and the old age cohort of the Hordaland Health Study (HUSK)
	Leversen, Ingrid	Adolescents' leisure activity participation and their life satisfaction: The role of demographic characteristics and psychological processes
	Hanss, Daniel	Explaining sustainable consumption: Findings from cross-sectional and intervention approaches
	Rød, Per Arne	Barn i klem mellom foreldrekonflikter og samfunnsmessig beskyttelse
2013 V	Mentzoni, Rune Aune	Structural Characteristics in Gambling
	Knudsen, Ann Kristin	Long-term sickness absence and disability pension award as consequences of common mental disorders. Epidemiological studies using a population-based health survey and official ill health benefit registries.
	Strand, Mari	Emotional information processing in recurrent MDD
	Veseth, Marius	Recovery in bipolar disorder. A reflexive-collaborative exploration of the lived experiences of healing and growth when battling a severe mental illness
	Mæland, Silje	Sick leave for patients with severe subjective health complaints. Challenges in general practice.
	Mjaaland, Thera	At the frontiers of change? Women and girls' pursuit of education in north-western Tigray, Ethiopia
	Odéen, Magnus	Coping at work. The role of knowledge and coping expectancies in health and sick leave.
	Hynninen, Kia Minna Johanna	Anxiety, depression and sleep disturbance in chronic obstructive pulmonary disease (COPD). Associations, prevalence and effect of psychological treatment.
	Flo, Elisabeth	Sleep and health in shift working nurses

	Aasen, Elin Margrethe	From paternalism to patient participation? The older patients undergoing hemodialysis, their next of kin and the nurses: a discursive perspective on perception of patient participation in dialysis units
	Ekornås, Belinda	Emotional and Behavioural Problems in Children: Self-perception, peer relationships, and motor abilities
	Corbin, J. Hope	North-South Partnerships for Health: Key Factors for Partnership Success from the Perspective of the KIWAKKUKI
	Birkeland, Marianne Skogbrott	Development of global self-esteem: The transition from adolescence to adulthood
2013 H	Gianella-Malca, Camila	Challenges in Implementing the Colombian Constitutional Court's Health-Care System Ruling of 2008
	Hovland, Anders	Panic disorder – Treatment outcomes and psychophysiological concomitants
	Mortensen, Øystein	The transition to parenthood – Couple relationships put to the test
	Årdal, Guro	Major Depressive Disorder – a Ten Year Follow-up Study. Inhibition, Information Processing and Health Related Quality of Life
	Johansen, Rino Bandlitz	The impact of military identity on performance in the Norwegian armed forces
	Bøe, Tormod	Socioeconomic Status and Mental Health in Children and Adolescents
2014 V	Nordmo, Ivar	Gjennom nåløyet – studenters læringserfaringer i psykologutdanningen
	Dovran, Anders	Childhood Trauma and Mental Health Problems in Adult Life
	Hegelstad, Wenche ten Velden	Early Detection and Intervention in Psychosis: A Long-Term Perspective
	Urheim, Ragnar	Forståelse av pasientaggresjon og forklaringer på nedgang i voldsrate ved Regional sikkerhetsavdeling, Sandviken sykehus
	Kinn, Liv Grethe	Round-Trips to Work. Qualitative studies of how persons with severe mental illness experience work integration.
	Rød, Anne Marie Kinn	Consequences of social defeat stress for behaviour and sleep. Short-term and long-term assessments in rats.
	Nygård, Merethe	Schizophrenia – Cognitive Function, Brain Abnormalities, and Cannabis Use
	Tjora, Tore	Smoking from adolescence through adulthood: the role of family, friends, depression and socioeconomic status. Predictors of smoking from age 13 to 30 in the "The Norwegian Longitudinal Health Behaviour Study" (NLHB)
	Vangsnes, Vigdis	The Dramaturgy and Didactics of Computer Gaming. A Study of a Medium in the Educational Context of Kindergartens.

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