JYU DISSERTATIONS 748

Simone Gorinelli

ACTing Virtually

The Impact of Virtual Reality on Psychological Processes in the Context of Social and Communication Anxiety — A Comprehensive Study on Acceptance and Commitment Therapy

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF EDUCATION AND PSYCHOLOGY

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Editors
Noona Kiuru
Department of Psychology, University of Jyväskylä
Päivi Vuorio
Open Science Centre, University of Jyväskylä

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ABSTRACT

Simone Gorinelli
ACTing Virtually: The impact of virtual reality on psychological processes in the context of social and communication anxiety— A comprehensive study on acceptance and commitment therapy
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The aim of this study was to examine the efficacy of delivering an acceptance and commitment therapy (ACT) intervention in virtual reality (VR) (VRACT) and to gain a deeper understanding of the psychological processes associated with social interaction and communication anxiety in university students. The intervention consisted of three exposure-based ACT sessions delivered via a VR head-mounted display. Study I (n = 76) examined the role of psychological flexibility and self-compassion, as well as the psychological subprocesses that may explain social interaction and communication anxiety. In Study II, a VRACT intervention group (n = 37) was compared to a waiting list control group (n = 39) with regard to self-reported measures, behavioral measures, and clinically significant improvements in anxiety. Study III explored the efficacy of the VRACT intervention (n = 37) in enhancing psychological flexibility in real-world contexts by using ecological momentary assessment (EMA). In addition, the third study aimed to explore the psychological flexibility processes of change involved in students who showed clinically significant improvements in anxiety measures (n = 8). The results of Study I confirmed that a higher level of social interaction and communication anxiety was associated with lower levels of psychological flexibility and self-compassion. Moreover, the study demonstrated that openness to experiences, self-judgment, and over-identification are important factors in explaining social interaction and communication anxiety. The findings of Study II showed how ACT can be successfully delivered in VR as a brief, automated intervention to significantly reduce self-reported social and communication anxiety, as well as to improve the psychological processes, well-being, and communication skills of students. Study III expanded on the previous findings by demonstrating the efficacy of VRACT in increasing students' psychological flexibility over time and across contexts using EMA in their daily lives. In addition, the results revealed that, even when trained with the same intervention, the processes of change vary significantly between individuals. This highlights the importance of treating each person as a unique individual.

Keywords: virtual reality, acceptance and commitment therapy, social anxiety, public speaking anxiety, psychological flexibility, ecological momentary assessment, university students

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Simone Gorinelli
Hyväksymis- ja omistautumisterapiaa virtuaalisesti:
Virtuaalitodellisuusharjoittelun vaikutukset sosiaaliseen ja kommunikaatioahdistukseen sekä psykologisiin prosesseihin yliopisto-opiskelijoilla.
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Tämän tutkimuksen tavoitteena oli tutkia hyväksymis- ja omistautumisterapiaan (HOT) pohjautuvan intervention vaikuttavuutta virtuaalitodellisuutta (VR) hyödyntämällä sekä syventää ymmärrystä sosiaalisen ja kommunikaatioahdistuksen eli esiintymispelon psykologisista prosesseista yliopisto-opiskelijoilla. Interventio koostui kolmesta harjoituskerrasta, joissa käytettiin VR-teknologiaa. Tutkimus I (n = 76) selvitti psykologisen joustavuuden ja itsemyötätunnon roolia sekä psykologisen joustavuuden prosesseja, jotka voivat selittää sosiaaliseen vuorovaikutukseen ja kommunikaatioon liittyvää ahdistusta. Tutkimuksessa II verrattiin interventioryhmää (VRACT; n = 37) kontrolliryhmään (WLC; n = 39) tarkastelemalla itsearviointimittareita, esiintymistehtävää ja kliinistä muutosta. Tutkimuksessa III selvitettiin VRACT-intervention vaikutusta psykologiseen joustavuuteen arjen tilanteissa ekologisen hetkellisen arvioinnin (EMA) avulla. Lisäksi tavoitteena oli tutkia niiden opiskelijoiden psykologisen joustavuuden muutosta, joilla tapahtui kliinisesti merkitsevä muutos ahdistusmittareissa (n = 8). Tutkimuksen I tulokset osoittivat, että korkea sosiaaliseen vuorovaikutukseen ja kommunikaatioon liittyvä ahdistus oli yhteydessä matalaan psykologiseen joustavuuteen ja itsemyötätuntoon. Lisäksi havaittiin, että avoimuus ajatuksille ja tunteille, itsensä arvosteleminen ja liiallinen uskominen omiin ajatuksiin olivat tärkeitä tekijöitä mahdollisen sosiaaliseen vuorovaikutukseen ja kommunikaatioon liittyvän ahdistuksen selittämisessä. Tutkimuksen II tulokset osoittivat, että hyväksymis- ja omistautumisterapiaa voidaan hyödyntää onnistuneesti VR-ympäristössä lyhyenä interventiona, joka vähentää merkitsevästi sosiaaliseen vuorovaikutukseen ja kommunikaatioon liittyvää ahdistusta sekä edistää opiskelijoiden psykologista joustavuutta, hyvinvointia ja viestintätaitoja. Tutkimus III osoitti, että interventio edisti opiskelijoiden psykologista joustavuutta erilaisissa arjen tilanteissa. Opiskelijoilla, joilla havaittiin kliinisesti merkitsevä muutos ahdistuneisuudessa, psykologiset muutosprosessit vaihtelivat merkittävästi yksilöiden välillä.

Avainsanat: virtuaalitodellisuus, hyväksymis- ja omistautumisterapia, sosiaalinen ahdistus, esiintymispelko, psykologinen joustavuus, ekologinen hetkellinen arviointi, yliopisto-opiskelijat

Author

Simone Gorinelli
Department of Psychology
University of Jyväskylä
simone.s.gorinelli@jyu.fi
ORCID 0000-0003-0895-2295

Supervisors

Professor Raimo Lappalainen
Department of Psychology
University of Jyväskylä

PhD Päivi Lappalainen
Department of Psychology
University of Jyväskylä

Reviewers

PhD, Professor Nuno Ferreira
Department of Social Sciences
University of Nicosia
Cyprus

PhD, Assistant Professor Clarissa Ong
Department of Psychology
University of Toledo
USA

Opponent

PhD, Assistant Professor Clarissa Ong
Department of Psychology
University of Toledo
USA

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Nel mezzo del cammin di nostra vita
mi ritrovai per una selva oscura,
ché la diritta via era smarrita.

- Dante Alighieri

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Jyväskylä, December 2023

Simone Gorinelli

LIST OF ORIGINAL PUBLICATIONS

I Gorinelli, S., Gallego, A., Lappalainen, P., & Lappalainen, R. (2022). Psychological Processes in the Social Interaction and Communication Anxiety of University Students: The Role of Self-Compassion and Psychological Flexibility. *International Journal of Psychology & Psychological Therapy*, *22*, 1, 5–19. https://www.ijpsy.com/volumen22/num1/603/psychological-processes-in-the-social-interaction-EN.pdf

II Gorinelli, S., Gallego, A., Lappalainen, P., & Lappalainen, R. (2023). Virtual reality acceptance and commitment therapy intervention for social and public speaking anxiety: A randomized controlled trial. *Journal of Contextual Behavioral Science*, *28*, 1, 289–299. https://doi.org/10.1016/j.jcbs.2023.05.004

III Gorinelli, S., Gallego, A., Lappalainen, P., Muotka, J., & Lappalainen, R. (2023). The impact of virtual reality-based acceptance and commitment training on psychological flexibility in everyday contexts: An ecological momentary assessment study. *Submitted manuscript.*

Taking into account the instructions given and comments made by the co-authors, the author of the present thesis participated in designing the research plan, the intervention, and the data collection. Moreover, the author also contributed to the statistical analysis and was the primary author of the three publications.

FIGURES

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1 INTRODUCTION

The world of reality has its limits; the world of imagination is boundless.

- Jean-Jacques Rousseau

During the 19th century, a number of industrial advancements, such as the spread of the railroad and the development of the steamboat enabled people of various social classes to enjoy the pleasure of travel (Byerly, 2012). During this period, pictures, stories, and lectures depicting travel to diverse and distant locations led to an increase in the desire to travel among middle- and working-class individuals (Byerly, 2012). Paintings frequently featured scenes from distant locations, previous conflicts, or historical events. The late 18th and early 19th centuries saw the entry of panorama paintings, which attempted to tell a story by placing the viewer in front of a very broad, flat, or curved background image so that they could immerse themselves in the painting. The first panorama was painted by Robert Baker in 1787, in Edinburgh. It was a reproduction of the real world that opened up the possibility of making the viewer believe that the scene in front of their eyes was real (Lescop, 2017; Oettermann, 1997). The panorama marks the beginning of attempts to transform reality into a perceptual illusion, that is, a virtual reality (Kikendall, 2012). As wide static paintings took up a lot of space, moving panoramas were created to further deepen the viewer's experience of immersion. These moving panoramas were in the form of scrolling canvases that were presented across a stage and were frequently accompanied by a narrator and background music (Routhier et al., 2015). The transformation of panorama paintings into moving panoramas led to the rapid emergence of a new form of entertainment wherein the observer's attention was drawn to the narration and moving story displayed in the painting. From the early 20th century, panorama paintings and moving panoramas paved the way to the earliest form of film—the starting point of future digital technology and immersive experiences. These inventions and their popularity are evidence of how imagination and invention contribute to the quality of life of humans.

1.1 Digital Technology

1.1.1 Digital technology in psychological interventions

The use of digital technology has become indispensable in all aspects of modern life (Valmaggia et al., 2016). The rise of computers, mobile devices, online networks, and applications have contributed to the rapid spread of digital technology. Nowadays, digital technology pervades almost every aspect of our lives, and has also altered the way care and psychological interventions are delivered (Valmaggia et al., 2016).

The majority of digital interventions were initially derived from or are slightly modified versions of self-help literature or in-person interventions that have already been published, particularly techniques in the realm of cognitive behavioral therapy (CBT; Fairburn & Patel, 2017; Karyotaki et al., 2017). Other than CBT (Anderson et al., 2004; Andersson, 2014; Wright et al., 2019), many other interventions have adopted digital technology, including acceptance and commitment therapy (ACT; Brown et al., 2016; Thompson et al., 2021), family therapy (McLean et al., 2021), and mindfulness-based therapies (Arpaia et al., 2022). All of these interventions that adopt digital technologies have the potential to improve mental health (Philippe et al., 2022), irrespective of whether they use phone and video communication (Chen et al., 2022), computerized therapy (Vallury et al., 2015), or innovative technologies such as mobile applications (Lui et al., 2017), web-based treatments (Davies et al., 2014; Wantland et al., 2004), social media platforms (Naslund et al., 2017), and virtual reality (Kampmann, Emmelkamp, & Morina, 2016; Powers & Emmelkamp, 2008).

Digital technology has progressed to a point where digital interventions are now used in conjunction with traditional therapy or as independent interventions in place of face-to-face therapy (Freeman et al., 2018; Lui et al., 2017; Marciniak et al., 2020). However, standalone open programs that are not guided have often reported higher dropout rates and smaller intervention effects (Baumeister et al., 2014; Torous et al., 2020) and may not be as suitable for patients with severe psychological conditions (Andersson et al., 2013). On the contrary, guided digital interventions are frequently more successful due to better intervention adherence and have been found to eventually achieve a similar success rate as in-person therapies (Andersson et al., 2014; Fairburn & Patel, 2017). Digital interventions can be programmed to have the same content and schedule as face-to-face therapy, or to have more frequent, targeted, and brief sessions to match the typical individual's pattern of use of web pages and mobile apps (Fairburn & Patel, 2017). Thus, the appeal of the sessions—from the complexity of navigation to the graphic and interactive tools employed—have become crucial in the development of psychological interventions (Fairburn & Patel, 2017). This has paved the way for more appealing forms of therapy such as interactive and gaming interventions (Gustavsson et al., 2022; Keinonen et al., 2023) designed to address complex conditions in novel ways and foster positive engagement (Lindner et al., 2017).

Digital technology is now used for the treatment of a wide range of mental health conditions (Andersson et al., 2019), such as anxiety disorders (Firth et al., 2018; Kampmann et al., 2016), depression (Li et al., 2014; Schueller et al., 2017), post-traumatic stress disorder (Kothgassner et al., 2019), schizophrenia (Chivilgina et al., 2021), and obsessive-compulsive disorder (Tumur et al., 2007), as well as mental health problems in children and young people (e.g., attention deficit hyperactivity disorder and autism; Hollis et al., 2017).

The development of digital tools for diagnosis, intervention guidance, facilitation, supervision, and online services are just a few examples of how digital technology has an impact not only on interventions but also on the educational training of future therapists and mental health workers (Naslund et al., 2019). That is, digital technology is central to the widespread dissemination of knowledge in the context of psychological interventions.

1.1.2 Digital and ecological momentary assessment

The current digital advancements are also influencing how studies can be differently designed and how researchers can test a variety of new data collection measures.

By replacing the paper-and-pen format with digital questionnaires, digital technology can facilitate new and simpler methods of assessing and tracking psychopathological characteristics and changes (Fairburn & Patel, 2017). In particular, online questionnaires provide a practical and innovative method for assessing individuals in general (Remillard et al., 2014), even though they are limited by the need for an internet connection. Moreover, they offer effective interventions in rural areas with limited resources or lack of access to psychological therapy (Vallury et al., 2015). The adoption of digital self-reported questionnaires has led to an improvement in the administration of the questionnaires and the interpretation of their results by reducing the risk of error through automatic scoring and, thus, has allowed for more rapid and accurate data analysis by clinicians and researchers (Fairburn & Patel, 2017).

Compared to traditional randomized controlled trials, the current methods of data collection, such as repeated ecological momentary assessment (EMA) and single-case design (SCD), might be better alternatives for assessing individuals and examining psychological interventions and the mechanisms involved in clinical and behavioral change (Hulbert-Williams et al., 2021; Morgenstern et al., 2014; Villatte et al., 2016). Traditional self-reported measures are often based on an individual's recall of past events and may, therefore, be influenced by the individual's perceptions of their behavior or surrounding environment (Schwarz, 2007; Stone & Shiffman, 1994). Thus, these measures may not account for how behavior changes over time and across contexts (Shiffman et al., 2008). These limitations necessitate the development of alternative data collection methods.

Spurred by the growing use of mobile technology, EMA was developed to address the limitations of traditional quantitative methods in the psychological sciences. EMA can be used to track a person's daily life experiences (Mitchell et

al., 2022; Runyan & Steinke, 2015; Shiffman et al., 2008; Wrzus & Neubauer, 2023) and to encourage behavior change (Dao et al., 2021). Importantly, EMA can improve the accuracy of evaluations and treatments because it collects data from people's everyday lives, as opposed to clinical settings and therapists' offices (Morgenstern et al., 2014; Schueller et al., 2017). EMA typically entails the evaluation of a situation or behavior several times a day over a period of days, at prompted or random times, or after engaging in a target behavior (Stinson et al., 2022). EMA measures are often obtained using applications on mobile phone devices that prompt surveys at a random or scheduled time. The ecological component of EMA refers to its high ecological validity, which makes it possible to apply the findings to real-life situations (Shiffman et al., 2008).

EMA has helped expand the assessment window and allowed for assessment in new contexts, and intervention based on momentary assessment (EMI) may be effective overall and can particularly increase behavioral change engagement (Heron & Smyth, 2010; Schueller et al., 2017). It is possible to use event-based rules to deploy EMA and EMI in response to user or contextual variables, such as being physically close to a particular location and when the user accesses the phone, or time-based rules that deploy at specific or random times throughout the day (Schueller et al., 2017). These features can lead the way to "just-in-time adaptive interventions", through which, using the user's data and information, tailored interventions can be adapted over time (Schueller et al., 2017; Hardeman et al., 2019). By reminding individuals of more valued and healthier actions within the actual context, this type of assessment and intervention can be especially beneficial if they are programmed to send prompts at times when individuals are likely to engage in unhealthy behaviors (Hardeman et al., 2019). EMA can be applied as a standalone intervention (Colombo et al., 2019; Marciniak et al., 2020; Schueller et al., 2017) or in conjunction with other technological solutions such as virtual reality (Berkhof et al., 2021; Bossenbroek et al., 2020; Geraets et al., 2020; Pot-Kolder et al., 2018) and augmented reality (Marquet et al., 2018; Sayette & Goodwin; 2020).

To summarize, these are a few characteristics of EMA that distinguish it from other measurements: (1) assessments are conducted while the phenomenon is occurring; (2) assessments are conducted carefully at a specific time; (3) assessments are repeated multiple times; and (4) assessments are administered in the context of the individual's daily life (Stone & Shiffman, 1994).

1.2 Virtual reality

1.2.1 Definition—What is virtual reality?

The terminology surrounding virtual reality (VR) technology is complex and diverse, and frequently leads to misunderstandings (Abbas et al., 2023).

From a technical perspective, VR is a set of technologies that provide a 3D visualization platform with the support of a head-mounted display (HMD) and

tracking technology (Riva, Baños, et al., 2016). An HMD is a device worn on the head that contains an optical display. From a psychological standpoint, VR is a subjective experience that deceives the individual into believing that what they are experiencing is real (Riva, Baños, et al., 2016). The illusion results from knowing that VR experiences that can be seen, heard, and felt are not real experiences but still cause thinking, feeling, and acting as if these experiences and places were real (place illusion) and happening (plausibility illusion) (Slater, 2009; Slater & Sanchez-Vives, 2005). While merely observing a stereo-display environment in which nothing changes could still generate a sense of presence or of "being there", the use of virtual elements in the scene that respond to the individuals and their behaviors creates the more believable illusion that what is happening is real (Slater & Sanchez-Vives, 2016). VR is also included in the concept of the metaverse, which refers to a VR world that exists beyond reality (Kye et al., 2021; Wang et al., 2023). Even though playing a video game or reading a very interesting book may induce a sense of immersion, it is unlikely that the individual will feel as though they are physically present in the scene, as is the case in VR, where a sense of virtual presence fosters immersion (Lindner, 2021; Slater & Sanchez-Vives, 2005).

Since the 1960s, the term VR has been used to describe a wide variety of software and hardware technologies, including the first HMD devices (Jensen & Konradsen, 2018) that tried to create the illusion of presence by digitally manipulating what can be seen, heard, and felt (Lescop, 2017). When Jaron Lanier first used the term "virtual reality" in 1989, the idea of VR became formally recognized, and it subsequently gained more traction in academic research and medical treatment (Maples-Keller et al., 2017). In line with these events, psychologists also started combining VR with prolonged exposure therapy in the 1990s and the early 2000s (Maples-Keller et al., 2017). However, until recently, such technological devices were prohibitively expensive and unavailable to the general public (Lindner, 2021). One way to archive immersion was to use cave automatic virtual environments where projectors displayed images on the walls of a cube-shaped walkable room to create a suspension of disbelief (Cruz-Neira et al., 1992; Gromer et al., 2018). However, it was stereoscopic HMDs which provided a depth illusion to a flat image by adding screen disparity (Ling et al., 2012; Wann et al., 1995) that led the way to expanding the reach of VR to consumers (Lindner, 2021). It was not until 2013 that a new generation of affordable VR technology was made available to consumers, with the release of the first developer versions of an HMD from the company Oculus Rift (Jensen & Konradsen, 2018). In the years that followed, a multitude of competitors introduced their own HMDs, making this new technology widely accessible to the general public and for research (Jensen & Konradsen, 2018).

It is challenging to comprehend what VR is, unless one is familiar with the immersive technology realm of extended reality (XR) (Abbas et al., 2023). Frequently, terms in immersive technology are incorrectly used interchangeably, thus limiting the comprehension and applicability of research findings (Abbas et al., 2023). The term "extended reality" is used to describe the wide range of

technologies that combine real-world and digital elements to create an interactive experience, such as augmented reality (AR), mixed reality (MR), and VR (Morimoto et al., 2022) (Figure 1).

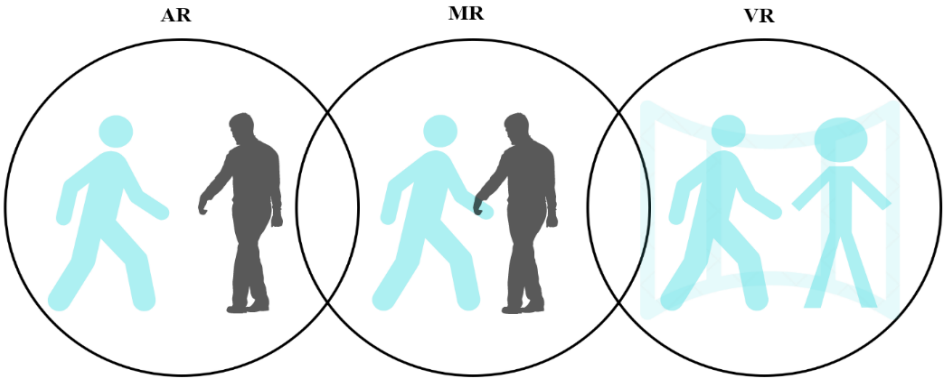


FIGURE 1 Extended reality: Difference between augmented reality, mixed reality, and virtual reality

AR enhances the user's experience by blending digital elements with real-world objects and reality (Abbas et al., 2023; Riva, Baños, et al., 2016), but there is often no true physical interaction between them. It provides a view of a real-world environment that has been augmented by the addition of virtual computer-based elements (Carmigniani et al., 2011). This type of experience has recently been widely used for a variety of purposes, including mobile gaming (Serino et al., 2016) and retailing services (Caboni & Hagberg, 2019). VR technology, on the other hand, allows users to completely immerse themselves in a synthetic world without allowing them to see the real world (Riva, Baños, et al., 2016) that still exists around them outside of the VR headset. MR is the result of blending the digital information within AR and VR with the experiences of the real world (Abbas et al., 2023). Although there is no universally accepted definition of MR (Speicher et al., 2019), it is frequently described as an advancement of AR in which real and digital objects interact in real time to address one of AR's limitations, which is the separation of the real and virtual worlds (Rokhsaritalemi et al., 2020). Recently, MR has gained a great deal of popularity, with MR devices enabling passthrough capabilities that allow users to quickly switch between fully immersive VR, MR, or viewing the entire real world through high-quality cameras while still wearing the HMD.

VR devices can track degrees of freedom, or the possible positions or movements within a physical space, and VR experiences can often be differentiated between three (3DOF) and six degrees of freedom (6DOF) (Sherman et al., 2018) (Figure 2). Individual interaction with the virtual world creates immersion in VR. Because vision is one of the most powerful human senses, 3DOF may present a simple, yet effective, solution for rotation tracking within VR applications (Lindner, 2021). In fact, the minimum requirement for

defining an immersive VR experience is often 3DOF tracking (Snoswell & Snoswell, 2019). 6DOF, on the other hand, adds positional tracking in addition to rotation, thereby increasing movement in the X, Y, and Z dimensions (Lindner, 2021). This adds an essential layer of immersion to the experience and increases the illusion that the virtual environment is real. However, it is challenging to archive such tracking when developing scenarios. Tracking was previously archived using tracking base stations that scanned the VR HMD within a physical area, but this method provided limited frontal angle view (Naranjo et al., 2020). Nowadays, standalone VR devices allow tracking by cameras placed inside the headset as well as sensors on possible hand controllers.

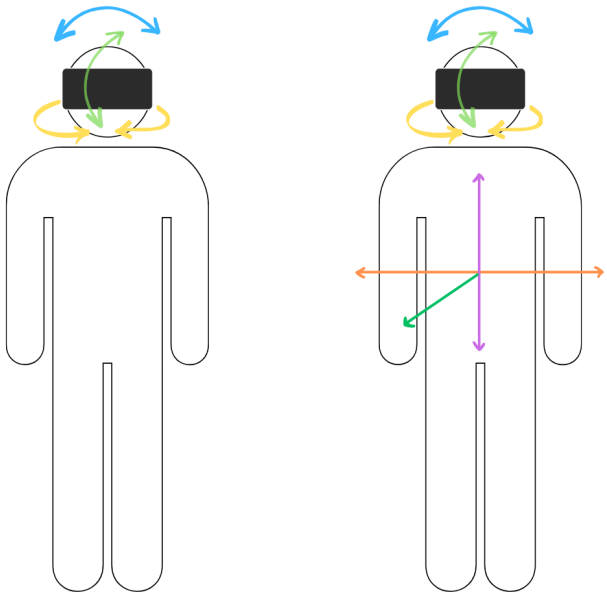


FIGURE 2 Difference between three degrees of freedom (left figure, rotation tracking) and six degrees of freedom (right figure, positional tracking)

Along with the advances in XR technologies, it is crucial to use precise language, maintain consistency, and convey knowledge and terminology about immersive technologies, as these concepts are subject to change and may apply differently in the future (Speicher et al., 2019).

1.2.2 VR devices and scenario development

The VR HMD hardware has evolved significantly over the years—from prototype devices to large-scale consumer devices. Ivan Sutherland created the first HMD, the "Sword of Damocles" HMD, in 1965, which encompassed and implemented the concept of modern AR/VR devices (Slater & Sanchez-Vives, 2016; Sutherland, 1968). Despite the fact that the technology used was different from today's VR systems, the HMD displayed two computer-generated images, a stereo pair, which were rendered based on the position of each eye in the

physical virtual scene (Slater & Sanchez-Vives, 2016). Long after this first HMD, in 2014 and 2015, mobile HMDs were developed to carry novel smartphones that, at a specific distance from the lenses, were able to process data (Anthes et al., 2016). The portability and affordability of mobile VR devices (e.g., Google Cardboard and Samsung Gear VR) have simplified the dissemination of VR applications, as well as psychological interventions, despite their lower quality and lower levels of interaction (Lindner et al., 2017). Although they allowed for the low-cost distribution of VR for use at home, these mobile VR devices have largely been discontinued due to hardware and phone compatibility issues and have been replaced by other types of stationary devices such as Oculus Rift, HTC Vive, and Playstation VR (Lindner, 2021; Riva, Wiederhold, et al., 2016). In addition, more expensive stationary or tethered HMDs have been developed that provide a higher quality VR experience and overcome the limitations of mobile VR devices by being powered by and connected to a computer or gaming console (Lindner et al., 2017). Tethered VR devices allow users to experience 6DOF by allowing them to move around in the physical space. Stationary VR devices can display the experience on a monitor so that a therapist may observe and use the information to tailor personalized interventions (Lindner et al., 2017). The experience can now also be displayed wirelessly using innovative standalone technological devices that do not necessarily require a gaming computer or console to operate. Oculus Go, one of the first standalone VR devices, attempted to persuade the world that standalone devices, developed at a similar cost to a phone, could represent the future (Lindner, 2021) by eliminating the need to connect the device to a phone, computer, or console. Standalone devices, however, like mobile HMDs, performed poorly when compared to stationary devices and only support non-positional 3DOF. However, standalone devices have now begun to receive positive reviews, following the recent release of the standalone Oculus Quest, or Meta Quest as it is now known, which supported 6DOF via inside-out camera tracking and could switch to the tethered mode for improved performance (Lindner, 2021). Recent trends indicate that, in terms of their content and function, immersive technological platforms are rapidly evolving into standalone devices (such as Meta Quest 3 and Apple Vision Pro) that can provide a wide range of extended reality experiences by combining VR, MR, and AR.

Currently, the content used to create immersion in VR is typically generated using experiences that were pre-programmed or 180°/360° videos that were recorded in the real world. Such programmed VR experiences are generated using computer knowledge and software (Snelson & Hsu, 2020) and can provide a high level of interaction. For instance, Seinfield et al. (2018) used a programmed scenario (Figure 3) to promote empathy and perspective taking by immersing the perpetrators in the body of a female victim avatar in an interactive domestic abuse situation. In this study (Seinfield et al., 2018), users could interact with their virtual body, and physically move in a 6DOF environment and decide how far away from the abusive avatar they wished to be.

FIGURE 3 Programmed-based immersive VR scenario used in Seinfield et al. (2018)

The development of programmed-based VR environments has been made possible by commercially available and easily accessible game engines such as the Unreal Engine and Unity, which offer unrestricted control over all design aspects while remaining user-friendly and requiring only intermediate programming skills (Lindner et al., 2017). These programming skills can, however, be a significant limitation for clinicians and researchers, especially when trying to design appealing, unique, and tailored VR experiences.

The adoption of easier forms of VR experiences, such as 360° and 180° videos, has been tested and applied (Gorinelli et al., 2023; Li et al., 2021; Nason et al., 2020; Reeves et al., 2021; Snelson & Hsu, 2020) (Figure 4).

FIGURE 4 A 180° 3D recorded video scenario of nature in Study II, Gorinelli et al. (2023)

However, there were previously doubts about whether 360° videos truly qualified as VR (Slater & Sanchez-Vives, 2016). It has now been established that 180°/360° degree videos are also part of the VR ecosystem, despite the fact that model or programmed-based VR and 180°/360° degree VR videos have distinct characteristics and capabilities (Nason et al., 2020; Slater & Sanchez-Vives, 2016). Currently, 180°/360° degree videos only permit 3DOF tracking movement. This means that the user can move their head but cannot physically move around the

scene unless they use controllers. This is in contrast to many advanced programmed-based scenarios in which it is possible for users to physically move their bodies. These videos emerged as a result of the development of low-cost technologies and the increase in online video content (Snelson & Hsu, 2020), but they have been criticized for their tendency to induce nausea when viewed on mobile HMDs due to the low quality of their graphic elements (Slater & Sanchez-Vives, 2016). The videos are typically captured in the real world with a camera system capable of recording in all directions and are stitched together with video editing software (Snelson & Hsu, 2020). While the video quality of older cameras was relatively poor, the exceptionally high-quality 3D recording offered by newer VR professional cameras often exceeds the realism of programmed-based scenarios (Nason et al., 2020) and the technical capabilities of VR devices. Nonetheless, increase in the quality and immersion of VR experiences has decreased VR sickness, as the level of presence and immersion is associated with VR sickness (Caserman et al., 2021; Saredakis et al., 2020; Weech et al., 2019).

Finally, VR interactions can be complex at times. All VR HMD devices track head rotation with 3DOF and gaze direction, which was initially adopted to enable point-and-click navigation in a similar manner to a computer mouse interaction (Lindner et al., 2017). With the advancement of technology, it is now possible to interact within VR environments using various types of controllers, which can facilitate interaction via multiple buttons and simultaneously track individuals' physical movements. Moreover, recently developed innovative technology implemented within the VR headset can also scan and track the user's hands and, thus, make it possible to interact with VR experiences by moving the hands, without the use of controllers (Buckingham, 2021; Lindner, 2021). Further, with the development of technology, VR headsets are showing improved inside-out tracking of the upper body and will integrate generative AI to create and track other body parts, such as virtual legs.

1.2.3 Efficacy of VR technologies

VR technology is seeing a wide variety of applications, even though entertainment and gaming are still important and popular applications of VR. VR technology has also been used for tourism and travel (Beck et al., 2019), as well as for fitness, athlete training (Hamad & Jia, 2022), and physical exercise rehabilitation (Tao et al., 2021). However, VR has special applications in neuroscience (Bohil et al., 2011; Slater & Sanchez-Vives, 2016) and has shown promising results for applications related to various psychological problems (Carl et al., 2019; Dellazizzo et al., 2020; Powers & Emmelkamp, 2008; Valmaggia et al., 2016). Several reviews and meta-analyses have investigated the efficacy of VR in different treatments and interventions (Dellazizzo et al., 2020), such as in cases of anxiety (Carl et al., 2019; Horigome et al., 2020; Kampmann et al., 2016; Powers & Emmelkamp, 2008), depression (Fodor et al., 2018; Yen & Chiu, 2021), post-traumatic stress disorder (Kothgassner et al., 2019), rehabilitation (Howard, 2017), and severe mental illnesses (e.g., schizophrenia; Välimäki et al., 2014). These studies show how VR can be an effective alternative to traditional

treatments. Researchers first attempted to use VR in a clinical setting to treat anxiety disorders and specific phobias in the early 1990s (Riva, Wiederhold, et al., 2016), with the specific phobias including common fears such as fear of flying or spiders (Parsons & Rizzo, 2008). In fact, VR can be used as an effective exposure tool to simulate a virtual experience that could be perceived as realistic and, therefore, induce anxiety. This makes it possible to create an effective training environment. Psychological exposure intervention for these issues typically involves a simulated or in vivo experience, with in vivo exposure offering the opportunity to directly confront the feared situation (Otte, 2011). Traditionally, in vivo exposure therapy presents the clinician with a number of practical and logistical challenges: anxiety-inducing stimuli may be inaccessible (e.g., fear of flying), difficult to create and maintain (e.g., keeping multiple spiders of varying sizes), or difficult or impractical to adjust and control during the exposure session (e.g., public speaking audience) (Lindner et al., 2019). Exposures in VR can be tailored to individuals by increasing the difficulty level and expanding the simulation based on their internal reality (Riva, Wiederhold, et al., 2016), thus allowing the user to interact with their physical sensations, thoughts, and emotions. Virtual reality exposure therapy (VRET) acts as an intermediary (Krijn et al., 2004) that enables the safe and controlled creation of personalized phobic stimuli (Miloff et al., 2016). This presents a game-changing opportunity for all clinicians willing to utilize exposure techniques. Moreover, VR has also been used in conjunction with other technological solutions for assessing individuals, such as EMA (see Berkhof et al., 2021; Bossenbroek et al., 2020; Geraets et al., 2020; Pot-Kolder et al., 2018). Unfortunately, few studies have examined the impact of VR interventions on the daily momentary assessment of stress and anxiety in a young population (Björling et al., 2022).

1.2.4 Why use VR? Pros and cons

Although VR appears to be an effective and promising tool for psychological intervention and research, there may also be some drawbacks to its use.

VR has significant appeal in the general population. As a result, people who are unsure about traditional psychological therapy may be more willing to seek help because they prefer VR exposure over in vivo exposure (Anderson et al., 2004). With its interactive and immersive virtual elements, VR could therefore increase intervention engagement. While in vivo exposure might be too scary for individuals, imaginal exposure might not be strong enough to produce results. Their limitations could be overcome with the use of VR, which may prove to be a viable alternative to standard exposure techniques (Klinger et al., 2005). This is because the stimuli in VR are as intense as real situations but can also be easily programmed and adjusted to ensure that they do not induce too much anxiety. Additionally, VR exposure exercises are easily repeatable, and this may enhance the training experience. In the past, the price of VR devices may have posed a barrier to their accessibility. However, the development of new standalone VR devices at relatively affordable prices is increasing the appeal of adding these methods to the clinician's toolkit (Kothgassner et al., 2019). With less expensive

VR devices, it is also possible to transfer the treatment from the clinical setting to the client's home, where it can be continued easily (Morel et al., 2015). Yet another advantage is that virtual environments and scenarios can be pre-programmed or video-recorded in order to provide the client with a variety of customized examples. Lastly, VR can facilitate research through the use of controlled and replicable scenario designs. As described above, there is a lot of ongoing research on the positive effect of immersive technologies.

VR also comes with several disadvantages. Even though VR devices are significantly less expensive today than they were in the past (Anderson et al., 2004), the average person or therapist may still believe they are not worth purchasing. Further, one of the most significant drawbacks of using immersive devices is that they may cause nausea (Caserman et al., 2021; Chang et al., 2020; Saredakis et al., 2020; Shaw et al., 2015), also known as simulator or motion sickness (Kennedy et al., 1993), cybersickness (Caserman et al., 2021; Kim et. Al, 2005; LaViola, 2000), and VR sickness (Chang et al., 2020; Kim et al., 2018). Several factors can contribute to nausea during or after immersion in a VR environment. Some of these causes are poor performance, older devices, limited field of view, latency between image and motion, image flickering, content that is heavily focused on motion (Shaw et al., 2015), graphics, and user characteristics such as age and prior VR experience (Chang et al., 2020). Nausea caused by a VR headset can be uncomfortable and may discourage users from trying or continuing to use this technology. However, with the increase in the quality and performance of VR devices over the years, nausea is being less frequently reported. Improvements in the previously mentioned factors for VR sickness have resulted in significantly higher immersion, which has reduced the occurrence of VR sickness (Caserman et al., 2021; Saredakis et al., 2020; Weech et al., 2019). Concerns about the content displayed in the headset may be an important issue in exposure therapy. For example, the virtual experience may not match the client's true fear, or the scenario may not feel real enough to elicit an anxious response (Anderson et al., 2004). VR could also induce suspicion in clients who might be fearful about providing sensitive data and protecting their privacy. This raises ethical concerns, which must be carefully considered before beginning VR or any digital intervention. Finally, as digital devices become more prevalent, clinicians and researchers need to be trained in how to use such technological devices, as some may find it difficult to use. They also need to be provided with knowledge on how to resolve technical issues, such as glitches and bugs, or connectivity issues. Overall, while VR has several drawbacks, the advantages are still good enough to envision an innovative future in which previously unimaginable experiences will become possible. Further, the technological advancements over the years have made immersive psychological interventions possible, and in the future, such interventions will become even more important for treating a range of mental health conditions, including anxiety disorders.

1.3 Social and Communication Anxiety

1.3.1 Definition, prevalence, and symptomatology

Anxiety is defined in neuroscience as a brain response, initiated in the amygdala, to a potentially dangerous stimulus (Garakani et al., 2006). Anxiety is a natural response of our bodies that helps us prepare for and defend against a potential threat, often by engaging in fight, flight, or freeze/hide (Marks & Nesse, 1994). While a normal level of anxiety may be a useful trait (Marks & Nesse, 1994), stress and anxiety that exceed normal levels may cause distress, impairment, and psychopathological disorders (Beesdo et al., 2009). Anxiety disorders are frequently associated with comorbidities, such as depression and mood disorders (Kaufman & Charney, 2000; Saha et al., 2021), eating disorders (Godart et al., 2002), and ADHD (D'Agati et al., 2019), as well as substance abuse (Lai et al., 2015). Anxiety disorders are considered among the most prevalent and earliest forms of mental disorders (Kessler et al., 2005; Bystritsky et al., 2013), with their prevalence ranging from 15% to 20% (Mohr & Schneider, 2013). It has been demonstrated that the lifetime prevalence of anxiety disorders in western nations ranges from 13.6% to 28.8% (Michael et al., 2007), with up to one-third of the US population affected (Bandelow & Michaelis, 2015). Anxiety disorders affect countries all over the world in a similar way, although most studies on the prevalence have been conducted in Western countries (Beesdo et al., 2009). According to the data, anxiety disorders may be a significant source of spending for nations, with estimates of $42.3 billion in annual costs in the US in the past (Greenberg et al., 1999) and, more recently, €74.4 billion in annual costs in the European Union (Olesen et al., 2012). Women are more likely to develop and nearly twice as likely to be affected by anxiety as men, with gender differences persisting over time (Costello et al., 2003; Remes et al., 2016). Education appears to play a role as well, as people with lower levels of education seem to experience higher levels of anxiety than those with higher levels of education (Beesdo et al., 2009). In general, anxiety disorders are considered to be the result of a complex interaction between biological and environmental factors, which range from traits associated with biological parents and their parenting style to stressful, traumatic experiences and attachment styles (Norton & Abbott, 2017).

Social anxiety disorder (SAD), which is often referred to as social phobia (Stein & Stein, 2008) and has a lifetime prevalence of 12% (Ebrahimi et al., 2019), is the most prevalent anxiety disorder. SAD accounted for an annual cost of €12.1 billion in the European Union (Olesen et al., 2012). It is extremely debilitating and can impact quality of life and occupational, social, and educational situations (Ebrahimi et al., 2019). SAD is frequently defined as an intense fear and avoidance of social situations, and those affected by SAD often worry about being negatively perceived by others (Leichsenring & Leweke, 2017; Schneier & Goldmark, 2015). Fear can impact a variety of situations, including small meetings (e.g., those that include one, two, or three people), small groups, audiences, and large crowds. However, it is crucial to distinguish this from

typical shyness, a common personality trait that is not accompanied by anxiety about being shy and consequent impairment of daily life (Stein & Stein, 2008). SAD is a common anxiety disorder with an early onset that affects 50% of individuals by the age of 11 and 80% by the age of 20, and is associated with risk factors for many other mental disorders (Stein & Stein, 2008). Generally, SAD is frequently associated with other conditions, such as other anxiety disorders and depression (Belzer & Schneier, 2004), eating disorders (Kerr-Gaffney et al., 2018), panic disorder, post-traumatic stress disorder, and substance abuse (Lydiard, 2001). Young people diagnosed with SAD appear to also have frequent comorbidities such as substance misuse (41.3%), mood disorders (31.1%), and a secondary anxiety disorder (49.9%; Pilling et al., 2013). This situation is worsened by the fact that, in addition to suffering and functional difficulties in contexts such as relationships and employment, individuals with SAD often do not seek treatment (Norton & Abbott, 2017).

Communication anxiety, very often referred to as public speaking anxiety, is the most common subtype of social anxiety (Blöte et al., 2009; Furmark et al., 2000), and it is commonly referred to as the fear of speaking in front of others or situation-specific social anxiety that occurs from the actual or anticipated performance of an oral presentation (Bodie, 2010). Public speaking anxiety is highly prevalent in people with general SAD, but it could also appear without other forms of SAD (Pull, 2012). Anxiety about communicating could result in distress or impairment in social, occupational, and other important areas of functioning (Pull, 2012). Bodie (2010) distinguished between physiological, cognitive, and behavioral signs of anxiety, and also used the trait–state distinction to distinguish between anxiety experiences occurring in a specific context at a specific time and a general tendency towards anxiety across situations and times. The physiological, cognitive, and behavioral manifestations of public speaking anxiety are associated with the nervous system (Bodie, 2010) and negative thoughts, as well as common signs such as tremors, blushing, sweating, and the avoidance of social situations (Leichsenring & Leweke, 2017; Spence & Rapee, 2016). Public speaking anxiety is a debilitating fear, with its onset occurring during adolescence at a prevalence range of 21% to 33% (Ebrahimi et al., 2019). In Finland, the adolescent population appears to be frequently affected by difficulties with social interaction (Ranta et al., 2009; Ranta et al., 2023), which, if left untreated, could have negative long-term consequences. In fact, many individuals with phobias do not seek appropriate treatment, even though these situations can disrupt their daily life (Ipser et al., 2013).

Social anxiety appears to be prevalent among college and university students, who need to engage in frequent interpersonal communication during their academic lives (Luan et al., 2022). For example, SAD was found to be as high as 25.8% in a Saudi Arabian student population (Hakami et al., 2017), between 15.3% and 19.5% in an Indian university sample (Jaiswal et al., 2020; Shah & Kataria, 2010), 16.1% in a Swedish university sample (Tillfors & Furmark, 2007), and 20.9% in a Turkish undergraduate sample (Gültekin & Dereboy, 2011). Speaking in front of others may be a common activity for university students,

particularly in countries where small group activities and presentations are the norm. In a survey conducted in the United States, 61% of students reported a fear of public speaking (Dwyer & Davidson, 2012), and a similar percentage (64%) of college students from Brazil also reported a fear of public speaking (Ferreira et al., 2015). According to Kunttu et al. (2017), one-third of students in Finland reported having severe stress, primarily as a result of having to perform in front of an audience. Therefore, given the high prevalence of social and public speaking anxiety, there seems to be a need to find effective solutions. One goal of research in this direction is to assist students in identifying the most effective tools for reducing anxiety associated with public speaking (Bodie, 2010).

1.3.2 Psychological interventions for social and communication anxiety

As social anxiety and public speaking anxiety are common conditions that affect people, a great deal of research has been conducted to identify psychological interventions that may be effective in reducing these conditions (see Table 1 for a few recent meta-analyses). A meta-analysis from Powers et al. (2008) examined 32 randomized controlled trials comparing traditional psychological treatments for SAD (e.g., CBT and exposure therapy) to control conditions and revealed how the treatment groups outperformed the waiting list (d = 0.86), psychological placebo (d = 0.34), and pill-placebo (d = 0.36) control groups. These findings were consistent with those of similar meta-analyses conducted in the 1990s (Feske & Chambless, 1995; Gould et al., 1997). Moreover, it has been reported that treatment gains were maintained at follow-up measurements (d = 0.76; Powers et al., 2008). Even though there were no differences between CBT, exposure therapy, and cognitive therapy alone in terms of effectiveness, the study revealed that all three were effective at reducing social anxiety. Although this study did not confirm the findings of Feske & Chambless (1995) that more sessions resulted in larger effect sizes, it did support earlier findings that there was no difference between individual and group therapy formats. Another meta-analysis from Mayo-Wilson et al. (2014) compared psychological and pharmacological treatments for SAD by including 101 studies conducted between 1988 and 2013. They discovered that individual CBT had larger effect sizes than other treatments (such as exposure and social skills, self-help with or without guidance, and group CBT). Specifically, individual CBT outperformed waiting list (g = 1.19) and psychological placebo (g = 0.56) control treatments and was found to be more effective than other psychological interventions such as interpersonal and mindfulness therapy. Even though Mayo-Wilson et al. (2014) also found pharmacological treatment to be effective, they recommended individual CBT as the treatment of choice for SAD. A third meta-analysis conducted by Barkowski et al. (2016), which included 36 studies, confirmed the previous meta-analysis and extended the results of Mayo-Wilson et al. (2014) by comparing the effectiveness of group psychotherapy treatment for SAD to a waiting list control. The results showed that group psychotherapy (mostly defined as group CBT) had a larger positive effect than the waiting list control treatment (g = 0.84) and was as effective as other alternative treatments. Despite the fact that group

psychotherapy was ineffective in treating general psychopathology, it was found to be effective in reducing the symptomatology. Similarly to the other meta-analyses (Feske and Chambless, 1995, Mayo-Wilson et al., 2014, Powers et al., 2008), Barkowski et al. (2016) also highlight how exposure treatments are very powerful for treating SAD. Additionally, Barkowski et al. (2016) found that group psychotherapy remained significantly superior to waiting list control treatment in the short- and mid-term (g = 3.91). Finally, another recent meta-analysis from Kindred et al. (2022) confirmed the efficacy of psychological interventions, specifically CBT, compared to control treatments for SAD (g = 0.74). The study expanded on previous findings by demonstrating that the effects of CBT can be long-lasting and that limiting the investigation to the immediate post-treatment period may lead to underestimation of the effectiveness of CBT. However, unlike Mayo-Wilson et al. (2014), Kindred et al. (2022) found no differences between different types of CBT interventions.

There also a lot of meta-analyses and reviews on communication and public speaking anxiety. One of them is a meta-analysis conducted by Ebrahimi et al. (2019). Which compared the effectiveness of short- and long-term psychological interventions for public speaking anxiety with active (attention placebo) and passive (e.g., waiting list) control conditions. They analyzed a total of 30 studies by searching for research that examined the effects of psychological interventions on fear of public speaking, fear of presentations, and communication anxiety. The results showed that psychological interventions had a significant effect on fear of public speaking (g = 0.74): the interventions had a large effect size in comparison to passive control conditions and moderate to large effect sizes when compared to active control conditions. Similarly to the results of Kindred et al. (2022) for SAD, the results from Ebrahimi et al. (2019) confirmed the long-term effects of psychological interventions for public speaking anxiety (g = 1.11). Different types of psychological interventions were found to have the same effect, with no differences observed between cognitive and behavioral therapies. An additional important objective of their study was to compare the efficacy of technology-assisted interventions (such as computer-, internet-, and VR-based interventions) to that of traditional interventions. According to their results, technology-assisted psychological interventions were not found to be different from traditional ones in terms of efficacy at the end of treatment, and this implied that they were a viable option for treating public speaking anxiety. Thus, for people who are hesitant to engage in traditional face-to-face psychological therapy, technologically assisted interventions may be a great alternative (Ebrahimi et al., 2019). The findings also point to the need for more research about the impact of technologically assisted interventions on social and public speaking anxiety.

TABLE 1 Meta-analyses that examined psychological interventions for social anxiety and public speaking anxiety

Meta-analysis	RCTs included	Number of participants	Control groups	Effect sizes
Powers et al., 2008	32	1479	WLC, psychological placebo, pill-placebo	d = 0.86, g = 0.84 for treatment vs. WLC, d = 0.34 for treatment vs. psychological placebo, d = 0.36 for treatment vs. pill-placebo
Mayo-Wilson et al. (2014)	101	13164	WLC, psychological placebo, pill-placebo	g = 1.19 for individual CBT treatment vs. WLC, g = 0.92 for group CBT vs. WLC, g = 0.56 for individual CBT vs. psychological placebo
Barkowski et al. (2016)	36	2171	WLC, common factors control	g = 0.84 (symptomatology), g = 0.62 (psychopathology) for group CBT treatment vs. WLC
Kindred et al. (2022)	25	1902	WLC	g = 0.74 for CBT treatment vs. WLC
Ebrahimi et al. (2019)	30	1355	active control conditions (e.g., attention placebo) and passive control conditions (e.g., WLC)	g = 0.74 for psychological treatments at pre-post, g = 1.11 for psychological treatments at follow-up

RCT = randomized controlled trial, WLC = waiting list control

1.3.3 VR interventions for social and communication anxiety

Exposure-based techniques are frequently used in behavioral therapies for anxiety disorders (Kaczkurkin & Foa, 2015). However, conducting and participating in exposure exercises can be difficult for both therapists and patients, especially if the exposure occurs outside of the therapy room (Miloff et al., 2016). The fearful situation can be difficult to confront in real life; for example, for a public speaking audience, in vivo stimuli may be difficult to create, control, and adjust during an exposure session (Lindner et al., 2019). As a result, exposure training has been implemented through technology-assisted interventions such as VRET, which has mostly been used in the treatment of anxiety-related disorders (Carl et al., 2019; Powers & Emmelkamp, 2008). VR allows users to create virtual scenarios (Figure 5) and control the intensity and repetition of a frightening situation; thus, it a viable alternative to imagined or in-person exposure (Gebara et al., 2016).

FIGURE 5 A 180° 3D recorded video scenario of an audience in Study II, Gorinelli et al. (2023)

According to Anderson et al. (2004), the use of VR for the treatment of anxiety appears to have several advantages, such as increased control over the exposure situation, increased convenience and confidentiality due to the therapy and exposure occurring in the therapy room, and increased ability to repeat exposure exercises and increase their duration as needed. However, due to the limited number of studies, the evidence regarding VRET is preliminary (Kampmann, Emmelkamp, & Morina, 2016). Nonetheless, the technology and research on VRET continue to advance, with recent findings indicating that VR may be an effective intervention for social and public speaking anxiety (Emmelkamp et al., 2020; Lim et al., 2023; Maples-Keller et al., 2017; Morina et al., 2023; Nazligul et al., 2017; Sarpourian et al., 2022; Stupar-Rutenfrans et al., 2017; Takac et al., 2019).

A number of meta-analyses and reviews have also been conducted to investigate technology and VR-based treatments for social and public speaking

anxiety (see Table 2 for a few recent meta-analyses). In the first such meta-analysis from Kampmann et al. (2016), internet-delivered treatments were compared with VRET for the treatment of SAD, with control conditions. The results showed a large effect size for the VR-based intervention after treatment (g = 1.09), and this effect was maintained during the short-term and long-term follow-ups (g = 0.93, g = 1.20). Further, although they reported no significant difference between VR interventions and active control conditions, there was a large post-treatment effect when compared to the passive control conditions (g = 0.82). Although Kampmann et al. (2016) and previous meta-analyses have examined and confirmed the effect of VR-based interventions (Opriş et al., 2012; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008), these analyses were often part of a larger analysis (Chesham et al., 2018). In contrast, the meta-analysis by Chesham et al. (2018) exclusively examined VR-based treatments for SAD and compared them to waiting list control (WLC) and other traditional treatments. The findings revealed how VR generates better outcomes than the control conditions (g = 0.82) and is comparable to other standard treatments for SAD (g = 0.01). Fodor et al. (2018) and Carl et al. (2019) examined the effect of VR treatment for overall anxiety disorders compared it to control and other traditional interventions. They reported that VR-based interventions were more effective than control conditions (g = 0.67, g = 0.97, respectively) and as significantly effective as other treatments (such as in vivo exposure) for SAD. Recently, Horigome et al. (2020) confirmed the previous findings that VR exposure interventions can be effective in the post-treatment (g = 0.86), mid-term (3 months; g = 1.03), and long-term (one year; g = 0.74) period for SAD; further, they reported that it may also outperform the control treatments (g = 1.23) and have similar effects as in vivo interventions (g = 0.07). However, the follow-up effect of VR treatments has been reported to be lower than that of in vivo treatments. Morina et al. (2023) have recently criticized the methodology and analyses of Horigome et al. (2020) and have attempted to provide a more accurate and up-to-date interpretation of the results. Morina et al. (2023) found that VR exposure treatments are very effective in treating SAD at the post-treatment (g = 1.20), 3-month (g = 1.17), and 1-year follow-up period (g = 1.06). The effect was significantly superior to the control conditions (g = 0.88) and also comparable to that of in vivo treatment according to observations at the 12-month follow-up (g = 0.02). With regard to public speaking anxiety, a recent meta-analysis from Reeves et al. (2022) revealed that VR exposure interventions are more effective when compared to control treatments (g = 1.39) and have a slightly lower positive effect than in vivo treatments.

The findings of all the meta-analyses presented in this section imply that there is a great deal of research on VR and CBT, which is the main psychological intervention used in conjunction with VR. However, little is known about the use of various VR devices and their integration with third-wave CBT or so-called process-based psychological interventions such as Acceptance and commitment therapy (ACT).

TABLE 2 Meta-analyses that examined virtual reality-based psychological interventions for social anxiety and public speaking anxiety

Meta-analysis	RCTs included	Number of participants	Control groups	Effect sizes
Kampmann et al. (2016)	37	2991	active and passive control groups	*g* = 1.09, *g* = 0.93, *g* = 1.20 for VR interventions at post-treatment, short-term, and long-term follow-up, respectively. *g* = 0.82 for VR treatment vs. WLC
Chesham et al. (2018)	9	573	WLC	*g* = 0.82 for VR interventions vs. WLC at post-treatment
Fodor et al. (2018)	39	869	WLC	*g* = 0.67 for VR interventions vs. WLC at post-treatment
Carl et al. (2019)	30	1057	psychological control, WLC	*g* = 0.97 for VR interventions vs. control conditions
Horigome et al. (2020)	22	703	WLC or TAU	*g* = 0.86, *g* = 1.03, *g* = 0.74 for VR interventions at post-treatment, short-term, and long-term follow-up, respectively. *g* = 1.23 for VR treatment vs. WLC or TAU
Morina et al. (2023)	12	228	WLC	*g* = 1.20, *g* = 1.17, *g* = 1.06 for VR interventions at post-treatment, short-term, and long-term follow-up, respectively. *g* = 0.88 for VR treatment vs. WLC
Reeves et al. (2022)	11	508	WLC	*g* = 1.39 for VR interventions vs. WLC at post-treatment

WLC = waiting list control, TAU = treatment as usual

1.4 Acceptance and Commitment Therapy

1.4.1 Acceptance and commitment therapy and psychological flexibility

Individuals with mental health and medical conditions are frequently able to find effective support through psychological interventions (Dindo et al., 2017). Standard anxiety treatment interventions often focus on controlling and replacing negative thoughts with more adaptive ones (Kaczkurkin & Foa, 2015). CBT is one of the most effective and widely used psychotherapies currently available (Hayes & Hofmann, 2018).

However, modern process-based transdiagnostic approaches, such as ACT (Hayes et al., 1999), emphasize the possible risk of counterproductive consequences when attempting to control dysfunctional experiences (Hayes, 2004; Kahl et al., 2012). Each letter of the acronym ACT, which is pronounced as a single word, summarizes its core principles: A = accept your thoughts and feelings while being present; C = choose a valued direction; T = take action (Harris & Hayes, 2009). A great deal of research in the ACT field has focused on anxiety. In ACT interventions, people are taught to relate to anxiety freely and without defense or trying to control it (Hayes et al., 2006; Hayes et al., 2012). The goal of this approach, broadly, is to improve willingness, acceptance skills, and psychological flexibility; more specifically, it focuses on the ability to be fully in contact with the present moment and, depending on the context, adapt one's behavior based on chosen values (Hayes et al., 2006; Ruiz & Perete, 2015; Ruiz et al., 2019). In a nutshell, ACT teaches people to accept the inevitable pain of life in order to live a rich, full, and meaningful life (Harris & Hayes, 2009). That is, ACT teaches skills for dealing with painful events and facilitating effective action. As a consequence, acceptance is frequently taught in ACT as the capacity to be receptive to personal experiences, regardless of whether they are positive or negative. Acceptance, along with a commitment to value-based actions, are two of ACT's fundamental components (Hayes et al., 2006).

ACT is a process-based approach that aims to increase psychological flexibility skills and is often said to be grounded in functional contextualism as a background philosophy and the relational frame theory (RFT) as a background theory of language (Hayes, 2004; Hayes et al., 2012). Accordingly, all actions are considered as events that only have meaning when used in context and follow the behavioral principles for precision (the number of ways a specific event can be defined), scope (the number of times an event is applicable), and depth (maintaining coherence across levels) (Hayes et al., 2012). According to RFT, the basic unit of human language is relating ability (Barnes-Holmes et al., 2001). Events can be related to one another in a variety of ways based on different frames of relationships (Barnes-Holmes et al., 2001). Several frames have been described in literature (Barnes-Holmes et al., 2001; Villatte et al., 2015), along with collections of language abilities that can be used as tools in the therapeutic context (Villatte et al., 2015). The frame of coordination is the most commonly used one, and it includes the frame of identity or sameness (Barnes-Holmes et al.,

2001) (e.g., "I am my thoughts"). In addition, the frame of distinction implies being distinct from (e.g., "I am distinct from my thoughts"); the hierarchical frame implies being included or a part of (e.g., "The thoughts are a part of me"); and the didactic frame implies the speaker's perspective (e.g., "What do you feel about this person?") (Villatte et al., 2015).

In general, ACT promotes psychological flexibility through six core processes, which form a hexaflex model (Figure 6): (1) acceptance of challenging experiences and thoughts that may arise when selecting one's values and goals; (2) contact with the present moment, that is, being in the here and now and developing awareness of one's thoughts and emotional reactions; (3) defusion, or taking a step back from one's thoughts, images, or memories and being able to act independently of what one's mind is telling them; (4) self-as-context, or taking an observer's stance toward the conscious part of one's mind to observe emotions, sensations, and feelings; (5) description of values or ongoing actions in line with what is important to one's life; and (6) committed actions, or undertaking actions towards creating a rich, full, and meaningful life consistent with one's values (Hayes, 2004; Hayes et al., 2012).

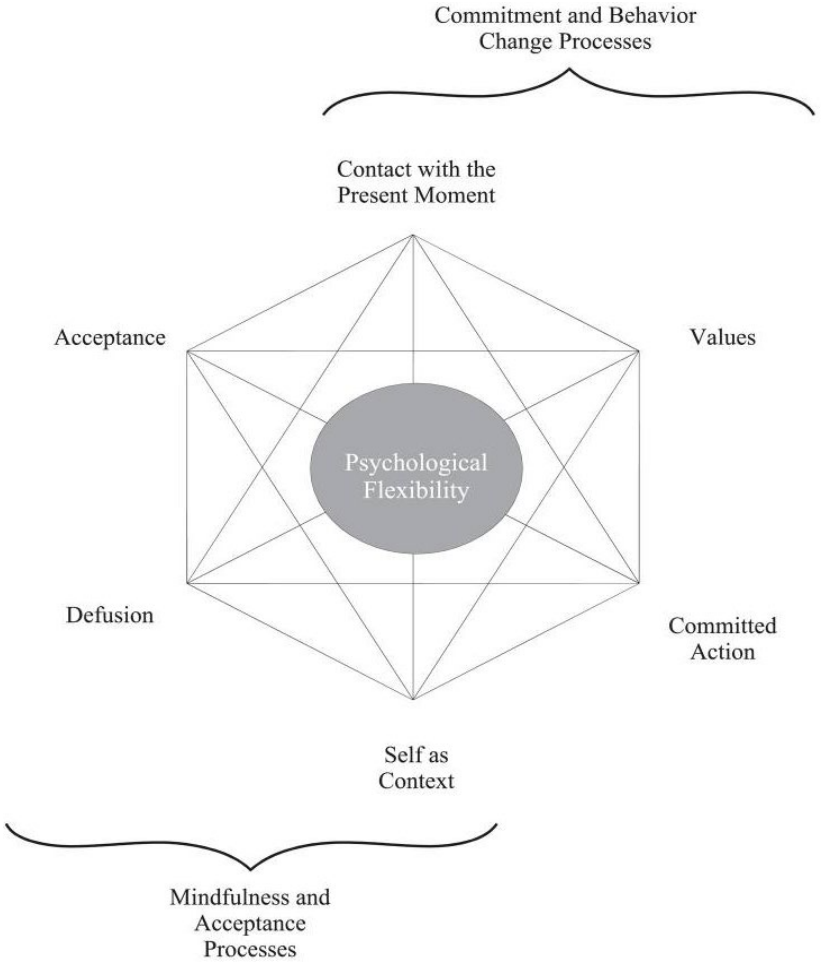


FIGURE 6 ACT psychological flexibility hexaflex model, Hayes et al. (2006).

On the other side of the hexaflex is a model of pathology, or psychological inflexibility. The inflexibility model is characterized by components that are in contrast to the model of health and treatment proposed by Hayes et al. (2006): (1) experiential avoidance; (2) loss of contact with the present moment by being stuck in the past or feared future; (3) cognitive fusion, or simply, being fused and over-identifying with thoughts; (4) attachment to the conceptualized self or, simply, difficulty in switching perspective; (5) lack of clarity in values; and (6) inaction, impulsivity, or avoidant persistence (Hayes et al., 2012). Experiential avoidance, in contrast to acceptance, refers to the tendency to engage in actions that modify the occurrence, duration, or shape of unwanted private events (i.e., thoughts, emotions, and physical sensations), which may lead to a disconnection from human experience (Eifert & Forsyth, 2005). This rigid stance to inner experiences seems to be associated with worse well-being (Ong et al, 2023). From an ACT perspective, these key processes contribute to human suffering (Hayes et al., 2006). As a result, the ACT model of therapy, with psychological flexibility and its counter processes, aims to promote a rich, full, and meaningful life.

The six processes of the psychological flexibility model can be further divided into acceptance and mindfulness processes (acceptance, defusion, present moment, and self) and commitment and behavior change processes (present moment, self, values, and committed action) (Hayes et al., 2012).

In recent years, RFT-focused research has condensed the six fundamental psychological flexibility processes into three essential therapeutic approaches (Luciano, 2016; Törneke et al., 2015). The first approach is to assist the client in identifying the connection between the client's current functional classes of responding and undesirable outcomes. This refers to the significance of identifying which behaviors lead to undesirable consequences. In RFT terms, this is called causal framing, wherein particular behaviors are related to particular consequences (Törneke et al., 2015). The second approach is to train this repertoire as an alternative functional class and assist the client in framing their own responses in hierarchy with the deictic I. This refers to assisting the client in reducing the behavioral control functions of verbal responding (e.g., thoughts) and increasing the likelihood of alternative responses (Ruiz & Perete, 2015). The last tactic is to assist the client in creating alternative repertoires that will specify the desired outcomes (appetitive augmental functions) of additional behavior. This involves motivating a behavioral change by outlining what matters most to the client and connecting it to a new behavior (Luciano et al., 2011; Törneke et al., 2015).

Hayes et al. (2011) argued that psychological flexibility could be characterized in terms of three "dyadic" processes or clusters: (1) psychological openness to experiences (acceptance and defusion), (2) flexible attention to the now and perspective taking (present moment awareness and self as context), and (3) motivation to change and meaningful actions (values and committed action) (Francis et al., 2016). This classification is the basis for CompACT (Francis et al., 2016), a measure of psychological flexibility that is widely used in research and was also applied in this study.

1.4.2 Self-compassion

According to Neff and Tirch (2013), some of the components of the ACT model are related to and essential for the roots and experience of self-compassion. From an ACT perspective, self-compassion is a component that emerges in multiple processes of psychological flexibility (Gillanders et al., 2014; Neff & Tirch, 2013). As self-judgment could decrease when promoting acceptance (Neff, 2006) (i.e., the willingness to observe our negative thoughts and emotions with openness and clarity, without attempting to suppress them), an ACT intervention may be able to foster self-kindness as a result. Similarly, we could observe an increase in non-judgmental mindfulness by reducing over-identification with thoughts when promoting cognitive defusion.

When external life circumstances are difficult to bear or when we experience suffering due to our own mistakes and failings, compassion can be extended to the self (Neff, 2011). Neff (2003a) defines the concept of self-compassion as being kind and understanding toward oneself when suffering or failure occur as opposed to being self-critical (this is also referred to as self-kindness); seeing one's experiences as a part of the greater human experience as opposed to isolating (this is referred to as common humanity); and holding up painful thoughts and feelings in mindful awareness as opposed to over-identifying with them (this is referred to as mindfulness). According to this definition, Neff (2003a) describes the self-compassion construct as a combination of three pairs of positive and negative aspects: self-kindness versus self-judgment, common humanity versus isolation, and mindfulness versus overidentification. However, an increase in one aspect does not necessarily translate into a decrease in the opposing dualistic factor because these factors are not mutually exclusive. Therefore, it is crucial to pay attention to how someone chooses to relate to negative thoughts rather than just focusing on the thoughts themselves, and this strategy is similar to that employed in ACT. According to Allen and Leary (2010), acting with compassion entails that when things go wrong, individuals may be comforting rather than critical by (1) practicing self-kindness to oneself through taking time off or engaging in positive self-talk, (2) realizing that one is not alone in the common human experience, and (3) taking a balanced perspective of the situation without being carried away by one's thoughts and emotions. If self-kindness, common humanity, and mindfulness constitute the definition of self-compassion, then their corresponding negative aspects can be defined as follows: self-judgment can be defined as a negative evaluation and criticism of personal aspects and experiences; isolation can be defined as feeling alone in one's struggle and separated from others; and over-identification can be described as the tendency to fixate on negativity and failure.

Research on student populations has revealed how self-compassion shows associations with well-being (Fong & Loi, 2016; Neely et al., 2009), resilience (Smeets et al., 2014), depression, and distress (Fong & Loi, 2016). In addition, some meta-analyses have also revealed that self-compassion is positively associated with well-being (Zessin et al., 2015) and negatively associated with psychopathology (MacBeth & Gumley, 2012). Self-compassion influences how

people respond to various negative situations and acts as a defense mechanism that can enable change in the face of negative emotions and experiences (Marshall et al., 2015). For the practice of self-compassion, as defined by Neff's model (2003a), it is important to identify which specific psychological processes are involved in psychopathology and how they can aid in therapeutic intervention.

1.4.3 Psychological processes of change

It has been argued that understanding psychological processes is useful because it can lead to more effective intervention change (Hofman & Hayes, 2019). Regardless of the therapeutic approach used, focusing on psychological processes of change seems to be important for achieving successful treatment outcomes (Ciarrochi et al., 2010; Rosen & Davison, 2003; Villatte et al., 2016).

ACT is based on six psychological processes of change (Hayes et al., 1999) that can increase psychological flexibility directly (Twohig, 2012). Changes in these processes are believed to have positive effects on human life (Hayes et al., 2011). ACT is an example of process-based therapy (Hofmann & Hayes, 2019), which is delivered in the form of a practical model that comprises a limited set of evidence-based processes tailored to an individual's needs and a set of practices deployed for the purpose of altering processes of change (Hayes, 2019). It is expected that this set of processes and practices can ultimately lead to an intervention method for a desirable treatment outcome (Hayes, 2019). Psychological flexibility is the primary psychological change process in ACT, and it is frequently fostered through skill training, experiential exercises, metaphors, and exposure (Hayes et al., 2006; Ong et al., 2020). Such approaches for increasing psychological flexibility involve examining the underlying core mechanisms of change, which frequently explains intervention outcomes, and extends beyond specific psychotherapy protocols (Hayes et al., 2020; Hofmann & Hayes, 2019). Distinct processes appear to be associated with particular symptoms: for example, cognitive fusion is associated with depressive symptoms (Pinto-Gouveia et al., 2020), and experiential avoidance is associated with depression, anxiety, and related disorders (Akbari et al., 2022). While various components of psychological flexibility may be negatively associated with stress, depression, and anxiety (Brandolin et al., 2023; Flowers et al., 2023; Francis et al., 2016; Kroska et al., 2020; O'Boyle-Finnegan et al., 2022; Rogge et al., 2019), multiple studies point to acceptance as a crucial process for anxiety in university students (Gallego et al., 2020; Morin et al., 2021).

Recently, there has been growing interest in investigating the processes of change that lead to individual differences in intervention outcomes (Hofmann et al., 2020). The studies in this area point to the need to pay attention to individual differences and appropriate measurements in research on identifying the processes of change in mental health (Akbari et al., 2022; Hofman & Hayes, 2019; Morin et al., 2021). EMA and EMI, which facilitate contextual assessment or interventions in real time, can be tailored to meet individual needs by providing support when users want or need support the most and can also flexibly address the user's need by providing the right amount or type of support at the right time

(Hardeman et al., 2019; Nahum-Shani et al., 2018). In addition, EMA can also serve as a useful tool for investigating psychological processes of change that occur in people's daily lives.

1.4.4 ACT interventions for social and public speaking anxiety

An individual experiencing anxiety often tends to see thoughts and anxiety not as they truly are, but rather as negative components that are intolerable and must go away (Eifert & Forsyth, 2005). As a result, experiential avoidance can occur when people do everything they can to avoid experiencing anxiety by engaging in behaviors that push away unwanted private events. Experiential avoidance has the potential to develop and maintain psychopathology and human suffering in a broader sense (Eifert & Forsyth, 2005). From an ACT standpoint, negative thoughts and emotions are just that—thoughts and feelings. They do not directly cause harm, and in the end, they are what makes us human (Eifert & Forsyth, 2005).

ACT is a process-based, transdiagnostic approach that can effectively address various psychological issues in diverse samples (A-Tjak et al., 2015; French et al., 2017; Gloster et al., 2020; Howell & Passmore, 2019). Across multiple studies, psychological flexibility and its related processes have been associated with psychological distress and well-being (Francis et al., 2016; Levin et al., 2014), depression (Masuda & Tully, 2012), chronic pain (McCracken & Morley, 2014), social and public speaking anxiety (Azadeh et al., 2015), and overall psychological and mental health (Kashdan & Rottenberg, 2010; Levin et al., 2019). Psychological flexibility, particularly in the context of university students, is also associated with mental health and academic success (Levin et al., 2019), academic emotions (Asikainen et al., 2018), self-efficacy (Jeffords et al., 2020), depression, and anxiety (Masuda & Tully, 2012). In general, studies show that psychological flexibility and self-compassion are important factors in the treatment of social and public speaking anxiety (Webb et al., 2016; Werner et al., 2012). Social anxiety, defined as the fear of one or more social situations, is associated with social isolation (Teo et al., 2013), has negative effects on well-being and can contribute to a lack of purpose in life and human suffering (Kashdan & McKnight, 2013). The literature indicates that psychological flexibility, self-compassion, and well-being are positively correlated; further, self-compassion may be a more significant predictor of well-being than psychological flexibility (Marshall & Brockman, 2016). There appears to be a need to investigate psychological processes in order to gain a better understanding of this subject. In light of the fact that psychological flexibility is strongly associated with social and public speaking anxiety (Webb et al., 2016; Werner et al., 2012), Glassman et al. (2016) have proposed acceptance-based interventions as alternatives to conventional treatments.

Gloster et al. (2020) conducted a review of 20 meta-analyses (n = 12477) to investigate the current state of ACT and its effectiveness as an intervention. The findings revealed that ACT was an effective treatment for all conditions included in the study, including anxiety, depression, substance abuse, pain, and

transdiagnostic groups. In addition, it was demonstrated that ACT is superior to control conditions and other intervention conditions, with the exception of CBT. Although CBT seems to be one of the best options for treating SAD, ACT appears to be a promising alternative treatment in terms of increasing psychological flexibility, defusion, connection, and acceptance of anxiety-related symptoms (Caletti et al., 2022). ACT can teach skills on how to handle emotional reactions and thoughts related to experiences that occur when exposed to fearful situations. Concerning public speaking anxiety, England et al. (2012) demonstrated the efficacy of acceptance-based intervention as a brief treatment, whereas Priestley et al. (2016) proposed that delivering ACT in the form of a self-help program could be a potentially promising intervention for reducing public speaking anxiety.

Even though research on ACT and its effectiveness is expanding rapidly (e.g., A-Tjak et al., 2015; Gloster et al., 2020), there is very limited research that combines VR with ACT or process-based interventions. A pilot study (n = 15) by Yuen et al. (2019) investigated the application of VR to deliver ACT and its impact on public speaking anxiety. The aim was to compare a homework exposure exercise using a video conferencing intervention or a VR exposure intervention. Due to the high cost of VR equipment, however, the content was delivered via webpages on a remote computer screen rather than a VR HMD device. Although the high cost of VR research is a significant limitation and a potential reason for the limited use of VR in ACT research, this technology has advanced rapidly in recent years and become generally affordable. Thus, it may now be easier to purchase a VR headset.

As a result of the progression of technology, EMA can now be used to aid research and provide information beyond traditional self-reported assessments. EMA studies are increasing in various areas of psychology (Wrzus & Neubauer, 2023), such as ACT (Grégoire et al., 2020; Hulbert-Williams et al., 2021). However, additional ACT studies utilizing EMA or daily assessment of interventions are required (Hayes et al., 2021; Ong et al., 2023). This is because repeated systematic measurements with EMA permit the observation of individuals over time and across contexts and can increase our knowledge about individual differences that are often observed in interventions. EMA methods are also well-suited for and strengthen the internal validity of SCD research, a technique frequently used to examine the psychological and behavioral changes of a single person or a small group of individuals (Bentley et al., 2019).

1.5 Research Aims

Even though VR appears to be a very promising technological tool for providing alternative effective interventions, there is a lack of research on using VR to deliver ACT for social and public speaking anxiety. Simultaneously, there is a growing interest in observing the mechanisms and processes of change in the treatment outcomes of individuals. Accordingly, the studies that form this

dissertation had two main objectives: (1) to examine the efficacy of a VR-based ACT (VRACT) intervention on social and public speaking anxiety and (2) to examine which psychological processes can be related to and possibly explain changes in anxiety.

Study I sought to gain a better understanding of the psychological processes associated with social interaction and communication anxiety in university students who reported high levels of anxiety. Furthermore, we were interested in discovering which specific sub-processes of psychological flexibility and self-compassion seem to be crucial when coping with these types of anxiety, as a greater understanding of the key psychological processes underlying social and communication anxiety can be instrumental in the development of more effective interventions. Psychological processes might also play a significant role in achieving a treatment objective and pointing us in the right direction in terms of evidence-based mechanisms of change (Hofmann & Hayes, 2019). We anticipated that low levels of psychological flexibility and self-compassion would correlate with elevated levels of social interaction and communication anxiety. Further, based on our prior knowledge of public speaking anxiety (Gallego et al., 2020), we anticipated that the psychological flexibility sub-skill "openness to experience" would be a crucial factor related to social interaction and communication anxiety. To the best of our knowledge, there are no studies that examine the aspects of both psychological flexibility and self-compassion, which are important factors related to anxiety when interacting with others among university students.

Technological advances show how immersive psychological interventions are now feasible and will become even more crucial for treating mental health with time. The primary psychological process of change in ACT is psychological flexibility, which is frequently promoted through skill development, experiential activities, metaphors, and exposure (Ong et al., 2020). Consequently, **Study II** attempted to address the dearth of research combining VR HMD devices and process-based interventions, such as ACT. The primary objective was to determine whether exposing university students to a VR process-based ACT intervention would improve their self-reported social anxiety, communication anxiety, and psychological flexibility. Particularly, we wished to observe whether a very brief, "automated" three-session VRACT would have a greater effect on participants' social and public speaking anxiety than the no-intervention condition (i.e., WLC). According to our hypotheses, the VRACT intervention would (a) reduce social interaction and communication anxiety and (b) improve university students' communication skills and psychological flexibility.

There are also a limited number of studies that have investigated the effect of VR interventions and included daily momentary assessment of symptoms in young populations (Björling et al., 2022). Accordingly, the first aim of **Study III** was to determine whether the VRACT intervention also had an effect on psychological flexibility across individual contexts (i.e., in everyday life) using EMA. The second objective was to investigate the individual psychological flexibility processes of change observed using EMA among students who

showed clinically significant improvements in social interaction and communication anxiety. To this end, we used the SCD approach to observe changes in individual participants using an AB design. According to our hypotheses, (1) the VRACT intervention would increase psychological flexibility in everyday life and across contexts, as measured by EMA, and (2) based on previous research, the psychological flexibility sub-dimension "openness to experiences" would be the most crucial component of change in anxiety.

This is, to the best of our knowledge, the first study to examine how ACT can be delivered via VR exposure with an HMD device to impact social and public speaking anxiety among students. The results of the study are expected to expand our understanding of brief process-based anxiety interventions utilizing VR.

2 METHODS

2.1 Participants

Participants for all three studies were recruited from various faculties at the University of Jyväskylä via newsletters and poster advertisements distributed throughout campus. The advertisement, in Finnish, started with the statements "Are you nervous before presentations?" and "Would you like to practice in virtual reality?" It also stated that student volunteers were being sought for a VR research study aimed at decreasing perceived insecurity and anxiety in performing and other social situations. The advertisement also provided contact information, the number of sessions to attend, and the compensation that would be provided for participating in the study. As compensation, the participants would receive two movie tickets after the study as a reward for the time spent taking part in the research. University students who contacted the research team via email or phone to request for more information or to express their willingness to participate in the study were sent a screening online survey link using Webropol with more detailed information about the research. In the screening survey, the participants were asked to provide their preliminary consent for the research and to indicate their willingness to sign the informed consent later on, at the first face-to-face meeting. It also briefly described the theoretical background and study design, as well as the eligibility criteria: (1) no current psychological intervention for performance anxiety and (2) no possible holidays during the intervention time frame. Those who met the criteria received an email with instructions on how to set up an initial session using the online scheduling tool Doodle. Students who were undergoing parallel psychological treatment or taking psychogenic medications and those who did not respond to the email or had problems participating in the research due to their schedules were excluded from the study and analyses. Informed consent was obtained from all participants taking part in the first study session. Ethical approval from the

University of Jyväskylä Ethical Committee was obtained for the study, the privacy policy, the storage of personal data, the informed consent policy, and the collection and use of background data.

In **Study I**, a total of 76 university students (out of 97 who initially contacted the research team, see also Figure 7) filled out pre-measurement data during the first face-to-face session. The participants (N = 76; age range = 19–68 years, M = 24.95, SD = 6.50) were primarily females (n = 53; 69.7%), with the remaining 30.3% identifying as males. They had studied for an average of 2.81 years (SD = 3.04), and most of them were not familiar with mindfulness, ACT (n = 54; 71.1%), or VR (n = 50; 65.8%). The sample consisted of university students who experienced social interaction anxiety (n = 46; 60.5%) and high levels of communication anxiety (n=54; 71.1%).

In **Study II**, the 76 university students selected in Study I were randomly assigned to either the intervention (VRACT) group (n = 37; age: M = 24.03, SD = 4.35; 70.3% females) or the WLC group (n = 39; age: M = 25.82, SD = 8.00; 69.2% females) using the randomization tool available on random.org (Figure 7). Figure 7 also contains information about the students who were excluded in the different phases of the study.

No statistically significant differences were found between the two groups with regard to the demographic and pre-measurement variables. Both groups included similar percentages of participants with social interaction anxiety (VRACT = 59.5%; WLC = 61.5%) and high communication anxiety (VRACT = 75.7%; WLC = 64.1%). Furthermore, the majority of the participants in both groups had no familiarity with mindfulness and ACT (VRACT = 70.3%; WLC = 71.8), or VR (VRACT = 64.9%; WLC = 66.7%). The WLC group waited for three weeks before they received the same VRACT intervention, with the only difference being that they did not fill in EMA surveys during the time frame of the study.

In **Study III**, the participants of the same VRACT intervention group described for **Study II** (n = 37, age M = 24.03, SD = 4.35, 70.3% females) were asked to fill out EMA data through the Metric Wire phone application during their daily lives while taking part in the study (Figure 8).

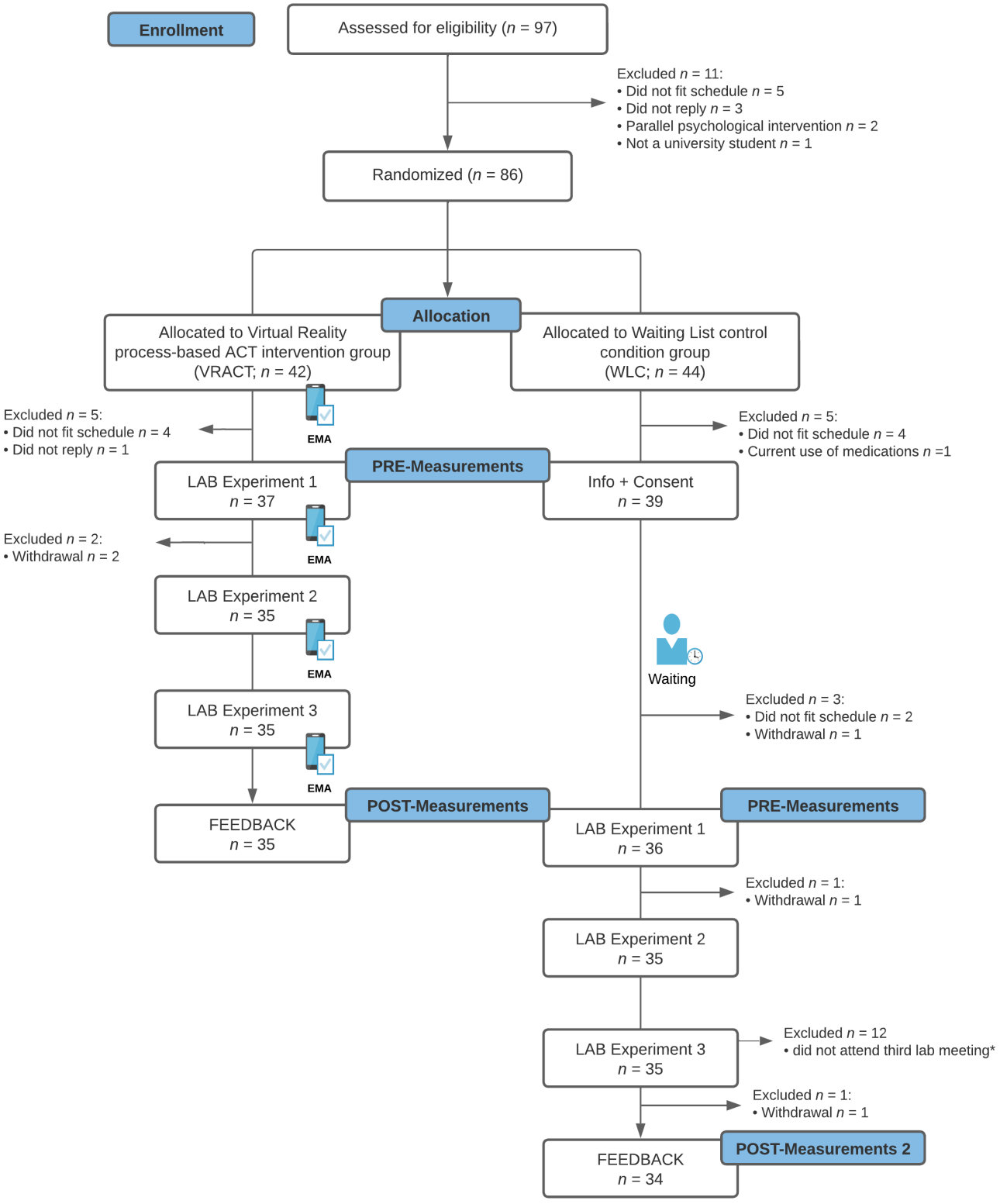


FIGURE 7 Flowchart depicting the protocol of Studies I, II, and III

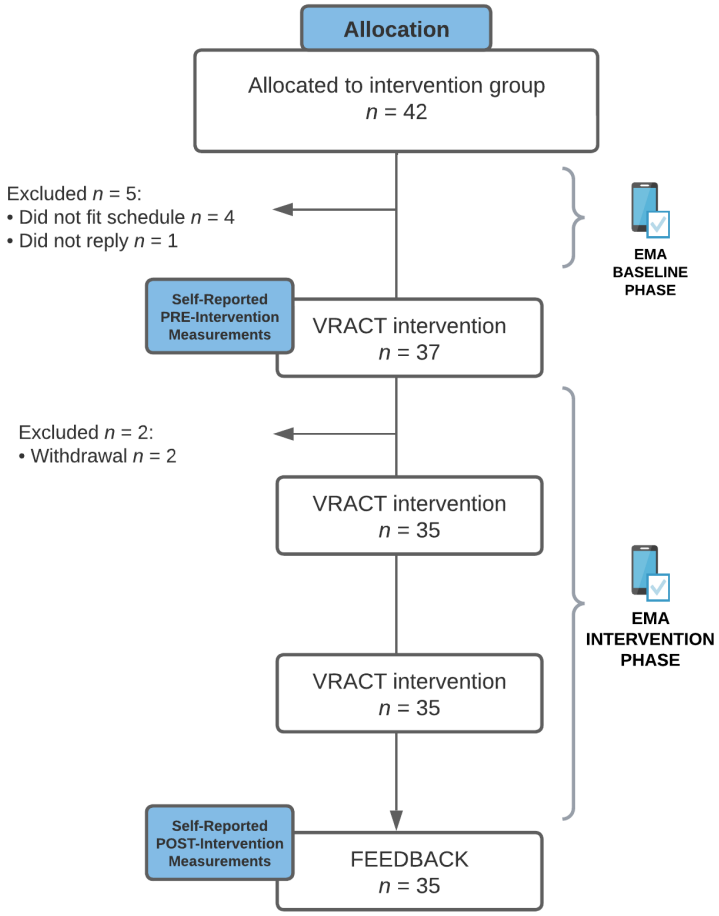


FIGURE 8 Flowchart depicting the detailed protocol of Study III

2.2 Procedure

The initial procedures for **Study I**, **II**, and **III** were the same and are described below.

The participants were individually welcomed to the lab room at the Department of Psychology by two researchers and instructed to read carefully and fill in documents pertaining to the nature of the study, informed consent, privacy notice consent, and personal background information. They were also informed that a camera was present in the room and was on, and that it was transmitting a real-time video to the researcher's monitor only for safety reasons. It was clarified that the camera was not recording. Throughout the session, the researchers and participants were in the same room but were separated by curtains to ensure the participants' privacy. After that, three electrodes were placed on the participants' bodies to measure heart rate, while two additional electrodes were placed on their non-dominant hands to measure skin

conductance. The researchers then provided a tablet to the students and asked them to fill out self-reported pre-measurement surveys. The self-reported questionnaires included measures of anxiety in social interaction (Social Interaction Anxiety Scale [SIAS]; Mattick & Clarke, 1998), anxiety while communicating with others (The Personal Report of Communication Apprehension [PRCA-24]; McCroskey, 1982), subjective anxiety reported visually (visual analog scale [VAS]), perceived stress (Perceived Stress Scale [PSS]; Cohen et al., 1983; Cohen & Williamson, 1988), well-being (Mental Health Continuum [MHC-SF]; Keyes, 2009), fear of negative evaluation (Fear of Negative Evaluation Scale-Brief Form [BFNE]; Leary, 1983), psychological flexibility (Comprehensive Assessment of ACT Processes [CompACT]; Francis et al., 2016), and self-compassion (the Self Compassion Scale-Short Form [SCS-SF]; Raes et al., 2011). See Table 3 for the list of self-reported questionnaires.

In **Studies II and III**, in addition to the procedure described above, the researcher continued the procedure by measuring the participants' interpupillary distance, adjusting the lens distance accordingly, and familiarizing the participants with the VR headset. The researchers asked if the participant had experienced VR in the past and adjusted the VR HMD to ensure that the participant was not experiencing any physical pain. The intervention video to be played via the HMD had already been prepared on the PC. Before the video was started, the initial frame only displayed a still image so that the participants could be instructed and the headset could be adjusted if required. Researchers instructed the participant about the possibility of moving their head in multiple directions to navigate their view through the VR scenario. If the image projected inside the headset was unclear, the headset's position and lenses were adjusted again to achieve the best possible resolution. Before the intervention was started, the participant was asked to wait for one minute to ensure the accuracy of physiological measurements even when the researchers moved behind the curtains. Once the VRACT intervention video began, the participant was instructed to notify the researchers if they were unable to hear the audio. The students watched and listened to the VR intervention scenario (which lasted for 20 to 25 min), and they were asked about their experience once the headset was removed at the end of the video. A tablet was then used to record the participants' answers to questions about how they felt while using VR. Once students had completing the short survey, they were prepared for and instructed regarding the following behavioral task: perform a speech in front of a virtual audience. The researchers voiced the same instructions that participants would hear then again via an audio prompt when immersed in a neutral scene in VR. This was done to ensure that the participants were prepared and not surprised or frightened in the VR scenario. The instructions were followed by a three-minute period of silence during which the participants were asked to come up with ideas for the speech. The participants were asked to speak for 10 min about themselves, their strengths, and their weaknesses. They were reminded of the importance of the task overall and their goal of reaching the 10-min mark. They were also reminded that they had the option to say "I want to stop" at any point

if they felt too anxious or unwilling to continue the speech. Three minutes later, they received a voice prompt that they could begin speaking, and a recorded virtual audience also appeared simultaneously in the VR scenario. The headset was taken off after the speech was over, and the participants used the tablets to complete the same questionnaires they had filled earlier in the session. In cases where the speech was interrupted, the researchers made sure to first understand the reason for the interruption (e.g., boredom and severe anxiety). When extreme anxiety was noticed, the researchers frequently advised the participant to take a few deep breaths before discussing their willingness to continue with the research, and they were also given the option of getting in touch with the supervisor of the research, an experienced psychotherapist, if required. The entire procedure consisted of three face-to-face sessions held once a week for three weeks (Lab Experiments 1, 2, and 3 in Figure 7) that totaled to nearly 2 hours, or 110 minutes, of VRACT intervention. Eventually, a feedback session was set up to collect post-intervention measurement data and additional subjective data regarding the participants' experience in the study. More details of the procedure can be seen above in Figure 7.

Study III included the additional aspect of EMA surveys compared to Study II. That is, the participants who first received VRACT (n = 37, see Figure 8) completed EMA surveys using their cell phones during their daily lives. A week before the first in-person session, students received instructions on downloading the Metric Wire application from the App Store or Play Store. As a result of the limited duration of the study, the surveys were sent out twice a day to increase the likelihood that data was collected from a range of activities and times throughout the individual's daily life. The surveys appeared at random times at least four hours apart, and they included five brief questions related to satisfaction with life, current activity, and contextual psychological flexibility. The baseline phase before the intervention lasted for seven days, so the total number of filled-in surveys was 14 for participants who responded to all phone notifications. Later, each student was also asked to complete surveys over the parallel three-week intervention period. This amounted to 42 EMA responses for participants who completed all the surveys in the intervention phase.

2.3 Lab Room and Technical Equipment

Various pieces of equipment were arranged in the lab room of the Department of Psychology, where the in-person sessions were conducted (Figures 9 and 10). The participant sat in the room on a specially designed armchair for resting arms with the physiological measurement devices attached to them. A small table in front of the chair held papers and a pen, a Samsung tablet, a VR HMD device, and a Canon LEGRIA HF G30 camera (which was placed at the far end). The camera did not record but, instead, transmitted a real-time video to a researcher's computer screen via an HDMI cable. This was used to monitor the participants' movements and reactions during the intervention to ensure their safety. While

the table was used to place objects, the tablet was used to collected self-reported online questionnaires using the Webropol website. On the participant's right, there was a curtain that separated them from the researcher. This curtain was kept closed while they were immersed in VR. A Brain Vision QuickAmp amplifier with five long cables running out of it was placed on a small shelf behind the participant's chair. Three of the cables were used to record electrocardiogram activity, while the other two measured electrodermal activity. The amplifier was connected to a computer on the other side of the space, which was only used to run the Brain Vision Recorder program for real-time physiological activity monitoring. Brain Vision used a sampling frequency of 1000 Hz, and it smoothed the signals by removing readings above 400 Hz and below 0.5 Hz from the heart rate and skin conductance analyses.

FIGURE 9 Lab and participants' setting

FIGURE 10 Lab and participants' setting

The tethered VR headset used in the research was the HTC Vive PRO. It had a resolution of 2,880 x 1600 (615 PPI), a refresh rate of 90 Hz, a field of view of 110 degrees, and integrated spatial audio. Two pole-mounted base tracking stations allowed head movements and headset tracking. One station was placed in front of the participant at the end of the table, and the other was placed behind. During the intervention, 180-degree stereoscopic 3D videos were used to create the VR content. The research team filmed the videos beforehand at the university campus with the Insta360 Pro 2 professional VR camera, which has six fisheye lenses and can record professional 180° and 360° 3D recordings at 7680 x 7680 (8K) @30 fps. The Insta360 Pro 2 can simultaneously capture two 8K videos with integrated stabilization and combine them to produce an immersive experience. One neutral scene was recorded in an empty room at the Department of Psychology, and a second neutral nature scene was recorded at the lake of Jyväskylä, Jyväsjärvi. The social scenes included students and staff members of the University of Jyväskylä. In scenes with only one or three participants, the actors were instructed to stare at the camera for the duration of the recording. In the two social scenes with an audience, however, a lecture and a student presentation were occurring behind the recording camera. The videos were then stitched together in a 3D 180° format and edited with the Insta360 stitcher software and Adobe Premiere Pro. A dedicated computer was used to connect the VR headset and display the locally stored videos via the Steam VR platform and the Virtual Desktop media player application.

2.4 Measures

Several types of measures were used in the studies: self-reported questionnaires, EMA measures, and behavioral measures. The measures used in each study and the time of their assessment are described in more detail below and in Table 3.

Several self-reported questionnaires were used in the studies. The primary outcome measures included Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) and Personal Report of Communication Apprehension (PRCA-24; McCroskey, 1982), which were used to assess social interaction anxiety and communication anxiety, respectively.

The secondary outcome measures included the Mental Health Continuum, Short Form (MHC-SF; Keyes, 2009) for evaluating well-being, the Perceived Stress Scale (PSS; Cohen et al., 1983; Cohen & Williamson, 1988) for evaluating the perception of stress, and Visual Analogue Scales (VAS) for assessing perceived anxiety related to giving a speech. The VAS scales measured subjective negative feelings related to speaking or giving a speech and ranged on a Likert scale from 0 to 10: a) "how uncomfortable do you feel about giving a speech?" (0 = not uncomfortable at all, 10 = very uncomfortable); b) "how stressful do you feel about giving a speech?" (0 = not stressful at all, 10 = very stressful); c) "how nervous does speaking make you?" (0 = not nervous at all, 10 = very nervous); d) "how willing are you to give a speech?" (0 = not willing at all, 10 = very willing).

The process measures included Comprehensive Assessment of Acceptance and Commitment Therapy Processes (CompACT; Francis et al., 2016) for assessing psychological flexibility and its sub-processes (openness to experiences, behavioral awareness, and valued actions). Openness to experience includes the processes of acceptance and defusion, behavioral awareness refers to present moment and self-as-context, and valued action to values and committed actions (Francis et al., 2016). The Self-Compassion Scale, Short Form (SCS-SF; Raes et al., 2011) was used for evaluating self-compassion and its sub-components (self-kindness, common humanity, and mindfulness vs. self-judgment, isolation, and over-identification). Self-Kindness involves showing concern for our distress, instead of being overly critical towards ourselves (Self-judgement). Common humanity helps us to feel connected to rather than separate from others (Isolation). Mindfulness refers to recognizing that our negative thoughts and feelings are just thoughts and feelings, which helps us to be less absorbed by them (Over-identification) (Neff, 2023). BFNE (Leary, 1983) was used for assessing the fear of being negatively evaluated by other people.

The behavioral measures included a Behavioral Assessment Task (BAT; Gallego et al., 2020) to expose participants to a fearful, controlled situation. In this task, participants faced a VR audience for 10 minutes to discuss their strengths and weaknesses. BAT was used to indirectly measure distress tolerance based on the duration of the speech and avoidance levels based on the number of times students decided to abandon the task before its completion.

The Ecological Momentary Assessment (EMA) measure was prompted via the Metric Wire phone application, and it included five questions related to participants' contextual processes, feelings, and activities. For 7 consecutive days during the baseline period and 21 consecutive days during the intervention period, each participant received two phone survey notifications at random times of the day. This corresponded to a maximum of 56 responses. The first question of the brief survey inquired about current life satisfaction, while the second one asked students to select from a list of activities what they were doing immediately before responding to the survey. The Brief Acceptance Measure (BAM; Assmann et al., 2018) was used with the last three EMA questions to measure daily psychological flexibility and its sub-processes openness to experience, behavioral awareness, and valued actions. It has been suggested that BAM and CompACT are correlated (Hulbert-Williams et al., 2019) and that they measure a similar component, that is, psychological flexibility.

Furthermore, during the lab sessions, feasibility and usability testing of VR was assessed using Likert scales from 0 to 10: a) how realistic did the situation feel when viewed in VR?" (0 = not realistic at all, 10 = very realistic), b) "did you feel nauseous while watching VR?" (0 = not at all, 10 = very much), c) "did you feel uncomfortable while wearing VR" (0 = not at all, 10 = very much). In addition, at the final feedback meeting, multiple Likert scales from 0 (not at all/nothing) to 10 (very much) were used to assess the overall satisfaction with the study. The study's benefit was evaluated, along with the participants' use of the intervention's skills and any impact it may have had on their behavior in

social situations. They were asked if they had learned anything in general and if their anxiety had decreased during the study. They were also asked if they thought the exercises would be useful for future presentations or if they would recommend this program to students who suffer from performance anxiety. Then, only students who completed the daily mobile assessment were asked if they learned anything from using the mobile surveys. Moreover, a final optional open-ended question was used to assess additional overall satisfaction.

TABLE 3 Measures used in Studies I, II, and III

Measures	Study I	Study II	Study III	Time of assessment
Self-reported measures				
Social Interaction Anxiety Scale (SIAS): Social interaction anxiety	X	X	X	Study I: pre- measurement Study II: pre- and post-measurements Study III: measurement of clinically significant change
Personal Report of Communication Apprehension (PRCA-24): Communication anxiety	X	X	X	Study I: pre- measurement Study II: pre- and post-measurements Study III: measurement of clinically significant change
Comprehensive Assessment of Acceptance and Commitment Therapy Processes (CompACT): Psychological flexibility and its sub-processes openness to experiences, behavioral awareness, and valued actions	X	X	X	Study I: pre- measurement Study II: pre- and post-measurements Study III: pre-measurement
The Self-Compassion Scale, Short Form (SCS-SF): Self-compassion and its sub-components self-kindness (vs. self-judgement), common humanity (vs. isolation), and mindfulness (vs. over-identification	X	X		Study I: pre- measurement Study II: pre- and post-measurements
Visual Analog Scales (VAS): Subjective negative feelings related to speaking or giving a speech.	X	X		Study I: pre- measurement Study II: pre- and post-measurements
The Perceived Stress Scale (PSS): Perceived stress		X		Study II: pre- and post-measurement

continues

TABLE 3 continues

Measures	Study I	Study II	Study III	Time of assessment
Self-reported measures				
The Mental Health Continuum, Short Form (MHC-SF): Wellbeing		X		Study II: pre- and post-measurement
The Fear of Negative Evaluation Scale-Brief Form (BFNE): Fear of being negatively evaluated by others		X		Study II: pre- and post-measurement
Behavioral measures				
Behavioral Assessment Task (BAT): Avoidance and distress tolerance		X		Study II: post-measurement
Ecological momentary assessment (EMA)				
Life satisfaction			X	Study III: repeated measures in the baseline and intervention phases
Current activity			X	Study III: repeated measures in the baseline and intervention phases
The Brief Acceptance Measure (BAM): Psychological flexibility and its sub-processes			X	Study III: repeated measures in the baseline and intervention phases
Feasibility and satisfaction with the study				
Feasibility and usability testing		X		Study II: lab sessions
Satisfaction with the study		X		Study II: post-measurement

2.5 Intervention

In **Studies II** and **III**, participants in the lab underwent a VRACT intervention while being exposed to different virtual environments. Students in the first randomized intervention group received the VR intervention right away, while those in the WLC group had to wait for three weeks before they were offered the same intervention.

2.5.1 VR intervention

The VRACT process-based intervention consisted of a long exercise in which participants listened to an ACT-based exercise while watching various virtual scenarios and a short active exercise in which they practiced their social interaction and public speaking skills while speaking to a virtual audience (BAT). The first exercise lasted between 20 and 25 minutes each time. It only differed

slightly between sessions one and three, and became more personal as the sessions progressed. Instead, the BAT exercise (speaking to a virtual audience) remained the same across all three lab sessions. The exercises were based on research from our earlier studies (Gallego, 2021) that identified psychological flexibility processes linked to anxiety about public speaking, as well as research on the effects of ACT-based exposure in a single session. Openness-to-experience exercises, behavioral awareness exercises, hierarchy-based exercises ("Your thoughts and emotions are a part of you"), and distinction-based exercises ("You are different from your thoughts") were, therefore, used throughout the VR intervention.

Overall, the exercise included a description of the ACT model ("The aim is not to alter or remove unpleasant thoughts, but instead, the aim is to alter the effect of the emotions and thoughts"), instructions for being present and noticing ("You are able to notice that you have thoughts and emotions when you are with other people"), and instructions about having an accepting attitude toward thoughts, emotions, and physical sensations ("When you notice thoughts and emotions, be open to what you experience"). The audio recording instructed the participants to pay attention to the impact and influence of their thoughts ("Observe the influence that these thoughts have on you") and emphasized that they can choose their actions independently of their thoughts and emotions ("You are able to choose what you do independent of your thoughts and emotions"). The audio instructions also applied the distinction ("You are different from your thoughts") and hierarchical frames ("Your thoughts and emotions are part of you") (Gorinelli et al., 2023).

Once the VR headset was in place and ready to display the exercise, the participants' immersion experience started with an empty room scenario in which an audio recording in a woman's voice explained the instructions and purpose of the exercise, as well as asked them to practice focusing on their own breathing and the present moment. Then, a natural setting appeared, and with the aid of audio-recorded metaphors, the students were able to concentrate on their own thoughts, feelings, and sensations while maintaining their rhythmic breathing. There were three additional gradual social exposure scenarios that followed this: one person, three people, and an audience. In the social environments, the students were able to learn new skills on how to be with their thoughts, feelings, and sensations. After a brief break from the long exercise, the short BAT exposure task (speaking to a virtual audience) was started again with the empty room scenario. The participant was able to put on the VR headset again and listen to the instructions for the next task, which required them to give a speech about their strengths and weaknesses for up to 10 minutes. After receiving the instructions, they had three minutes to reflect before they could begin the speech. After the 3 minutes of reflection, a virtual audience appeared, and they were asked to begin speaking.

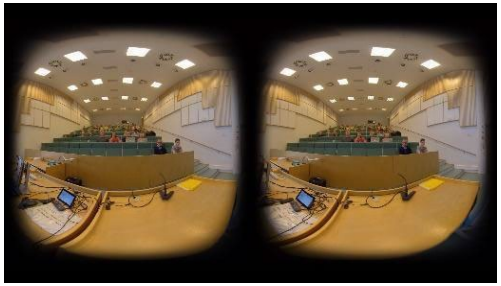
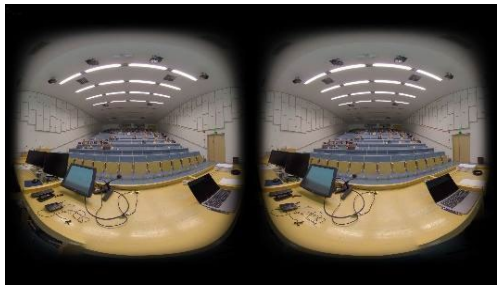
More details of the VRACT intervention can be seen in Table 4 below (Gorinelli et al., 2023), and the full written script translated from Finnish to English can be found in Appendix 1.

2.5.2 Waiting list control group

Participants in the WLC group filled in the self-reported pre-measurements and were asked to wait for three weeks before they were offered the VRACT intervention. Before starting the VRACT intervention, they filled in self-reported measures that acted as a post-measurement of the control period and as a pre-measurement of the VR intervention. The aim behind having the WLC group was to evaluate the impact of other (confounding) variables based on changes during the waiting period (e.g., the impact of self-reported measures). The VRACT intervention was identical to the one provided for the first intervention group, with the only difference being that students in this group did not do the EMA surveys outside of the lab sessions.

TABLE 4 Structure and content of the VR -based ACT intervention

Environment Scenes	Themes
1 – Baseline 	Time: session 1 = 3.00 minutes; session 2 = 3.48 minutes; session 3 = 3.10 minutes **Instructions, aim, and importance of the exercise; place the focus on breathing and the present moment** *Purpose*: "The purpose of these exercises is to teach a new perspective on thoughts and feelings." […] "In order to achieve this, we need to learn certain skills to deal with these thoughts and feelings." […] "Note that this exercise will teach you the principles and general methods that you can use and practice later on as well." *Noticing*: "Just as you can notice when breathing is taking place or what you can feel on your shoulders, you can also notice what thoughts and feelings you have and how you choose to treat them." This scene did not include social interaction.
2 – Neutral scene 	Time: session 1 = 4.10 minutes; session 2 = 5.27 minutes; session 3 = 5.30 minutes **Thoughts and feelings as passing clouds, breathing is a part of you—sky metaphor** *Metaphor*: "Like the clouds in the sky, your breathing comes and goes. Similarly, your thoughts and feelings can come and go. You can notice what thoughts and feelings you have here and now in the same way you can notice and observe the clouds in the sky." *Framing*: "Note that clouds are different from the sky; clouds move along the sky. In the same way, you can notice that your thoughts are different from you and that your thoughts come and go in you." This scene did not include social interactions.
3 – One person 	Time: session 1 = 5.05 minutes; session 2 = 5.11 minutes; session 3 = 6.20 minutes **Thoughts and feelings in individual social interaction** *Acceptance*: "Look at the person in front of you. You might notice feelings of anxiety, unsure of yourself." […] "Just notice thoughts and emotions. Practice being open and accepting" […] With unpleasant feelings, you can still look at another person." This scenario comprised two versions to counterbalance the gender difference.

Environment Scenes	Themes
4 – Three people 	Time: session 1 = 4.05 minutes; session 2 = 3.45 minutes; session 3 = 4.25 minutes **Thoughts and feelings in group social interactions** *Noticing*: "See those people in front of you…." […] "What thoughts and feelings do you notice right now…" *Defusion and acceptance*: "You are not your thoughts, but you have thoughts. Note that we can distinguish two things here: you and your thoughts in this situation, at this moment. In another situation, you may have other thoughts." […] "Thoughts and emotions come and go." […] "be open, accepting what you experience…" This scenario comprised two versions to counterbalance the gender difference.
5 – Lecture hall 	Time: session 1 = 5.09 minutes; session 2 = 4.09 minutes; session 3 = 4.45 minutes **Thoughts and feelings in front of an audience** *Noticing and accepting:* "You are in front of a group of people. Imagine that you have to say something or hold a presentation." […] "Notice what thoughts and feelings you experience right now, and be open…." […] "View your thoughts and feelings as you look at the clouds in the sky" […] "You can continue looking at the listeners with all the feelings and thoughts you have in this moment." *Choosing value-based actions*: "Now, look at the people sitting. You can choose to look at them." […] "You are able to look at them independent of what you are feeling or thinking." […] "Every single choice and action take you towards a greater goal or destination." […] "Practice these skills over the next week."
6 – Behavioral task (BAT) – Lecture hall 	**Instructions (1 minute), 3-minute baseline + 10-minute speech** The participants were instructed to prepare a 10-min speech about their strengths and weaknesses. They had a baseline of 3 minutes in the empty room to think about the topic. Following this, a virtual audience, recorded from a university lecture, appeared, and they had to start their speech. They could stop at any time; however, the instructions contained a specific framing to increase motivational factors and encourage the students to speak for as long as possible ("Remember, just engaging in the process of the task is the most important part of your participation"; Eswara Murthy et al., 2019, p. 36).

2.6 Statistical Analysis

Most of the statistical analyses included in the studies were performed using IBM SPSS Statistics 26 and Mplus (version 8; Muthén & Muthén, 2017). In Table 5, a summary of the variables and statistical analyses employed is provided.

In **Studies I and II,** a pre-assessment analysis was performed to identify the number of students with social interaction anxiety (SIAS), communication anxiety (PRCA-24), as well as subjective stress and nervousness while giving a speech (VAS). For SIAS, a cutoff score of 34 or higher was considered to indicate social anxiety, whereas for PRCA-24, a cutoff score greater than 80 was considered to indicate a high level of communication anxiety. The analysis demonstrated that, even though we did not include a clinical sample of participants, a significant number of students experienced social interaction and communication anxiety.

In **Study I**, we first investigated the distribution of the variables by Shapiro-Wilk's test and a visual inspection of histograms, normal Q-Q plots, and box plots. Following this, the primary analyses concentrated on correlations and regressions. Correlation analyses were used to explore the associations between outcome measures (SIAS and PRCA-24) and process measures (CompACT with subscales and SCS-SF with subscales). For analyzing data that were not normally distributed, nonparametric Spearman's correlations were used rather than Pearson's correlations. Here, we defined low correlation by an r value in the range of 0.10–0.29; moderate correlation, by an r value of 0.30–0.49; and high correlation, by an r value of 0.50–1 (Cohen, 1992; Kraemer et al., 2003). Using regression analyses, we also investigated which components of psychological flexibility and self-compassion were particularly involved in social interaction and communication anxiety. Here, only process variables that significantly correlated with SIAS or PRCA-24 were used. Finally, we calculated tolerance and variance inflation factors (Kutner et al., 2004) to determine whether multicollinearity posed a problem.

In **Study II**, using the *t*- and chi-square tests, we first determined if there were any differences at the baseline level between the intervention group and the WLC group. Additional *t*-tests were used to calculate differences in distress tolerance between sessions one and three. The intervention effect or interaction effect determined by the Wald test and significance values were computed with structural equal modeling and latent change scores using the full information maximum likelihood estimation method in Mplus. Latent change score models were used to determine whether there were differences between the VRACT intervention and WLC groups with regard to changes based on the pre- and post-measurements, while structural equal modeling was used to analyze within-group changes in the WLC group over time, including before and after the waiting period and after participation in the intervention. Missing data were assumed to be missing at random. Therefore, all randomized participants who completed the pre-measurements were included in the analyses. Effect sizes (ESs)

were reported using Cohen's *d*. The corrected between-group ES was determined by dividing the mean difference in change between the intervention and WLC group by the mean standard deviation of the pre-measurements, whereas within-group ES (which indicated the size of change from pre- to post-measurement in each group) was calculated by dividing the mean difference in change between the pre- and post-measurements by the mean standard deviation of the measurements. A within- and between-group ES of 0.20 was interpreted as small; an ES of 0.50 was considered moderate; and an ES above 0.80 was interpreted as large (Cohen & Williamson, 1988). Lastly, using the two-stage Jacobson-Truax method (Jacobson & Truax, 1991) for assessing an individual's recovery (Lambert & Ogles, 2009; McGlinchey et al., 2002), we determined clinically significant change in the primary outcome measures (SIAS and PRCA-24). The first step is to calculate the reliable change index (RCI) in order to determine if the change in the participants' scores is due to measurement unreliability, and the second step is to calculate a cut-off score to indicate a point that each participant with social interaction or communication anxiety must cross in order to shift from a dysfunctional to a functional distribution. For SIAS, the functional normative sample from Heimberg et al. (1992) and the non-functional sample from the pre-assessment in the current study were used to calculate a weighted midpoint between the means of a functional and dysfunctional population (Cut-off C). Due to the lack of a functional normative sample for PRCA-24, the non-functional pre-assessment sample of this study was used to calculate a point at two standard deviations beyond the range of the mean at pre-assessment (Cut-off A). Based on these cut-off points, individuals were classified as recovered (those who met both the cutoff and the RCI criteria), improved (those who met the RCI criteria but not the cutoff), unchanged (those who met neither criteria), or deteriorated (those who met the RCI criteria for worsening of the condition).

In **Study III**, the difference in compliance between the baseline and intervention phase periods was calculated by observing the number of completed surveys for each participant. SPSS was used to analyze the change in EMA data over time from baseline to the intervention phase for the entire sample using generalized estimating equations (GEEs; Zeger et al., 1988). GEE analysis was conducted using an autoregressive AR (1) matrix structure to obtain more accurate estimates and determine the within-subject dependencies for potential autoregressive effects on the subsequent survey. Additional SCD analyses were conducted on a subsample of participants with at least 50% compliance who reported a clinically significant change after receiving the VR intervention. This resulted in a subsample of eight students who were identified using pseudonyms. In accordance with the SCD protocol, we conducted two major analyses: visual inspection and baseline-corrected Tau. First, a SCD Package for R (Hussey, 2019) was used for visual analysis of the EMA data between phases A and B (baseline and intervention). This provided a standardized way to examine the data, with linear regression trend lines and the median absolute deviation. Following the visual analysis, a baseline-corrected Tau single-case analysis (Tarlow, 2017) was carried out to compare EMA ES from the baseline to

the intervention phase with the help of an online web-based calculator (Tarlow, 2016). Before quantitative comparison of ES between the baseline and intervention phases, the baseline trend was adjusted when a statistically significant trend was identified. An improvement in the outcome between the baseline and the intervention periods was considered to be indicated by baseline-corrected significant positive Tau ES values.

TABLE 5 Summary of the statistical analyses and variables in Studies I, II, and III

Study	Variables	Analysis
Study I	Outcome measures: Social interaction anxiety (SIAS), communication anxiety (PRCA-24), and visual analog scales (VAS) Process measures: Psychological flexibility total score (CompACT), openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), valued actions (CompACT-VA), self-compassion total score (SCS-SF), self-kindness (SCS-SF-SK), common humanity (SCS-SF-CH), mindfulness (SCS-SF-MI), self-judgment (SCS-SF-SJ), isolation (SCS-SF-IS), and over-identification (SCS-SF-OI)	Social interaction and communication anxiety screening (pre-assessment) Internal consistencies (Cronbach alpha, α) Shapiro-Wilk's test and visual inspections Correlation analyses (Pearson and Spearman) Regression analyses with the linear and stepwise methods Multicollinearity analyses based on tolerance and variance inflation factors

continues

TABLE 5 continues

Study	Variables	Analysis
Study II		Social interaction and communication anxiety screening (pre-assessment)
	Outcome measures: Social interaction anxiety (SIAS), communication anxiety total score (PRCA-24), general discussion anxiety (PRCA-24-GD), meeting anxiety (PRCA-24M), interpersonal communication anxiety (PRCA-24-IC), public speaking anxiety (PRCA-24-PS), perceived stress (PSS), wellbeing (MHC-SF), and visual analog scales (VAS)	*t* and $\chi 2$ tests for analysis of baseline differences between the groups Internal consistencies (Cronbach alpha, α) Means and standard deviations for pre- and post-measures (*M* and *SD*) Latent change score models of pre- and post-measures for between-group changes with the Wald test, p-values, within-group effect sizes (d_w), and between-group effect sizes (d_b)
	Process measures: Psychological flexibility total score (CompACT), openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), valued actions (CompACT-VA), self-compassion (SCS-SF), and fear of negative evaluation (BFNE)	Structural equation modeling of pre-, post-, and post-intervention measures for evaluating change in the WLC group with the Wald test, p-values, and within-group ES (d_w)
	Behavioral measures: Avoidance and distress tolerance (BAT)	Clinical significance change (Jacobson-Truax method) *t* tests for distress tolerance
Study III	EMA and processes measures: Contextual psychological flexibility (BAM), contextual openness to experiences (BAM-OE), contextual behavioral awareness (BAM-BA), contextual valued actions (BAM-VA), psychological flexibility total score (CompACT), openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), and valued actions (CompACT-VA	Internal consistencies (Cronbach alpha, α) Generalized estimating equations (GEEs) Compliance calculation SCD visual inspection Baseline-corrected Tau
	Anxiety measures: Social interaction anxiety (SIAS) and communication anxiety (PRCA-24)	

3 SUMMARY OF THE RESULTS

3.1 Study I

3.1.1 Psychological Processes in Social Interaction and Communication Anxiety among University Students: Role of Self-Compassion and Psychological Flexibility

The purpose of this study was to investigate the psychological processes involved in and related to the anxiety that university students experience during social interactions and communication. Furthermore, the aim was also to learn which specific components of psychological flexibility and self-compassion are most relevant and should be included when developing clinical interventions for dealing with social interaction and communication anxiety in university students.

Symptoms of anxiety. Even though our sample comprised university students and was not a clinical sample, all the participants reported at least mild communication anxiety (PRCA-24 score, >51). Overall, 60.5% of the students met the criteria for social interaction anxiety, while 69.7% met the criteria for high levels of communication anxiety (SIAS score, ≥ 34; PRCA-24 score, >80). The VAS scores were also high, indicating that students felt uncomfortable, stressed, and nervous when giving presentations.

Associations between psychological processes and anxiety measures. As expected, our anxiety outcome measures of social interaction anxiety (SIAS) and communication anxiety (PRCA-24) strongly correlated with each other ($r(74) = .71$, $p < .001$). In addition, as previously shown in the literature, our anxiety measures also correlated with psychological flexibility (CompACT total) and self-compassion (SCS-SF total). These results can be seen in Figure 11.

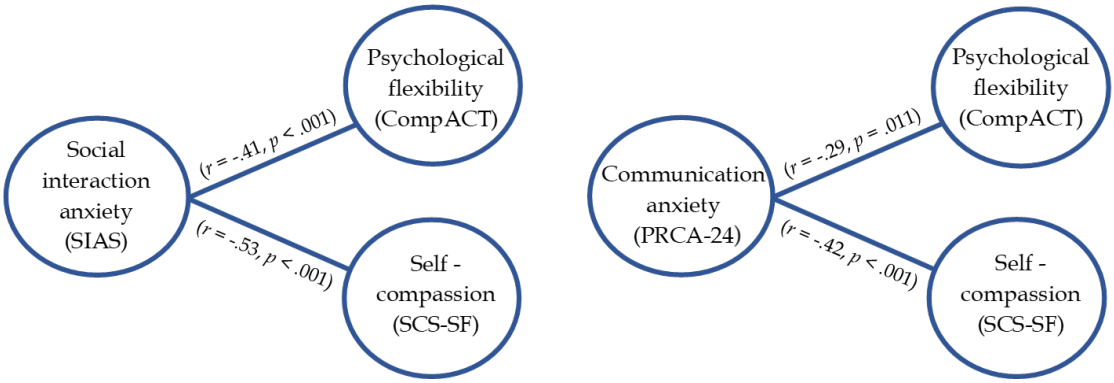


FIGURE 11 Correlations of social interaction and communication anxiety with psychological flexibility and self-compassion

With regard to the components of psychological flexibility, social interaction anxiety (SIAS) had a moderate negative correlation with openness to experiences (CompACT-OE; $r(74) = -.40$, $p < .001$) and a small negative correlation with valued actions (CompACT-VA; $r(74) = -.25$, $p = .029$), whereas PRCA-24 was correlated only with openness to experiences (CompACT-OE; $r(76) = -.24$, $p = .036$). The subprocess behavioral awareness (as measured by CompACT-BA) was not correlated with either social interaction anxiety or communication anxiety. A graphic representation of these results can be seen below in Figure 12.

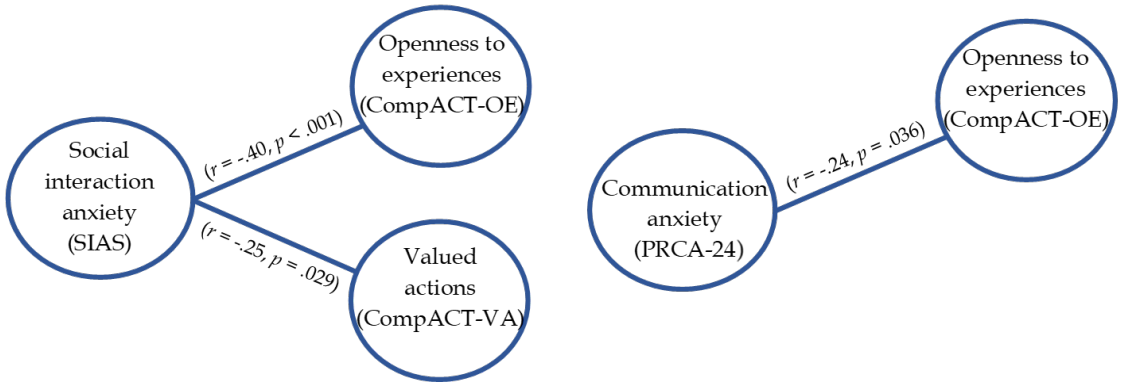


FIGURE 12 Correlations of social interaction and communication anxiety with the psychological sub-processes of psychological flexibility

With regard to the components of self-compassion (Figure 13), social interaction anxiety (SIAS) was positively and strongly correlated with self-judgment (SCS-SJ; $r(76) = .55$, $p < .001$) and over-identification (SCS-OI; $r(76) = .54$, $p < .001$), while it was moderately correlated with isolation (SCS-IS; $r(76) = .46$, $p < .001$). Communication anxiety (PRCA-24) was positively and moderately correlated with self-judgment (SCS-SJ; $r(76) = .39$, $p < .001$), over-identification (SCS-OI; $r(76) = .40$, $p < .001$), and isolation (SCS-IS; $r(76) = .32$, $p = .006$). The other aspects of self-compassion, such as self-kindness, common humanity, and mindfulness, were not correlated with either social anxiety (SIAS) or communication anxiety (PRCA-24).

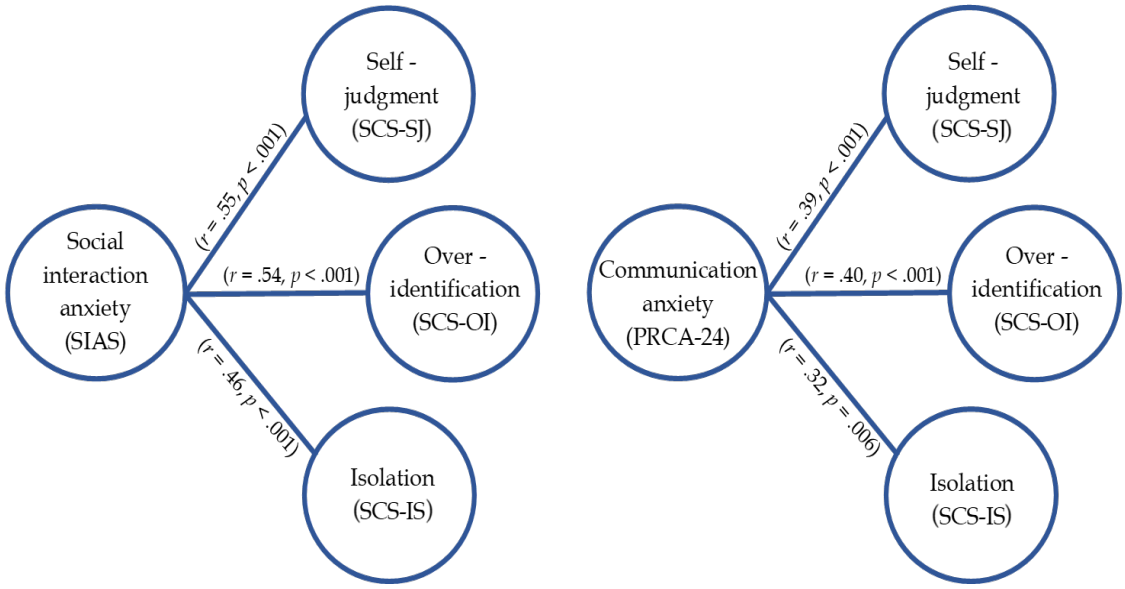


FIGURE 13 Correlations of social interaction and communication anxiety with the psychological sub-processes of self-compassion

Psychological processes as possible predictors. Regression analyses were conducted to investigate which psychological processes were especially implicated in and may predict social interaction and communication anxiety. We found that psychological flexibility accounted for 16% of the variance in social interaction anxiety (β = -.41, p < .001) and 8% of the variance in communication anxiety (β = -.29, p = .011). Self-compassion accounted for 28% of the variance in social interaction anxiety (β = -.53, p < .001) and 18% of the variance in communication anxiety (β = -.42, p < .001). When examining the components of both psychological flexibility and self-compassion, only those process variables that correlated significantly with social interaction anxiety (SIAS) and communication anxiety (PRCA-24) were included. Openness to experiences and valued actions were found to be potential significant predictors, as they individually explained 16% and 6% of the variance in social anxiety (SIAS), respectively. Further, openness to experiences explained 6% of the variance in communication anxiety (PRCA-24). When both openness to experiences and valued actions were examined together as predictors of social interaction anxiety (SIAS), however, only openness to experiences remained a significant predictor (Figure 14).

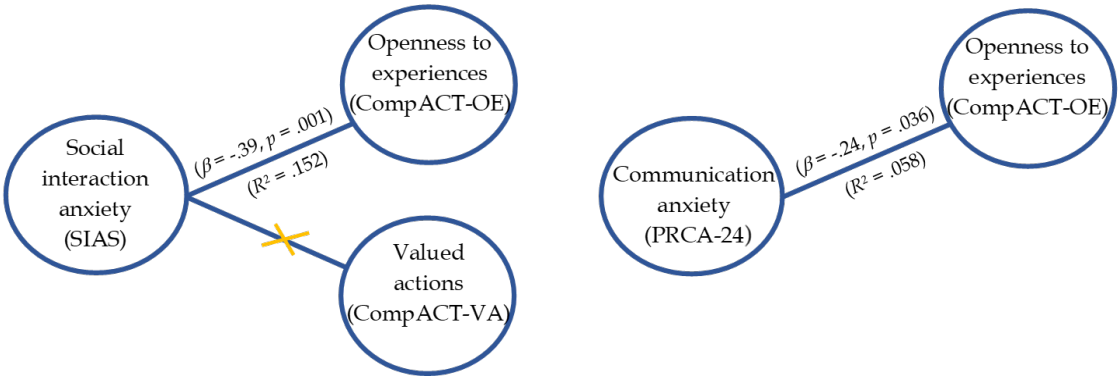


FIGURE 14 Sub-processes of psychological flexibility as potential predictors of both social interaction and communication anxiety

Self-judgment, over-identification, and isolation were identified as potential significant predictors, as they individually explained 32%, 31%, and 22% of the variance in social interaction anxiety (SIAS), respectively, and 16%, 20%, and 10% of the variance in communication anxiety (PRCA-24), respectively. When all the potential significant subprocesses of self-compassion were examined as predictors of social anxiety (SIAS), only self-judgment and over-identification remained significant. In contrast, when the significant potential predictors of communication anxiety (PRCA-24) were examined together, only the over-identification sub-process remained significant in the model. These results can be seen in Figure 15.

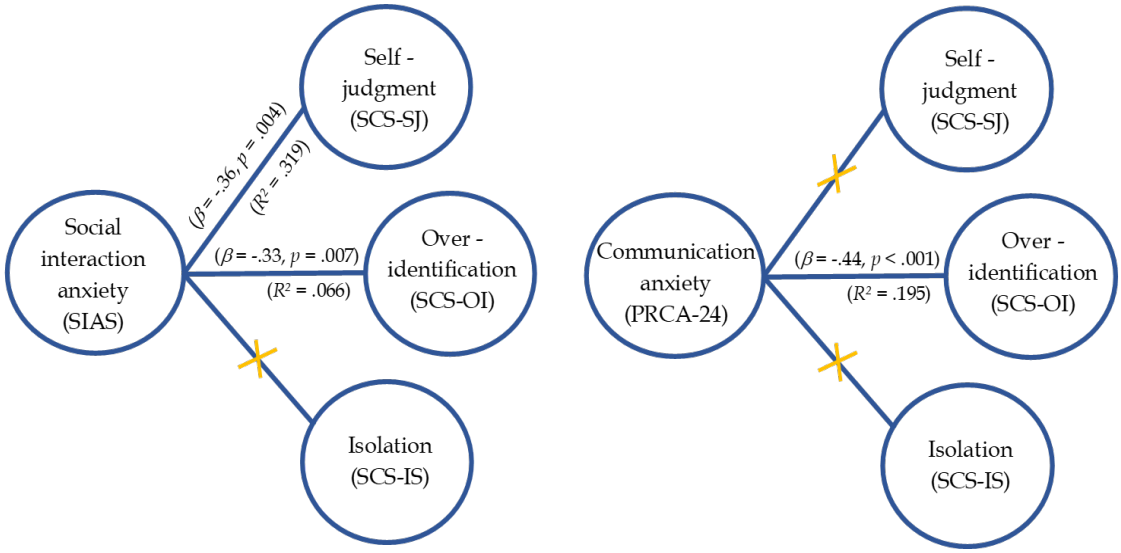


FIGURE 15 Sub-processes of self-compassion as potential predictors of both social interaction and communication anxiety

Finally, additional regression analyses were performed to identify the most significant potential predictors of psychological flexibility (CompACT) and self-compassion (SCS), with all subscales included (CompACT: openness to experiences, valued actions—only for SIAS; SCS: self-judgment, isolation, and over-identification). Over-identification and self-judgment persisted as the only significant predictors of social interaction anxiety (SIAS), potentially explaining 39% of the variance, while over-identification remained the only significant predictor of communication anxiety (PRCA-24), contributing to 20% of the variance.

Conclusions. Students with high levels of social interaction and communication anxiety reported having lower levels of both psychological flexibility and self-compassion. When the components of psychological flexibility were examined, the results indicated that openness to experiences was the most crucial process in social interaction and communication anxiety. In contrast, when the components of self-compassion were examined, the results indicated that both self-judgment and over-identification were key processes in social interaction anxiety, with over-identification being the most important element in communication anxiety.

3.2 Study II

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

This study aimed to determine whether exposure to a VR process-based ACT intervention could improve social anxiety, communication anxiety, and psychological flexibility among university students. We were particularly interested in observing how participants' social and public speaking anxiety would change after undergoing a brief, three-session VRACT intervention in comparison to a WLC condition. In this way, we also aimed to advance our understanding of how ACT can be delivered effectively using VR to improve mental health outcomes for university students with social anxiety.

Symptoms of anxiety and group differences. The results for the entire sample indicated that, despite the non-clinical nature of the sample, students still experienced significant anxiety in social and public speaking situations (based on the SIAS and PRCA-24 measures). Additional analyses showed that both groups reported having similar levels of anxiety, with a large percentage of students having social interaction anxiety (VRACT, 59.5%; WLC, 61.5%) and high communication anxiety (VRACT, 75.7%; WLC, 64.1%). Finally, there were no statistically significant differences between the intervention and control groups at the baseline level.

Intervention effects: intervention group vs. WLC group. Nearly all the measures revealed a significant interaction effect, demonstrating the superiority

of the intervention over the WLC condition. A graphic representation of the primary results is shown in Figure 16 below.

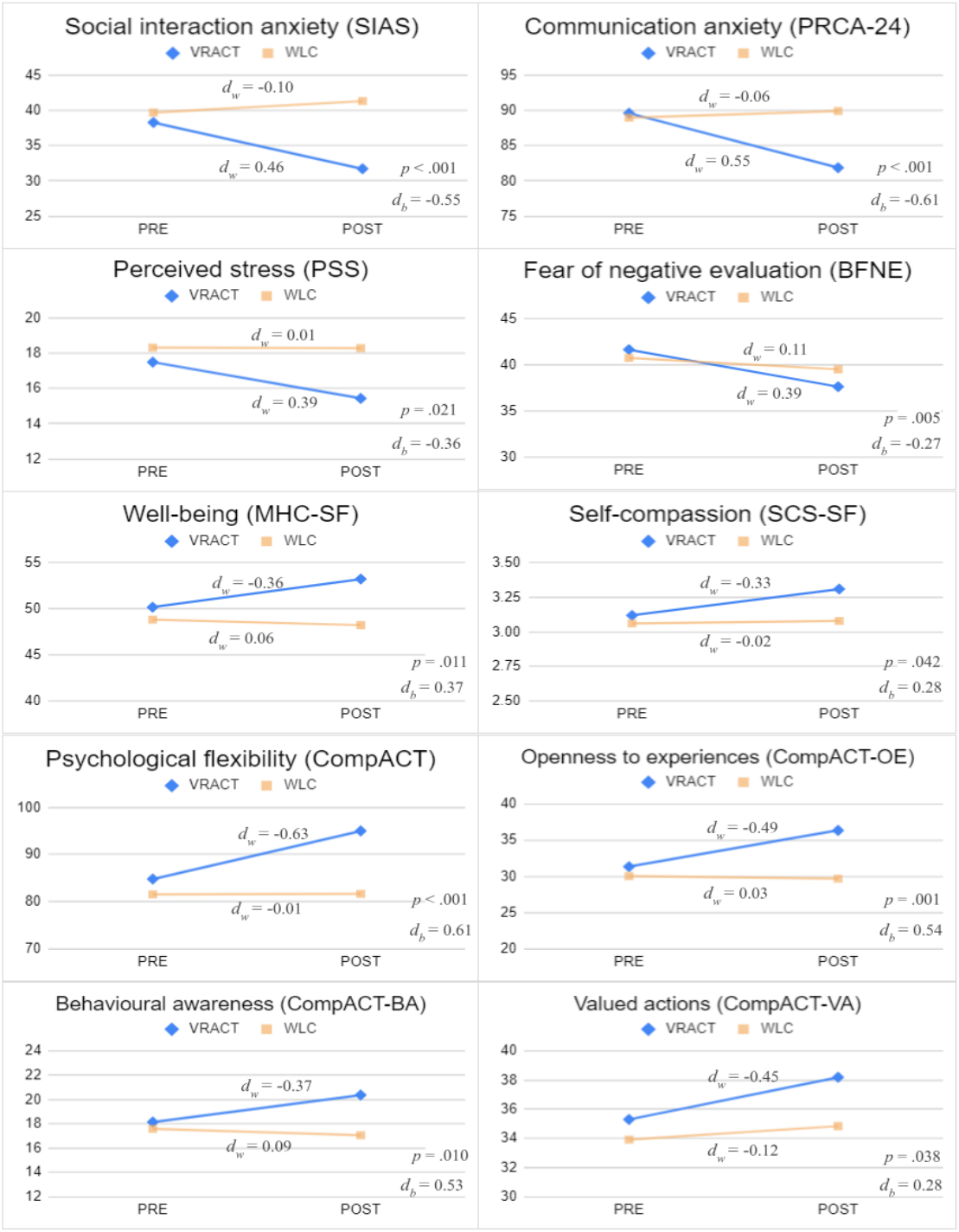


FIGURE 16 Pre- and post-measurement change in the intervention group and the waiting list control group along with within-group and between-group effect sizes Change was determined using the Wald test and p values

VRACT = virtual reality-based acceptance and commitment therapy
WLC = waiting list control
d_w = within-group effect size
d_b = between-group effect size

Social interaction anxiety (SIAS) and communication anxiety (PRCA-24) showed a bigger change in the VRACT intervention group than in the WLC group, with moderate between-group ESs (d_b = -0.55 and -0.61 for the VRACT and WLC groups, respectively). Examination of the subscales of PRCA-24 revealed a moderate between-group ES for general discussion (PRCA-24-GD, d_b = -0.50) and public speaking (PRCA-24-PS, d_b = -0.68) and a small between-group ES for meetings (PRCA-24-M, d_b = -0.37) and interpersonal communication (PRCA-24-IC, d_b = -0.26, which indicates a non-significant effect). The secondary outcome measures revealed a large between-group ES for the VAS scales related to feeling uncomfortable, stressful, and nervous about speaking (d_b = -1.17, -1.56, and -1.40, respectively), but a non-significant change in scale for willingness to give a speech. Additionally, small between-group ESs were reported for well-being (MHC-SF, d_b = 0.37) and perceived stress (PSS, d_b = -0.36). With regard to the process measures, between-group ESs were moderate for psychological flexibility (CompACT, d_b = 0.61) and small for self-compassion (SCS-SF, d_b = 0.28) and fear of being negatively evaluated (BFNE, d_b = -0.27), but the within-group ESs for both measures were larger in the intervention group than in the WLC groups. For the sub-processes of psychological flexibility, moderate between-group ESs were found for openness to experiences (CompACT-OE, d_b = 0.54) and behavioral awareness (CompACT-BA, d_b = 0.53), and a small between-group ES was found for valued action (CompACT-VA, d_b = 0.28). Within-group ES in the intervention group was moderate for psychological flexibility (CompACT, d_b = -0.63), close to moderate for its subscale openness to experiences (CompACT-OE, d_b = -0.49), and small for the remaining measures. In contrast, the WLC group had only very small ESs overall.

Intervention effects for the WLC group after receiving the intervention. The WLC group was offered the VRACT intervention after a three-week waiting period. The results (Figure 17) showed that students in the WLC group showed significant improvement in the three primary measures of social interaction anxiety (SIAS), communication anxiety (PRCA-24), and psychological flexibility (CompACT). However, the within-group ESs were small (d = 0.22–0.45).

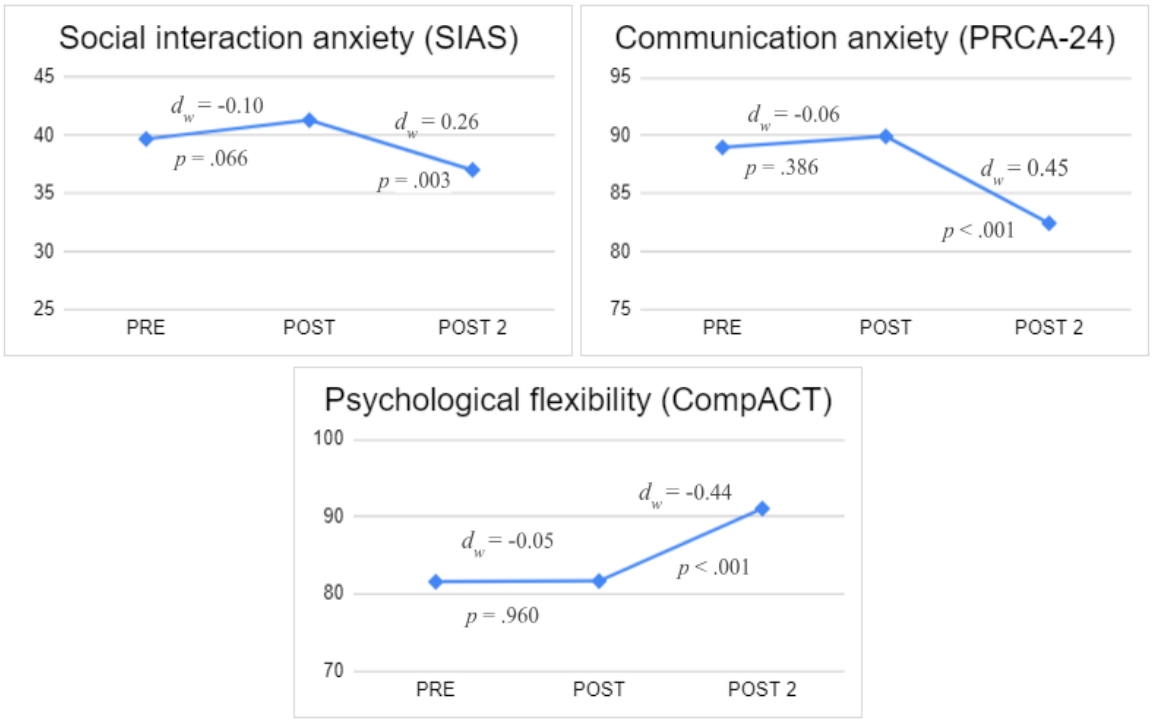


FIGURE 17 Change in primary measures in the waiting list control group during the waiting period and during the intervention period along with within-group effect sizes

d_w = within-group effect size
PRE = pre-waiting period measurement
POST = post-waiting period/pre-intervention measurement
POST2 = post-intervention measurement

Clinically significant change. Based on the primary outcome measures for social interaction anxiety and communication anxiety (SIAS and PRCA-24), the participants were grouped into four categories at the post-intervention assessment: (1) recovered, (2) improved, (3) unchanged, and (4) deteriorated. Due to dropouts and students who reported being below the cutoff scores, some participants in the VRACT group were excluded from the clinically significant change analyses (SIAS, n = 20; PRCA-24, n = 28). The results for social interaction anxiety change showed that 20% (n = 4) of the students had recovered, 5% (n = 1) had improved, and 75% (n = 15) were unchanged, while none of them had "deteriorated." Similarly, for communication anxiety, the results showed that 25% (n = 7) had recovered, 14.3% (n = 4) had improved, 57.1% (n = 16) were unchanged, and 3.6% (n = 1) had "deteriorated." Clinically significant change was also calculated for participants in the WLC group who attended the intervention after the waiting list period. In this group, 18.2% (n = 4) of the students had recovered and 4.5% (n = 1) had improved in terms of social interaction anxiety, while 12% (n = 3) had recovered and 24% (n = 6) had improved in terms of communication anxiety. In the WLC group, none of the participants were classified as "deteriorated" for either social interaction or communication anxiety.

Avoidance and distress tolerance. The time at which participants decided to stop the behavioral task (BAT) during the 10-minute presentation was used to calculate avoidance levels. Further, the amount of time spent in the task was used to assess distress tolerance. During the first session, 21.05% of the participants chose to end the task before the 10-minute mark; however, by the third lab session, only 10.53% chose to end the task. This demonstrates that avoidance decreased over time. The participants also showed an improvement over time for distress tolerance (n = 57; $t(56)$ = -3.204, p = .002), with an average of 8.49 minutes spent in the speech during the first lab session and an average of 9.38 minutes during the third lab session. Participants in both the VRACT and WLC (when attending the intervention) groups showed similar significant improvements in the behavioral task (VRACT, n = 35; $t(34)$ = -2.289, p = .028; WLC, n = 22; $t(21)$ = -2.212, p = .038).

Conclusions. The findings demonstrate that the VRACT intervention reduced self-reported social interaction and public speaking anxiety, fear of negative evaluation, and stress, and increased well-being, psychological flexibility, and self-compassion. These results were compared to those of a WLC group, which did not show any changes during the waiting period but showed similar improvement, although to a lesser extent, after participating in the same intervention. Moreover, investigation of clinically significant change provided evidence that several students recovered from or improved clinically from social interaction anxiety and communication anxiety after participating in the intervention study. Finally, avoidance and distress tolerance were found to be positively affected. Overall, this study makes a significant contribution by demonstrating how VR can be used to successfully implement and deliver ACT to improve mental health outcomes among university students with social anxiety.

3.3 Study III

3.3.1 The impact of virtual reality-based acceptance and commitment training on psychological flexibility in everyday contexts: An ecological momentary assessment study

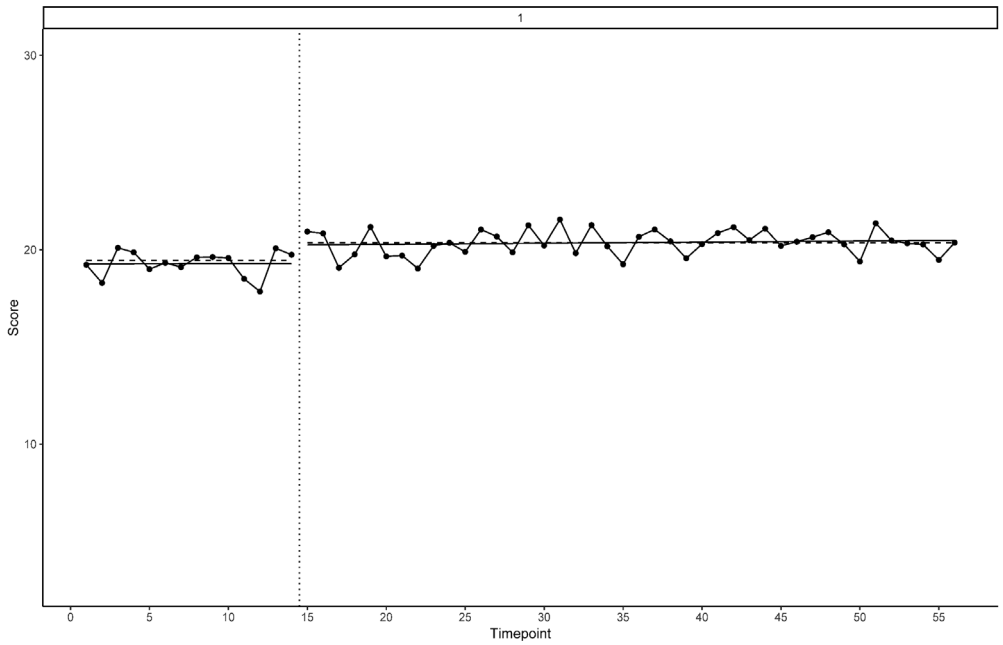
Study II revealed significant group-level changes in psychological flexibility as a result of the VRACT intervention based on pre- and post-intervention measurements (using the CompACT scale).

The purpose of the third study was to expand the investigation on the efficacy of applying VR to ACT by observing psychological processes of change (changes in psychological flexibility) in daily contexts through EMA. The second aim was to investigate individual changes in psychological flexibility during the VRACT intervention. More precisely, the aim was to investigate individual changes in psychological flexibility skills among students who show clinically significant improvements in social interaction and communication anxiety. The

second aim was achieved with SCD analyses, a method to observe the change of single participants over time.

Compliance. When participants entered data twice a day for 7 days during the baseline period and twice a day for 21 days during the intervention period, compliance was considered to be 100%. Baseline compliance averaged 77.41% (n = 37; an average of 10.84 responses out a possible total of 14), while compliance during the intervention phase averaged 73.68% (n = 36; an average of 30.94 responses out a possible total of 42). This was consistent with the average rate of EMA compliance reported in other studies, which reported an overall rate of 75.06% (Jones et al., 2019).

VRACT intervention effect: EMA over time. When the entire sample (n = 37) was examined, it was observed that the participants' psychological flexibility did not increase during the baseline phase. In contrast, it increased after the first VRACT session and remained at high levels throughout the intervention phase, as shown in Figure 18.



Note. The x-axis represents EMA responses over time, while the y-axis represents the total score of psychological flexibility. The vertical dotted line marks the baseline phase on the left and the intervention phase on the right. The horizontal dashed line represents the median value for each phase.

FIGURE 18 Graphical visualization of the effect of the VRACT intervention on psychological flexibility between the baseline and intervention phase

GEE analysis (n = 37; Zeger et al., 1988) showed statistically significant time interactions, and therefore an increase over time between baseline and intervention phases, for the BAM total score (p < .001) and the scores for its sub-processes openness to experiences (p = .012), behavioral awareness (p = .018), and

value actions (p = .013) between the baseline and intervention phases (Table 6). Life satisfaction, on the other hand, showed no significant interaction.

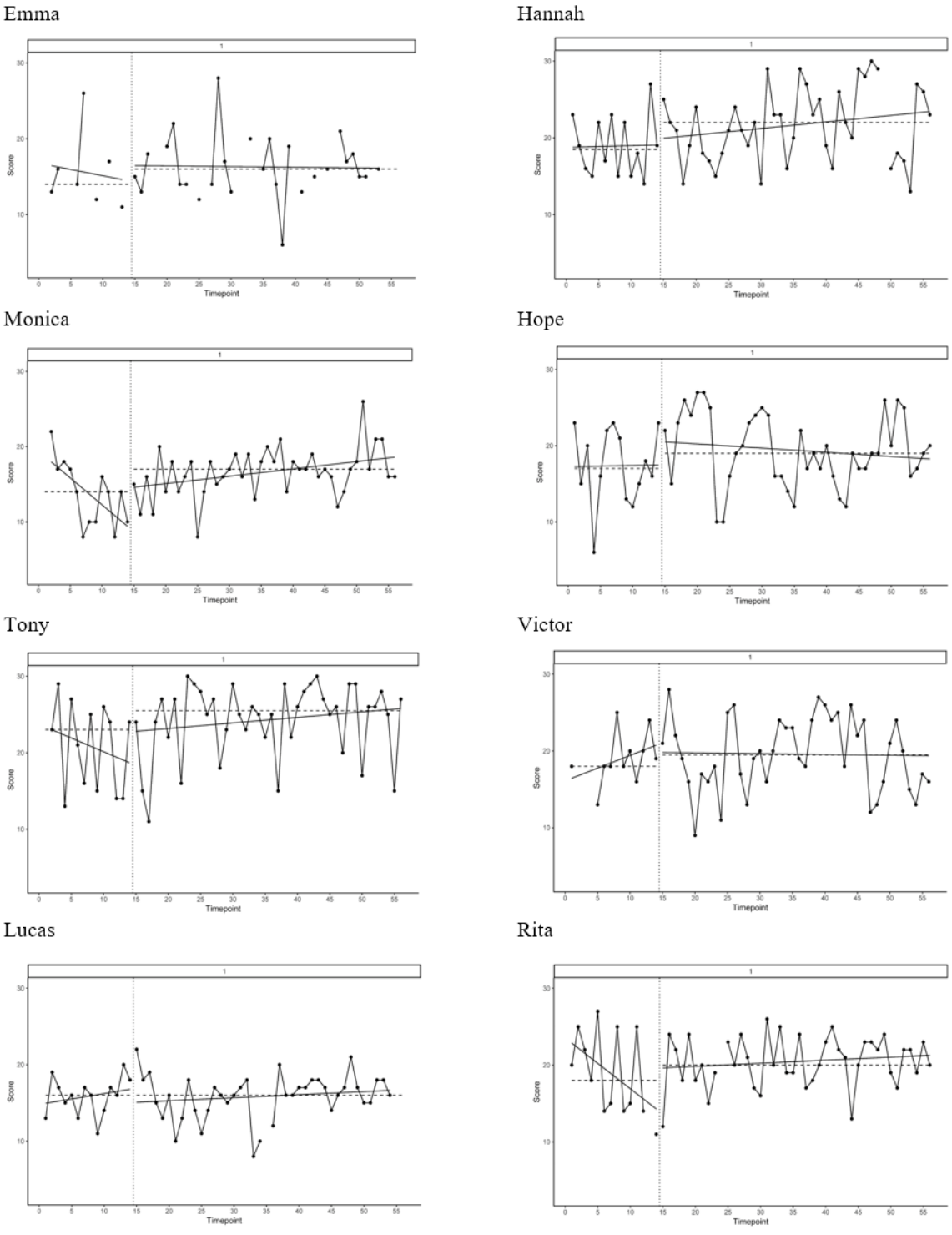
TABLE 6 Changes in BAM scores from baseline to the intervention phase

	B	95% *CI*	Interaction effect	*p*-value
Life Satisfaction	-0.16	[-0.44, 0.12]	1.27	p = .260
BAM-Total	-1.07	[-1.56, -0.58]	18.22	p < .001
BAM-OE	-0.33	[-0.59, -0.07]	6.29	p = .012
BAM-BA	-0.38	[-0.70, -0.07]	5.61	p = .018
BAM-VA	-0.34	[-0.61, -0.07]	6.15	p = .013

GEE analysis was used to estimate mean differences (beta values) with 95% confidence intervals, and the Wald chi-square test with *p*-values was used to calculate the interaction effect

Clinically significant processes of change. SCD analyses: visual inspection and baseline-corrected Tau. Students who had taken part in the VRACT intervention and reported at least 50% compliance and a clinically significant improvement in either social interaction anxiety (SIAS) or communication anxiety (PRCA-24) were examined with SCD analyses (n = 8) to closely observe how their psychological flexibility changed over time in real-life contexts. A preliminary visual inspection was performed in line with SCD practices, and this was followed by a more precise analysis using baseline-corrected Tau to investigate participant differences. As shown in Figure 19, there were large individual differences in the changes in psychological flexibility both during the baseline phase and during the intervention phases.

The total score for psychological flexibility improved from baseline to the intervention phase, based on the median values (represented by the dashed horizontal lines in Figure 19), in seven out of eight participants (Emma, Monica, Tony, Hannah, Hope, Victor and Rita). When Monica, Tony, Hannah, and Rita's psychological flexibility scores were compared between the baseline and intervention phases, however, visual inspection suggested a trend toward improvement over time. When unstable baseline trends were identified through visual inspection, they were accounted for and corrected in the baseline-corrected Tau analyses.



Note. The x-axis represents EMA responses over time, while the y-axis represents the total score of psychological flexibility. The vertical dotted line marks the baseline phase on the left and the intervention phase on the right. The horizontal dashed line represents the median value for each phase.

FIGURE 19 Graphical visualization of psychological flexibility assessed by SCD analysis of individuals who reported a clinically significant change in social or communication anxiety

After correcting for possible significant baseline trends, baseline-corrected Tau analyses revealed that Monica, Tony, and Hannah significantly improved in terms of the psychological flexibility total scores, whereas the other participants did not improve significantly overall. Between the baseline and intervention phases, none of the students significantly worsened.

Baseline-corrected Tau revealed individual differences among participants for different psychological flexibility processes of change. Emma, Monica, Tony, Hannah, and Hope demonstrated a few significant changes in the desired direction. After correcting for the baseline trend, Monica showed a significant improvement in openness to experiences and valued actions. In addition, Tony also showed an improvement in openness to experiences, while Emma showed a significant improvement in valued actions alone. Finally, both Hannah and Hope exhibited a significant increase in behavioral awareness. Three of the eight students (Lucas, Victor, and Rita), however, did not demonstrate significant changes in openness to experience, behavioral awareness, or valued action processes.

Conclusions. The results demonstrate that the VRACT intervention effectively improves not only self-reported psychological flexibility measured in the pre- and post-intervention phase, but also psychological flexibility measured in the context of the participants' daily lives using EMA. Furthermore, there were significant individual differences in the processes of change of psychological flexibility among students reporting clinical improvement. Five of the eight students analyzed by SCD showed the presence of different crucial subprocesses: in one student, it was both openness to experiences and valued action; in one student, it was only openness to experiences; in another, valued action; and in the last two students, behavioral awareness was the primary subprocess of change.

3.4 Acceptability and feasibility of the intervention

3.4.1 Attendance and dropout

When recruiting students and assessing them for eligibility (n = 97), 11 were excluded because they had problems with scheduling the intervention (n = 5), they did not response (n = 3), they were undergoing a simultaneous psychological intervention (n = 2), or they were not university students (n = 1). The remaining eligible 86 students were then randomized into the two groups: the VRACT intervention group (n = 42) and the WLC group (n = 44).

In **Study I**, a total of 86 students were divided into two distinct groups and asked to complete some pre-assessment measurements. Before the measurements, 10 individuals were excluded because they had problems with scheduling the intervention (n = 8), they did not respond (n = 1), or they were

currently using medication (n = 1). Thus, the final study included 76 students who then completed the pre-assessment measures.

In **Study II**, the sample (n = 86) was divided into two groups before the start of the VRACT intervention, and in this phase, there were five dropouts each from the intervention and the control group (VRACT: problems with the schedule, n = 4; lack of response, n = 1; WLC: problems with the schedule, n = 4; current use of medication, n = 1). In the VRACT intervention group, two students decided to withdraw and drop out of the study after taking part in the first VR lab session, and as a result, 35 participants eventually completed the study and filled in the feedback form. This resulted in a dropout rate of 5.41%. In the WLC group, three students dropped out during the three-week waiting period (problems with the schedule, n = 2; withdrawal, n = 1), while two students dropped out of the study after participating in the VRACT intervention (withdrawal, n = 2), offered after the waiting period. Accordingly, we report here that the control group (WLC) had a dropout rate of 7.69% during the waiting list period and a dropout rate of 5.55% during the following intervention period. In addition, when the WLC group received the intervention after the waiting period, 12 students were unable to attend the third VR lab session due to an external university regulation necessitated by the Covid-19 pandemic. However, the data for these students were included in the M+ statistical analyses. Consequently, the WLC group had 39 participants at the pre-waiting period measurement, 36 at the post-waiting period measurement, and 34 at the final post-intervention measurement.

In **Study III**, the sample was identical to the VRACT intervention group of **Study II**. The informed consent form was signed during the first face-to-face session, and the dropout rate was the same, that is, 5.41%. Students used EMA during their daily lives and completed 77.41% of the baseline surveys and 73.68% of the intervention phase surveys.

3.4.2 Feasibility and satisfaction with the intervention

During the first lab session, participants rated the realism of the VR content on a scale from 0 ("not realistic at all") to 10 ("very realistic") as 6.34 (n = 71; SD = 2.00). This score indicates that it was quite immersive even though it only allowed for three degrees of freedom. In addition, while they reported almost no nausea during the VR scenes, as indicated by a score of 1.37 (n = 71; SD = 1.63), they reported relatively higher scores when asked if the VR headset was uncomfortable to wear, with a score of 3.78 (n = 71; SD = 2.59) (rated on a scale of 0 ["not at all"] to 10 ["very much"]). However, students who were able to provide feedback on the use of VR from sessions one to three (n = 56) still reported very low levels of nausea, from 1.48 (SD = 1.77) in the first session to 1.45 (SD = 2.02) in the third session. In addition, the rating for discomfort while wearing the VR headset decreased significantly from 3.95 (SD = 2.56) in the first session to 2.82 (SD = 2.34) in the third session.

At the end of the study, during the feedback meeting, students (N = 69: VRACT, n = 35; WLC, n = 34) were able to provide their overall satisfaction with the study through multiple questions. The students provided their ratings for

how much they had benefited from the program on a scale of 0 to 10 (0 = not at all, 10 = very much). The mean (*M*) rating was 6.61, with a standard deviation (*SD*) of 1.83 (VRACT: *M* = 6.83, *SD* = 1.58; WLC: *M* = 6.38, *SD* = 2.06). They also provided feedback on how useful the experience might be for future presentations (0 = not at all, 10 = very much). The mean score was 6.42 with a *SD* of 2.21 (VRACT: *M* = 6.69, *SD* = 2.11; WLC: *M* = 6.15, *SD* = 2.31). They also provided a mean score of 6.30 with a *SD* of 1.93 (VRACT: *M* = 6.09, *SD* = 1.99; WLC: *M* = 6.53, *SD* = 1.86) for the question of whether they felt they had learned something (0 = nothing, 10 = very much).

They replied with a mean score of 5.07 (*SD* = 2.26) (rated on a scale of 0 ["not at all"] to 10 ["very much"]) when asked whether their anxiety decreased while participating in the study (VRACT: *M* = 5.29, *SD* = 2.38; WLC: *M* = 4.85, *SD* = 2.15) and with a mean score of 3.91 (SD = 2.37) (rated on a scale of 0 ["not at all"] to 10 ["very much"]) when asked if the intervention affected their behavior during social situations (VRACT: *M* = 4.23, *SD* = 2.57; WLC: *M* = 3.59, *SD* = 2.13). Moreover, they were asked if they used the skill learned during the intervention on a scale of 0 to 10 (0 = not at all, 10 = very much), scoring with a mean value of 4.90 and a SD of 2.46 (VRACT: *M* = 4.57, *SD* = 2.51; WLC: *M* = 5.24, *SD* = 2.39). When students in the VRACT intervention group were asked to respond to the question "Did you learn anything useful from the mobile surveys?" (with regard to the use of EMA) on a scale of 0 to 10 (0 = nothing, 10 = very much), the mean score was 3.37 (*SD* = 2.80). Finally, participants were also asked to rate how likely they were to recommend the program to students who struggle with performance anxiety (0 = "not at all likely"; 10 = "very likely"). The mean rating and SD were 7.00 and 2.21, respectively (VRACT: *M* = 7.03, *SD* = 2.22; WLC: *M* = 6.97, *SD* = 2.24).

In addition to Likert scale feedback, participants were given the option to provide more comments on a final open-ended question. While someone hoped for more interaction and immersion in the VR exercise (e.g., "*The difficulty in VR was that the situation lacked genuine interactivity, which in itself is a big, significant thing that increases anxiety*"), most students reported that they were pleased with the VR intervention program, and some also mentioned that they were able to apply the skills they had learned to a real-life situation: (e.g., "*It was great to notice that each time speaking was easier in practice. In recent years, I have been talking about the topic in itself to an increasing extent, so I do not think it was just because I got used to talking about myself. Especially the first time, speaking in front of the VR audience felt difficult, even though I knew very well that they were not really listening. I had a remote presentation and a small group discussion at the university seminar after the third session, and it was the least nervous presentation I have ever given*").

4 DISCUSSION

4.1 Objectives

The studies in this dissertation had two main goals: to investigate the effectiveness of an ACT-based Virtual Reality training (VRACT) on anxiety in social and public speaking situations, and to investigate how psychological processes were related to the level of and changes in anxiety. The aim of the first study was to gain a deeper knowledge of the psychological processes that are connected to social interaction and communication anxiety in university students who reported having high levels of anxiety. In addition, we wished to understand which particular sub-processes of psychological flexibility and self-compassion appear to be important when coping with these types of anxiety. The second study compared the impact of the VRACT intervention to change in a waiting list control group (WLC) in terms of self-reported and behavioral measures. The VR intervention was delivered using a VR head-mounted display (HMD). The third study used Ecological Momentary Assessment (EMA) to support the efficacy of the VRACT intervention in enhancing psychological flexibility in real-world contexts and also examine individual psychological flexibility change processes in participants who show clinically significant improvement in social interaction and communication anxiety.

4.1.1 Psychological Processes in Social Interaction and Communication Anxiety among University Students: Role of Self-Compassion and Psychological Flexibility

Previous studies have shown that social or public speaking anxiety is negatively associated with psychological flexibility (Kashdan & Rottenberg, 2010; Gallego et al., 2020; Kashdan et al., 2020) and self-compassion (Blackie & Kocovski, 2018; Potter et al., 2014; Werner et al., 2012). This implies that individuals, particularly

students who have social anxiety disorders, have lower levels of these psychological processes.

The results of the first study suggested the negative association of psychological flexibility and self-compassion with social interaction anxiety and communication anxiety and demonstrated that they are important key elements for students who wish to enhance their social skills. As observed in earlier studies (Marshall & Brockman, 2016), psychological flexibility (CompACT) and self-compassion (SCS) were strongly correlated in the current study; this may indicate that the SCS and CompACT measures are evaluating a similar phenomenon. Previous research has also linked social anxiety with experiential avoidance (Akbari et al., 2022; Kashdan & Rottenberg, 2010; Levin et al., 2017), that is, the attempt to avoid or escape internal experiences such as thoughts, emotions, and physical sensations. In addition, social anxiety has been linked to a fear of being judged negatively (Weeks et al., 2005). This points to the importance of self-judgment and how people cope with and identify with negative experiences in social interactions. Experiential avoidance is frequently contrasted with acceptance or being open to experiences such as thoughts, emotions, and bodily sensations. On the other hand, self-judgment refers to thoughts about oneself and the critical or negative judgment contained in those thoughts, while over-identification refers to fixating on these negative thoughts and emotions. Our findings indicated that the main factor that could possibly explain social interaction and communication anxiety was openness to experiences—a subprocess of psychological flexibility related to acceptance. In our examination of the role of self-compassion, we discovered that self-judgment and over-identification appeared to be the primary components explaining social interaction anxiety, with over-identification remaining the only factor of self-compassion that explained communication anxiety. The findings suggested that individuals with low levels of openness to thoughts, emotions, and physical sensations and high levels of self-judgment and over-identification may show high levels of social interaction and communication anxiety.

When all aspects of psychological flexibility and self-compassion were considered, self-judgment and over-identification were the only significant sub-processes that remained which could possibly predict social interaction anxiety, while over-identification remained as the only significant sub-process that could possibly predict communication anxiety. Self-judgment and over-identification are closely related, and this may reveal how people are able to criticize their own thoughts and feelings while simultaneously becoming fixated on their negative experiences. Finally, our findings imply that, when teaching students how to manage social interaction and communication anxiety, it is important to pay close attention to how students respond when they are self-critical, judgmental, or identify (fuse) with their own thoughts, as well as how to inculcate and encourage an accepting attitude toward one's own physical feelings, emotions, and thoughts.

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

The findings of the second study revealed that after three VRACT sessions, participants in the intervention group reported significantly decreased self-reported social interaction and public speaking anxiety, fear of negative evaluation, and stress, as well as significantly increased well-being, psychological flexibility, and self-compassion. In addition, between 23% and 39% of participants in the VRACT intervention group showed clinical recovery or improvement of social interaction anxiety and communication anxiety. In contrast, students who were not offered the intervention (that is, those in the WLC group) did not show changes in anxiety, psychological flexibility, or self-compassion. Moreover, our behavioral speech task indicated how students increased their skills over time (i.e., they exhibited less avoidance and gave longer speeches as the sessions progressed). Previous studies indicated the importance of acceptance when combating social anxiety or fear of public speaking (England et al., 2012; Flowers et al., 2023; Kocovski et al., 2009). Psychological processes related to acceptance were included in the VRACT intervention, which may counteract experiential avoidance, a key process that contributes to the maintenance of suffering in social and communication anxiety. The VRACT intervention decreased symptoms of anxiety, and these changes were associated with increases in the process measures. Thus, these findings are in line with previous observations that psychological flexibility and self-compassion are associated with social and public speaking anxiety (Blackie & Kocovski, 2018; Gorinelli et al., 2022; Kashdan & Rottenberg, 2010; Kashdan et al., 2020; Webb et al., 2016; Werner et al., 2012).

Previous research (Anderson et al., 2013; Emmelkamp et al., 2020; Horigome et al., 2020; Kampmann et al., 2016; Reeves et al., 2022; Schröder et al., 2023; Wong et al., 2023) has confirmed the effectiveness of VR-based interventions in the treatment of social or communication anxiety. None of these studies, however, implemented ACT via VR. Despite the fact that ACT has been shown to be effective for a large number of symptoms (Gloster et al., 2020), studies combining VR and ACT are scarce. Our VRACT intervention resulted in a reduction in social interaction and communication anxiety and an increase in psychological flexibility and self-compassion, and thus, we were able to suggest the effectiveness of combining VR with ACT. The effectiveness of the VRACT intervention was strengthened when the WLC group showed comparable outcomes on receiving the intervention after the waiting period. Furthermore, the current findings suggest that recorded VR videos may be an accessible and promising alternative for treating social or public speaking anxiety (Nason et al., 2020; Reeves et al., 2021; Zainal et al., 2021).

It is noteworthy to mention that while the VR exercise aimed to address social and communication anxiety by primarily emphasizing ACT processes associated with openness to experiences and behavioral awareness, positive effects were also observed in other variables, such as self-compassion. Dahl et al. (2009) claimed how hexaflex ACT processes can directly affect compassion for

oneself and others, resulting in an increase in the ability to willingly mindfully observe and experience challenging emotions (Neff & Tirch, 2013). Likewise, during the VRACT intervention, students were frequently instructed to observe and embrace their difficult emotions and thoughts while mindfully staying in the moment and engaging in the task. Self-compassion is a component that can be seen in all of the psychological flexibility processes (Gillanders et al., 2014; Neff & Tirch, 2013), such as promoting acceptance and defusion, which can lead to an increase in mindfulness and self-kindness.

In terms of effect sizes, our findings were comparable to those of Kampmann et al. (2016), but the effect sizes were lower (Anderson et al., 2013) than those reported for other VR-based treatments for social or public speaking anxiety symptoms (Carl et al., 2019). In contrast to previous studies in which CBT was frequently delivered by a therapist during VR exposure and over several sessions (e.g., 8 sessions in Anderson et al., 2013 and Bouchard et al., 2017; 10 sessions in Kampmann et al., 2016; and 12 sessions in Klinger et al., 2005), in our study, all the participants received the same three sessions of less than 2 hours "automated" intervention without additional therapeutic assistance during or between the VR sessions. The current study adds to recent research showing that VR interventions can be effective even when delivered over a fewer number of sessions (Lindner et al., 2017; Reeves et al., 2021). Nevertheless, the effectiveness of the current study reflects an aggregate metric for the entire sample, and thus the VRACT may not be helpful for every individual.

To conclude, this study showed how VR may be utilized to efficaciously deliver ACT in order to enhance the mental health outcomes of university students who are socially anxious.

4.1.3 The impact of virtual reality-based acceptance and commitment training on psychological flexibility in everyday contexts: An ecological momentary assessment study

This study suggests the efficacy of the VRACT intervention by expanding on our prior findings (Gorinelli et al., 2023) and going beyond self-reported measures of psychological flexibility administered in the laboratory before and after the intervention. This was done by showing that contextual daily measured psychological flexibility also improved during the intervention through daily contextual measurements with EMA surveys conducted outside of the lab room. This is an important finding because it implies the generalization of the results to students' real-world contexts. As shown in previous studies, VR can be used to decrease social or public speaking anxiety (Anderson et al., 2013; Bouchard et al., 2017; Carl et al., 2019; Kampmann et al., 2016), and recently, the effect of VR has been tested and confirmed using daily assessment or repeated EMA (Berkhof et al., 2021; Bossenbroek et al., 2020; Geraets et al., 2020; Pot-Kolder et al., 2018). To date, however, no studies have implemented ACT via VR and observed its effect using EMA.

The second aim of this study was to investigate individual differences in the processes of change observed in university students who exhibit clinical

improvement after the VRACT intervention. The current literature suggests that it is important to focus on individual differences when identifying processes of change in psychological interventions (Hofman & Hayes, 2019). All the students in our study underwent the same intervention, which was automated to ensure that the sessions were exactly the same for all students. Despite this, there were wide individual differences in changes in social interaction (SIAS) and communication anxiety (PRCA-24), as well as in psychological flexibility, in the students who showed significant improvement. Based on earlier research (Flowers et al., 2023; Gallego et al., 2020; Morin et al., 2021) and the content of our VRACT intervention (which focused on openness to experiences), we hypothesized that the majority of the clinically significant change in participants could be explained by the acceptance subprocess of psychological flexibility, that is, openness to experience. However, five of the eight students who reported a clinically significant improvement in either the SIAS or PRCA-24 demonstrated significant increases in subprocesses of psychological flexibility, and these changes were not limited to openness to experience. Specifically, in two of the five students, openness to experience was the main subprocess of change out of the three subprocesses. However, in one of these two students (Monica), valued actions also emerged as a significant process of change. The remaining students (Emma, Hannah, and Hope) reported significant increases either in valued actions or in behavioral awareness. Thus, although all five students reported clinically significant decrease in anxiety after attending the structured VRACT intervention, there were individual differences in the subprocesses of psychological flexibility that were involved in the changes in anxiety symptoms.

Overall, this study highlighted the significance of investigating personal and individual processes of change when providing, as well as when designing, customized interventions.

4.2 Acceptability and feasibility of the intervention

4.2.1 Attendance and dropout

Dropout rates are important elements in intervention studies (Barret et al., 2008), but based on the criteria used, they can differ considerably. In the current study, there was a high proportion of students who completed the study once they had started it and a low number of participants who dropped out. This was possibly the result of positive student feedback on the current research.

Previous studies have highlighted the importance of reporting dropouts, even in studies with WLC groups (Cisler et al., 2007). Overall, the dropout rate of the present study was relatively low during the VR intervention. The dropout rates were significantly lower than those of other VR studies with a higher number of sessions (Anderson et al., 2013; Kampmann et al., 2016), but they were comparable to those of studies with brief VR sessions (Reeves et al., 2021).

Moreover, the EMA survey completion rate in this study was similar to that of previous studies, which indicated an overall compliance rate of 75.06% (Jones et al., 2019).

4.2.2 Satisfaction with the intervention and feedback

The training study program was well-received by the students, who provided their feedback at the end of the study (N = 69: VRACT, n = 35; WLC, n = 34). The collection of feedback and satisfaction levels is important for understanding students' positive and negative perceptions of the study and identifying potential areas of improvement for future studies. The students reported to generally have learned something, that the study was beneficial overall and that these types of exercises could be useful for future presentations. This is valuable feedback in light of the fact that a substantial number of students did not necessarily experience high levels of social interaction or communication anxiety. Simultaneously, those individuals with minimal anxiety levels may have indicated only a slight change in their anxiety and behavior while in social situations, as their anxiety was low to begin with. Furthermore, some students appeared to try to use the skills learned during the study, but other students did not. This may be due to the fact that the final questionnaires were collected only one week after the third lab meeting, during which time many students may not have yet been in a situation in which they could apply the skills they learned during the VR intervention. Eventually, the majority of the students appear to recommend the program to other students who may struggle with performance anxiety, possibly highlighting the intervention's potential. Interestingly, when students in the VRACT intervention group were asked whether they learn anything useful from using the EMA mobile survey during their daily life, the average score was relatively low. This could be because the EMA surveys were provided to participants without any explanation about how it might help the study or help them personally.

Feasibility and usability testing questions revealed that the VR intervention was quite immersive even though it only allowed for three degrees of freedom. They also reported almost no nausea during the VR scenes, but they reported relatively slightly higher scores when asked if the VR headset was uncomfortable to wear. Nevertheless, the nausea and discomfort decreased between session one and three. Finally, participants were provided with the opportunity to express their positive or negative sentiments about the study by responding to an open-ended question. Students who chose to leave comments expressed, among other things, their desire for more interactive and realistic scenes, as well as their satisfaction at having learned something useful to apply in their daily lives.

4.3 Limitations

The studies included in this dissertation are not exempt from a few limitations. One major limitation affects all studies: the generalizability of the results is limited by the small sample size, the majority of female participants in the average sample, and the recruitment of participants from the student population. Initially, the sample size was even smaller because it was not possible to recruit more participants during the Covid-19 pandemic. However, we were able to expand the sample once the pandemic regulations were more relaxed, and we continued recruiting and conducted another round of data collection. Eventually, we were able to increase the sample size to a total of 76 students for **Study I**. **Study II,** therefore, had more than 30 individuals per group. Even though we were able to increase the sample size, it can be argued that the sample size is still too small and may influence the generalizability of the results. The use of the same participants across studies could also raise concerns with sampling. In addition, the sample consisted primarily of female participants. Having a sample with a majority of female participants could have led to a bias because, according to the literature, women report lower self-compassion scores (Neff, 2003b) and higher levels of psychological distress (Bernhardsdóttir & Vilhjálmsson, 2013). In **Study II**, however, when the sample was divided into two groups, the groups were very similar, with approximately 70% of the participants in each group being female. The third factor limiting generalizability is that the participants were recruited from a student population and participated voluntarily in the study. As a result, they may not represent a clinical population. To elaborate, students may approach some items of the social interaction anxiety scale (SIAS) differently than a clinical population, thus lowering their chances of meeting the cutoff, according to Rodebaugh et al. (2006). In our studies, however, we examined two outcome measures for social anxiety (SIAS and PRCA-24) and found comparable results. Despite the non-clinical nature of the sample, approximately 60% of the participants were classified as having social interaction anxiety and high communication anxiety levels. While students with high anxiety levels and a willingness to participate to improve their social skills enrolled in the study, there may have been individuals who decided to participate due to the compensation provided in the form of two movie tickets. Thus, the compensation could have potentially influenced the research. Furthermore, although anxiety reported by Finnish student often appears to be similar to that of other international populations, it is important to note that the cross-cultural nature of social and communication anxiety could limit the generalizability of the study to different cultures, which might exhibit distinct characteristics. This underline again the importance of treating people as individuals whenever feasible, rather than using a one-size-fits-all approach.

Study I is a single time-point observation at the pre-intervention measurement and, thus a cross-sectional study. Thus, it may not reflect changes over time, and it is particularly susceptible to recall bias. The use of self-reported

questionnaires to collect data in **Studies I and II** is, therefore, a further limitation that may have impacted the validity of the current research. In **Study I**, self-compassion sub-processes were measured using the subscales of SCS, but these are not always recommended due to the possibility of low internal consistency. Although Raes et al. (2011) suggest using the scale's full form for a detailed analysis of the subscales, they also suggest that reliabilities above .60 for the subscale scores, as demonstrated in our study (with the exception of the self-kindness subscale), are generally considered acceptable. Self-reported measures are also arguably not reflective of actual behavior. However, it has been shown (Gallego et al., 2022) that participants' self-reported public speaking anxiety is consistent with their actual behavior. This is evidenced by the observations in our second study, in which a decrease in social interaction and communication anxiety was accompanied by longer speeches in the behavioral test.

Despite the positive findings in **Study II**, we cannot rule out the possibility that the results were significantly influenced by the exposure VR task rather than the ACT-based exercise. This is because VR exposure by itself has been shown to be effective in reducing social anxiety, with no difference observed when VR exposure was compared to in vivo or imagined exposure (Chesham et al., 2018). This limitation needs to be acknowledged, as the findings of **Studies II** and **III** were obtained with ACT and exposure-based training via VR. In **Study II**, the VRACT intervention group also filled in EMA phone measures, which might have influenced or enhanced the change in anxiety and process measures. Nonetheless, when the WLC group was offered the VRACT intervention without EMA, we observed similar results, although of a lesser magnitude. The reasons for lower levels of change in the WLC participants when taking part in the intervention could be attributed to (a) the waiting time, which might have influenced future intervention effectiveness (Kyllönen et al., 2018); (b) the inability of 12 participants to attend the third face-to-face lab meeting due to the spread of Covid-19 and the resulting tight university regulations; and (c) the lack of EMA phone measures. The use of the VR headset and the content in **Studies II** and **III** also presented a few usability issues on their own. One of the limitations was that the scenarios were less interactive than computer-generated scenarios. However, we used 180° video recordings from real-world experiences, which provided high-quality experiences of the people and objects within the VR scenarios. The VR headset also carried a risk of nausea and skin irritations. We made sure to disinfect the headset after each use in order to reduce this risk. Even though the headsets were carefully adjusted to prevent discomfort, a small number of students were uncomfortable with the fit of the headset. In addition, a small number of students also reported mild headaches and general distress from wearing the headset or watching the VR content. However, during the sessions, reports of nausea were rare, and self-reported discomfort from wearing the headset decreased significantly from session one to session three. Moreover, the participants did not experience any severe events, such as seizures, or have any strong adverse reactions, and the overall intervention was well received.

In **Study III**, there was an additional limitation concerning the primary measure used in EMA, that is, BAM, which is a relatively new measure that had lower internal consistency levels at the baseline in our study than that reported in previous studies. This may have impacted the reliability and accuracy of the instrument used to measure psychological flexibility in students' daily lives. Even though the small number of items in BAM may have affected its internal consistency (Cortina, 1993; McNeish, 2018), the measure was found to be correlated with CompACT, a widely used measure of psychological flexibility, in a previous study (Hulbert-Williams et al., 2019). This correlation was confirmed in the current study. Additionally, baseline test-retest reliability demonstrated the stability of BAM over time. The scale of the BAM outcome (psychological flexibility) often showed a small visual range improvement between baseline and post intervention as variations in day to day patterns emerged, making it difficult to draw broad conclusions. These variations could be due to the different time or activity performed prior to responding to the survey. Another limitation of **Study III** is the lack of a control group, without which it cannot be ruled out that the observed increases in psychological flexibility could have been caused by factors other than the VRACT intervention (such as the EMA measures). Nevertheless, **Study II** showed how after the intervention in the WLC group, self-reported measures (including psychological flexibility) showed a similar improvement to the intervention group, who were offered the intervention in the first phase. The increase in psychological flexibility was observed without the use of EMA. This implies that the EMA measures alone did not affect flexibility.

Finally, this study is limited by the lack of follow-up evaluations. Studies using VR to treat social or public speaking anxiety have reported that the results were maintained at three- or six-month follow-up evaluations (Kampmann et al., 2016; Zainal et al., 2021), but we cannot confirm the sustainability of the results over a longer period of time due to the lack of follow-up.

4.4 Future research

This research highlights several areas for future research. Despite the rapid expansion of digital technology and VR intervention studies, there is relatively little research on combining ACT with VR. However, numerous studies examine the efficacy of VR together with other psychological interventions, such as CBT, as alternatives to traditional interventions (Carl et al., 2019; Powers & Emmelkamp, 2008; Valmaggia et al., 2016). Prior to our studies, however, there has been no research on the effectiveness of VR-based ACT interventions in university students with social interaction or communication anxiety. There is a need to investigate further how ACT can be delivered effectively and safely in VR in various contexts and conditions, as well as in larger samples.

Future research in VR should ideally describe in more detail the design and methodology used, for example, by describing the type of equipment used and whether virtual scenes were displayed using a VR head-mounted display

(HMD). This would be helpful for those who wish to replicate the studies. As technology advances, it will become necessary to distinguish between VR, augmented reality (AR), and mixed reality (MR), as there are significant differences between the three technologies. Future studies could compare a similar intervention with different content, such as a computer-generated scenario versus real-world video recordings, or three degrees of freedom versus six degrees of freedom.

Even though **Study I** identified potential psychological processes that could account for social interaction and communication anxiety, more research is required to confirm how psychological flexibility and self-compassion, particularly acceptance, tolerance, and an approving attitude toward oneself, are related to anxiety. Bigger sample sizes than those used in the current study are recommended, especially for investigating individual differences. In addition to increasing the sample size in terms of the number of participants, it could also be expanded to include functional or clinical populations in order to generalize the findings of the current study. When investigating potential anxiety predictors, it may be advisable to include additional temporal assessments to strengthen the results. Based on the results of **Study II,** it is suggested that potential future research on VR interventions use more stringent exclusion criteria, perhaps by excluding people with conditions such as epilepsy and recurrent migraines, who may not be suitable for wearing a VR headset. In addition, the effectiveness of VR studies can be tested by comparing longer and shorter sessions. Further, future studies could compare traditional VR exposure therapy (VRET) with VR exposure combined with ACT training. Such comparative studies could investigate both the effectiveness and acceptance of the interventions as well as dropout rates and long-term effects. Moreover, studies with larger sample size could explore moderators that could potentially predict the positive response to VRACT for social and communication anxiety. **Study III** also pointed out the significance of expanding research on the effectiveness of VR interventions by going beyond traditional self-report questionnaires; some alternatives are repeated measures or EMA to explore process and anxiety measures. This would allow for a more personalized study design in which individuals can be observed closely using a single-case design (SCD) approach. Compared to the simple A-B (baseline-intervention) design used in the current study, more complex designs (such as multiple baseline) could be applied. Additionally, future research could explore the processes of change entailed in the recovery from diverse clinical conditions. Finally, more follow-up studies are needed to confirm the long-term effects of VR interventions.

4.5 Clinical implications

Several clinical implications can be drawn from the results of **Studies I, II, and III**. To start with, our findings contribute to the existing body of knowledge and reinforce the notion that psychological flexibility skills are associated with and

are important for attempting to understand, explain, and reduce social anxiety. In addition, the current work contributes vital knowledge regarding the use of VR to improve mental health outcomes and its implementation with psychotherapy exercises.

Study I provided useful information that strengthened the hypothesis that a psychological intervention aimed at reducing social and public speaking anxiety would benefit from a focus on increasing psychological flexibility and self-compassion. Specifically, attention should be given to how university students negatively evaluate or criticize their personal aspects and how they fixate on those negative thoughts and emotions, as students with social interaction or communication anxiety would greatly benefit from training in skills that promote acceptance, tolerance, and an approving attitude towards themselves. Clinicians following these guidelines may employ metaphors and exercises that emphasize acceptance, cognitive defusion, and compassion, especially when working with social and communication anxiety. **Studies II and III** showed how a brief ACT training delivered via VR can be used as an additional therapeutic tool to help users face their phobias in an immersive, controlled, and safe environment, due to VR lying, optimally, in the middle of the spectrum ranging from imaginal to in vivo exposure. In addition, VR-based psychological interventions may have clinical implications because they can be applied in cases where traditional therapy is not accessible. Our intervention comprised pre-recorded video and audio presentations, without additional face-to-face assistance from a therapist or a specialist, and it demonstrated significant improvements in social and public speaking anxiety, as well as in psychological processes. In addition to reducing social and public speaking anxiety, the increase in psychological flexibility and self-compassion could also have an effect on the daily lives of those receiving the intervention. Due to the high levels of social and communication anxiety among university students, VR interventions could be used to teach public speaking skills as part of teaching practices. For students who want to practice speaking skills on their own, a VR headset with an integrated psychological exposure exercise combined with ACT-based exercises could be an easily accessible and convenient solution. Today, psychological interventions can be provided remotely, which can be a significant benefit for many individuals.

As technology advances and extended reality (XR) headsets become more widely available, immersive interventions may also be delivered in new and flexible ways. Different exercises designed to target specific processes could be made available for a variety of needs. Furthermore, future forms of remote interaction may allow the therapist to interact with the client while immersed in an immersive environment. Nevertheless, whenever possible, therapists should attempt to tailor interventions to the individual, as the current study demonstrated that the effect of VR interventions on psychological processes, such as psychological flexibility, may vary significantly from one person to another. This could happen even when the intervention is delivered in exactly the same manner, as observed in our study. As a result, it is crucial to determine which

change processes are occurring in each individual and tailor subsequent sessions accordingly. This requires continuous measurement of changes in symptom and process measures during the intervention.

4.6 Conclusions

Digital and technological solutions will play a significant role in delivering psychological interventions as digital innovation progresses. As knowledge regarding these digital solutions increases, therapeutic interventions will benefit from technological innovations and the identification of the specific processes of change underlying distinct mental health conditions. Our studies demonstrated how ACT can be efficaciously delivered using VR to improve self-reported, contextual, and behavioral outcomes for university students with social interaction or communication anxiety. Furthermore, we showed that psychological flexibility, self-compassion, and their subprocesses openness to experiences, self-judgment, and over-identification were closely related to and may predict social interaction and communication anxiety.

To summarize, using a very brief VRACT-based exposure intervention, the current work indicated that it is possible to help university students improve their psychological flexibility skills while simultaneously reducing their anxiety. In addition, our work suggests that it is important to pay close attention to the effects of the intervention on each individual, as they may react differently to a standardized intervention and acquire different skills. The data in this study suggest that similar changes in psychological symptoms may be associated with or explained by individually different psychological processes.

YHTEENVETO (SUMMARY)

Hyväksymis- ja omistautumisterapiaa virtuaalisesti: Virtuaalitodellisuusharjoittelun vaikutukset sosiaaliseen ja kommunikaatioahdistukseen sekä psykologisiin prosesseihin yliopisto-opiskelijoilla.

Virtuaalitodellisuutta (VR) hyödynnetään yhä enemmän myös erilaisten psykologisten ongelmien hoidossa (Carl et al., 2019; Dellazizzo ym. 2020; Powers & Sanchez-Vives 2016). Emmelkamp 2008; Valmaggia ym. 2016). Psykologinen altistushoito esimerkiksi pelkojen hoidossa sisältää tavallisesti in vivo -kokemuksen, jossa on mahdollista suoraan kohdata ahdistusta aiheuttava tilanne. In vivo-altistus on kuitenkin usein vaikea järjestää käytännössä. Virtuaalitodellisuuden avulla altistus voidaan räätälöidä yksilön tarpeen mukaan ja sen vaikeutta voidaan säädellä. Virtuaalitodellisuuden avulla pelkoa ja ahdistusta aiheuttavat tilanteet voidaan kohdata turvallisesti ja kontrolloidusti (Miloff ym. 2016).

Sosiaalisten tilanteiden pelko ja kommunikaatioahdistus eli esiintymispelko ovat yleisiä ongelmia yliopisto-opiskelijoilla maailmanlaajuisesti (mm. Dwyer & Davidson 2012; Ferreira ym. 2015; Tillfors & Furmark 2007). Suomalaisen tutkimuksen (Kunttu et al., 2017) mukaan noin yksi kolmasosa suomalaisista opiskelijoista kokee voimakasta stressiä yleisön edessä esiintymisestä. Opiskelijoiden sosiaalisen ja esiintymispelon hoitoon tarvitaankin tehokkaita hoitokeinoja. Yksi varteenotettava menetelmä sosiaalisen ahdistuksen hoitoon on virtuaalitodellisuus. Viimeaikaiset tutkimukset ovat osoittaneet, että virtuaalitodellisuuden hyödyntäminen voi olla tehokasta myös sosiaalisen ja esiintymisahdistuksen hoidossa (Emmelkamp ym. 2020; Lim ym. 2023; Maples-Keller ym. 2017; Morina ym. 2023; Nazligul ym. 2017; Sarpourian ym. 2022; Stupar-Rutenfrans ym. 2017; Takac ym. 2019).

Tämän tutkimuksen tavoitteena oli tutkia hyväksymis- ja omistautumisterapiaan (HOT) pohjautuvan intervention tehokkuutta virtuaalitodellisuutta (VR) hyödyntämällä sekä syventää ymmärrystä sosiaalista ja kommunikaatioahdistusta selittävistä psykologisista tekijöistä yliopisto-opiskelijoilla. Tutkimuksessa I (n = 76) selvitettiin psykologisen joustavuuden ja itsemyötätunnon roolia sekä psykologisia osaprosesseja, jotka voivat selittää sosiaaliseen vuorovaikutukseen ja esiintymispelkoon liittyvää ahdistusta. Yli 60 % tutkimukseen osallistuneista opiskelijoista täytti sosiaalisen ahdistuksen kriteerit (SIAS ≥ 34) ja lähes 70 % koki voimakasta esiintymispelkoa (PRCA-24 > 80). VAS-asteikon mukaan opiskelijat kokivat esityksen pitämisen epämiellyttävänä, stressaavana ja hermostuttavana. Sosiaalinen ahdistus ja esiintymispelko olivat voimakkaasti positiivisesti yhteydessä toisiinsa ja negatiivisesti yhteydessä psykologiseen joustavuuteen ja itsemyötätuntoon.

Tulokset osoittivat, että voimakasta sosiaalista ja kommunikaatioahdistusta kokevilla opiskelijoilla oli alhainen psykologisen joustavuuden ja itsemyötätunnon taso. Tarkasteltaessa psykologisen joustavuuden eri osa-alueita havaittiin, että avoimuudella omille sisäisille kokemuksille (ajatuksille, tunteille ja

tuntemuksille) oli merkittävä rooli sosiaalisessa ja kommunikaatioahdistuksessa. Kun tutkittiin itsemyötätunnon eri osa-alueita, itsensä arvostelu ja liiallinen omiin ajatuksiin uskominen olivat tärkeimpiä prosesseja sosiaalisessa ahdistuksessa. Sen sijaan esiintymispelossa liiallinen uskominen omiin ajatuksiin näyttäytyi tärkeimpänä prosessina. Tutkimuksen I tulokset vahvistivat sen, että sosiaalinen ja esiintymispelko olivat yhteydessä psykologiseen joustavuuteen ja itsemyötätuntoon. Lisäksi havaittiin, että avoimuus ajatuksille ja tunteille, itsensä arvostelu ja liiallinen uskominen omiin ajatuksiin selittivät sosiaalista ahdistusta ja esiintymispelkoa.

Tutkimuksen II tavoitteena oli selvittää, voidaanko virtuaalitodellisuuden avulla tarjotulla, hyväksymis- ja omistautumisterapian menetelmiin pohjautuvalla interventiolla vaikuttaa myönteisesti yliopisto-opiskelijoiden sosiaaliseen ahdistukseen, esiintymispelkoon ja psykologiseen joustavuuteen. Interventio koostui kolmesta harjoituskerrasta, joissa hyödynnettiin VR-teknologiaa. Tavoitteena oli tutkia, kuinka lyhyt, virtuaalitodellisuutta hyödyntävä HOT-interventio (VRACT, n = 37) vaikuttaa opiskelijoiden sosiaaliseen ahdistukseen ja esiintymispelkoon verrattuna kontrolliryhmään (Odotusryhmä, WLC, n = 39). Vaikuttavuutta mitattiin oire-, hyvinvointi- sekä psykologisen joustavuuden ja itsemyötätunnon itsearviointimittareilla sekä esiintymistehtävällä. Esiintymistehtävä muodostui ns. Behavioral Assessment Task -tehtävästä (BAT; Gallego ym. 2020), jossa osanottajat altistettiin pelkoa aiheuttavalle tilanteelle siten, että he saivat tehtäväksi pitää virtuaalisen yleisön edessä noin 10 minuutin puheen, jossa he kertoivat vahvuuksistaan ja heikkouksistaan.

Tulokset osoittivat, että opiskelijat kokivat ennen interventiota merkittävää ahdistusta sosiaalisissa ja esiintymistilanteissa. Yli puolella opiskelijoista havaittiin sosiaalista ahdistusta (SIAS; VRACT, 59,5 %; WLC, 61,5 %) ja huomattavaa esiintymispelkoa (PRCA-24; VRACT, 75,7 %; WLC, 64,1 %). Ryhmät eivät eronneet tilastollisesti toisistaan ennen interventiota. Lisäksi tulokset osoittivat, että virtuaalitodellisuuden avulla tarjottu HOT-interventio (VRACT) vähensi itseraportoitua sosiaalista ahdistusta ja esiintymispelkoa, negatiivisen arvioinnin pelkoa ja stressiä sekä lisäsi psykologista hyvinvointia, joustavuutta ja itsemyötätuntoa verrattuna kontrolliryhmään. Kontrolliryhmän tulokset eivät muuttuneet kolmen viikon odotusajan aikana. Tulokset kuitenkin paranivat samansuuntaisesti, kun odotusryhmä sai vastaavan intervention. Kliinisesti merkitsevää muutosta tarkasteltaessa havaittiin, että 25–40 % opiskelijoista luokiteltiin sosiaalisen ahdistuksen tai esiintymispelon suhteen joko parantuneiksi tai hyötyneiksi intervention jälkeen. Lisäksi opiskelijoiden välttämiskäyttäytyminen väheni ja stressinsietokyky lisääntyi.

Tutkimuksessa III selvitettiin VRACT-intervention (n = 37) vaikutusta opiskelijoiden psykologiseen joustavuuteen, jota mitattiin ekologisen hetkellisen arvioinnin (EMA) avulla erilaisissa arjen tilanteissa. Lisäksi tavoitteena oli tutkia niiden opiskelijoiden psykologisen joustavuuden muutoksia, joilla tapahtui kliinisesti merkitsevä ahdistuneisuuden väheneminen (n = 8). Interventioryhmän osallistujat vastasivat EMA-kyselyyn Metric Wire-puhelinsovelluksen kautta kahdesti päivässä satunnaisina aikoina seitsemän päivän ajan ennen

interventiota ja kahdesti päivässä 21 päivän ajan intervention aikana. Kyselyt sisälsivät kulloinkin viisi lyhyttä elämään tyytyväisyyteen, senhetkiseen aktiivisuuteen ja psykologiseen joustavuuteen liittyvää kysymystä.

Kun tarkasteltiin koko otosta (n = 37), havaittiin, että osallistujien psykologinen joustavuus lisääntyi ensimmäisen VRACT-session jälkeen ja säilyi koko interventiovaiheen ajan. Näin ollen interventio edisti opiskelijoiden psykologista joustavuutta eri tilanteissa heidän arkielämässään. Lähempään tarkasteluun valittiin kahdeksan opiskelijaa, jotka olivat vastanneet vähintään 50 % EMA-kyselyistä ja joilla havaittiin kliinisesti merkitsevä hyötyminen joko sosiaalisessa ahdistuksessa tai kommunikaatioahdistuksessa. Yksilöanalyysien (SCD; Single Case Design) avulla selvitettiin, kuinka kahdeksan hyötyneen opiskelijan psykologinen joustavuus muuttui intervention aikana. Tulokset osoittivat, että vaikka opiskelijat saivat saman intervention, psykologiset muutosprosessit yksilöiden välillä vaihtelivat merkittävästi.

Yhteenvetona voidaan todeta, että merkittävä osa tähän tutkimukseen osallistuneista yliopisto-opiskelijoista koki voimakasta sosiaalista ahdistusta ja esiintymispelkoa. Korkea ahdistus oli yhteydessä alhaiseen psykologisen joustavuuden ja itsemyötätunnon tasoon. Avoimuus ajatuksille ja tunteille, itsensä arvostelu ja liiallinen uskominen omiin ajatuksiin ovat keskeisiä tekijöitä sosiaalisen ahdistuksen ja esiintymispelon selittämisessä. Tutkimus osoitti myös, että hyväksymis- ja omistautumisterapiaa voidaan hyödyntää onnistuneesti virtuaalitodellisuuden avulla tarjottavana interventiona, joka vähentää merkitsevästi yliopisto-opiskelijoiden sosiaalista ahdistusta ja esiintymispelkoa sekä lisää heidän psykologista joustavuuttaan, itsemyötätuntoaan, hyvinvointiaan ja viestintätaitojaan. Lisäksi interventio edisti opiskelijoiden psykologista joustavuutta heidän arkielämässään, kun joustavuutta mitattiin arjen tilanteissa ekologisen hetkellisen arvioinnin (EMA) avulla. Huomionarvoista oli kuitenkin, että psykologisen joustavuuden muutokset interventiosta hyötyneillä opiskelijoilla vaihtelivat yksilöiden välillä suuresti. Suurin osa tutkimukseen osallistuneista opiskelijoista arvioi intervention myönteisesti, ja he kokivat pystyvänsä hyödyntämään oppimiaan taitoja omassa elämässään.

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DISCLOSURE

Generative AI technology, specifically ChatGPT, has only been used to translate the following content in Appendix 1 from the Finnish language to the English language. After using this tool, the authors reviewed and edited the text as needed and take full responsibility for the translated content. Generative AI has not been used elsewhere. Other tools (e.g., Word, Grammarly) were used to enhance the grammar and flow of sentences, and the entire manuscript was proofread by an editor at Scribendi, a professional editing and proofreading service.

APPENDIX

1 Complete translation of the VRACT exercise script from the Finnish language to the English language:

SESSION 1

Part 1 - Empty room

During the exercise, I will present you with some thoughts and perspectives. The purpose of these exercises is to teach a new perspective on thoughts and emotions. The goal is not to change or remove thoughts or feelings, as that would likely be difficult or even impossible. Instead, the goal is to change the impact of thoughts and emotions. To achieve this, we need to learn certain skills for handling thoughts and emotions. In the following narrative, presented in a virtual environment, we aim to offer you a new perspective on thoughts and feelings, as well as skills to manage thoughts and emotions in a way that promotes your well-being. Please note that this exercise will teach you principles and general methods that you can use and practice further later on. Metaphors and examples are used in the exercise to help you better understand the goal of the exercise.

One of the objectives of the training is an open and accepting attitude toward your own thoughts and feelings. We will begin by focusing on attention and observation through breath. Focus your attention on your breath. Take a deep breath now and notice how the air enters your body, passes through your nostrils, fills your lungs, and then notice how the air exits. Do the same again and observe where you feel the breath in your body.

Notice that you have the ability to observe when the breath occurs. Similarly, in some situations, such as when you are with others, you can observe thoughts and feelings. Next, pay attention to how your shoulders feel. Take note that it is you who notices these sensations. Pay attention to the fact that you are the one making observations. Just as you can notice when the breath occurs or how your shoulders feel, you can also take note or observe what thoughts and feelings you have, and you can choose how to relate to them. When you notice thoughts and feelings, be open to what you observe.

Part 2 - Nature environment

Next, we will practice how we can perceive thoughts and feelings. What perspective could we take on them... As you sit there and breathe, can you examine your breath as a part of you? You could think of your breath as just a part of you in the same way that certain thoughts and feelings are just a part of you. Like clouds in the sky, your breath comes and goes. Similarly, your thoughts and feelings can also come and go. You can notice and observe what thoughts and feelings you have in the here and now, just as you can notice and observe clouds in the sky. When you observe the clouds, think of accepting all kinds of clouds, whether they are dark or light or of any shape. Learn to approach your thoughts and feelings in the same accepting way, regardless of whether they are unpleasant or pleasant.

Notice that clouds are different from the sky; clouds move in the sky. Similarly, you could think that your thoughts are different from you, and thoughts come and go within you. Take a moment to observe how the clouds come and go while you make observations. Consider that you can examine your thoughts and feelings in the same way while being open and accepting of what you observe...

Your thoughts also come and go, while a part of you has always been present and can make observations of what is happening. You may not be able to chase away all the clouds, no matter how much you want to. They are just what they are. Your thoughts and feelings are also what they are, and they come and go. The weather is what it is. You may not like the weather, but still, it is what it is, and you can take an accepting perspective on it. Feelings and thoughts are what they are. You may not necessarily like all of your feelings and thoughts, but still, they are what they are, like the weather. You can walk in the rain, wind, and snow. It may not be very pleasant, but still, you can walk. Similarly, with unpleasant thoughts and feelings, you can also walk with them or give a presentation or do something else that may not be very comfortable, just like walking in the wind and snow. We can distinguish two things: you and your thoughts and feelings in a specific situation and moment. You can observe your thoughts and feelings, just as you can observe clouds in the sky... You can take the same perspective on your feelings and thoughts as you can on the clouds in the sky or the weather. They are what they are, and you can choose to accept what you observe. They are what they are, like the weather. And even in this moment, you have the ability to choose what you do and how you relate to your own thoughts and feelings.

Part 3 - One person

There are often situations where attention is somehow directed towards you, you are being looked at. It's possible that you may feel a bit uncomfortable, uncertain, perhaps sometimes stressed, or maybe anxious. Maybe you should say something or express your opinion. In situations where you are with others, you may experience various thoughts and feelings. They can be pleasant or unpleasant. What thoughts and feelings do you notice right now when you are being looked at?...

Think of there being space within you for different thoughts and feelings, just as there is space for different clouds in the sky. Thoughts and feelings vary, just like the weather varies. Can you see yourself as a place where your thoughts and feelings manifest? Furthermore, notice that when you have thoughts and feelings, whether they are pleasant or unpleasant, you can distinguish two things: on one hand, there's you who observes things, and on the other hand, there's your experience of what you observe here and now. Take a moment to observe what thoughts and feelings you notice right now... just let them be and observe for a moment...

Look towards the person in front of you. For example, you may notice the thought, "Am I accepted?" You may not be able to chase away that thought and the related feelings, no matter how much you want to. There's no need to. Your thoughts and feelings are what they are, and they come and go, just like the weather is what it is. You may sometimes experience feelings of uncertainty, self-critical thoughts, anxiety, or perhaps fear of being accepted or what someone else thinks of you. Take a moment to observe what thoughts and feelings you notice within yourself...

Learn to be open and accepting of the thoughts and feelings that arise within you. You can take an accepting perspective on them. Feelings and thoughts are what they are. You may not necessarily like all of your feelings and thoughts, but still, they are what they are, just like the weather is what it is, no matter how much you might wish it were different. You can walk in the rain, wind, and snow. It may not be very pleasant, but still, you can walk. Similarly, with unpleasant thoughts and feelings, you can be in the company of others, give a presentation, or do something else that may not be very comfortable, just like walking in the wind and snow. You can even look towards another person with unpleasant feelings. You can observe your thoughts and feelings in the same way as you can observe clouds in the sky. Take a moment to notice what you observe...

You can take the same perspective on your feelings and thoughts as you can on the clouds in the sky or the weather. They are what they are, and you can choose to accept what you observe. They are what they are, like the weather. And even in this moment, you have the ability to choose what you do and how you relate to your own thoughts and feelings. When you practice this skill, you may have the opportunity to increase your freedom and ability to act. You can choose how to relate to your ever-changing thoughts and feelings. Let your thoughts appear, whatever they may be. Learn to be open and accepting of the thoughts and feelings you have. You can choose to do things with unpleasant feelings, just like you can choose to walk in the wind and rain, even if it's not always comfortable.

Part 4 - Three people

Notice what thoughts you have...

If you develop the skill of observing thoughts as if you were observing clouds, you may have a greater chance of choosing how you relate to your own thoughts and feelings. You might more often choose whether to follow what your thoughts say or do something differently from what you're used to.

Look at the people in front of you... You may have a critical or unpleasant thought. For example, you could think, "I'm not good enough, those others are better than me, or I'm bad and a failure." What thoughts and feelings do you notice that you have right now...

Could you think of these thoughts as just thoughts, understanding that you are not just your thoughts, you are something different from an individual thought. You are not your thoughts; you have thoughts. Notice that we can distinguish two things here: you and your thoughts in this situation, in this moment. In another situation and moment, you may have a different thought. It may be important to note that we have a certain thought or feeling in this moment, and in another moment or situation, we may have a different thought or feeling. Feelings and thoughts are changeable. If thoughts and feelings are changeable, you can be open to receiving all kinds of feelings and thoughts, because we can distinguish two things: you and your feelings and thoughts. In this way, you can choose to do things with unpleasant thoughts and feelings if you wish. It may be that sometimes you feel uncertainty, have critical thoughts about yourself, experience anxiety, or perhaps fear of being accepted or what someone else thinks of you. What do you notice right now...

Learn to be open and accepting of the thoughts and feelings that arise within you. You can take an accepting perspective. Try simply examining and observing your thoughts and feelings without interfering with them. Observe them in the same way you would observe clouds...

Feelings and thoughts are what they are. You may not necessarily like all of your feelings and thoughts, but still, they are what they are, just like the weather is what it is, no matter how much you might wish it were different. You can walk in the rain, wind, and snow. It may not be very pleasant, but still, you can walk. Similarly, you can also be with or do something with unpleasant thoughts and feelings, such as being in the company of others, giving a presentation, or doing something else that may not always be very comfortable.

Part 5 – Audience

There are situations where you are being looked at. Notice what thoughts and feelings you are experiencing right now... Learn to be open and accepting of the thoughts and feelings that arise within you.

You are in front of a group. Imagine that you have to say something or give a presentation. What do you notice... Maybe you have feelings of uncertainty, self-critical thoughts, anxiety, or perhaps fear of being accepted or what someone else thinks of you. Examine your thoughts and feelings as if you were observing clouds in the sky, be open, and just let the thoughts and feelings be...

Learn to be open and accepting of the thoughts and feelings that arise within you. You can take an accepting perspective...

Feelings and thoughts are what they are. You may not necessarily like all of your feelings and thoughts, but still, they are what they are, just like the weather is what it is, no matter how much you might wish it were different. You can walk in the rain, wind, and snow. It may not be very pleasant, but still, you can walk. Similarly, you can also be with or do something with unpleasant thoughts and feelings, such as being in the company of others, giving a presentation, or doing something else that may feel difficult and laborious, just like walking in the wind and snow.

Perhaps you have to give a presentation in a course... Maybe you notice a thought like "this is probably a bad presentation" or "I might not make it"... Notice that this is just one thought among many, and thoughts vary like clouds in the sky. You can choose how you relate to your thoughts and feelings. Take a moment to observe the thoughts you have. You may have thoughts like, "What do others think of me?", "I'm going to embarrass myself," "I'll probably say something silly"... Choose to approach them openly, try it in this situation...

Notice that we can distinguish two things here: you and your thoughts in this situation, in this moment. In another situation and moment, you may have a different thought. It may be important to note that we have a certain thought or feeling in this moment, and in another moment or situation, we may have a different thought or feeling. Feelings and thoughts are changeable. If thoughts and feelings are changeable, you can be open to receiving all kinds of feelings and thoughts, because we can distinguish two things: you and your feelings and thoughts. In this way, you can choose to do things with unpleasant thoughts and feelings if you wish.

Remember and notice also that every individual choice and action takes you closer to a larger goal or objective. Choose to look openly at the people in front of you... Giving the presentation and completing the course takes you toward a larger picture, and you can do it regardless of the thoughts and feelings you have.

Remember that these things described above can be seen as skills that can be practiced. When you practice and apply these skills, you may have the opportunity to increase your freedom and ability to act. You can choose how you relate to your ever-changing thoughts and feelings, and you can choose how you act.

SESSION 2

Part 1 - Empty room

In this exercise, the goal is to enhance your skills in handling emotions and thoughts and to pay attention to how they affect you. This is a skill-building exercise, and these skills can be applied during your studies and in other situations later on. The aim is not to change or eliminate all the unpleasant feelings associated with performance situations. Instead, the goal is to change the impact of thoughts and emotions. This requires two things. First, you need to notice what thoughts and feelings you have. Second, you need to learn how to choose how to act when you notice a thought or feeling. This also involves the courage to act differently than what your thoughts tell you, as well as trying out new ways of acting. In the following narrative presented in a virtual environment, the aim is to offer you a new perspective on thoughts and feelings and the skills to handle them in a way that promotes well-being. Note that this exercise teaches you principles and general methods that you can use and practice further later on. Metaphors and examples are used in the exercise to help you understand the goal of the practice.

One goal of the practice is to have an open and accepting attitude towards your own thoughts and feelings. We will start by practicing directing and observing your attention using your breath. Focus your attention on your breath. Take a deep breath and notice how the air enters your body, passes through your nostrils, fills your lungs, and then notice how the air exits. Repeat this and notice where you feel your breath in your body.

Note that you have the ability to notice when your breath is happening. Similarly, you can notice that in certain situations, such as when you are with others, you have thoughts and feelings. The first part of the practice is to enhance your skills in noticing the effects of thoughts and feelings. Next, pay attention to how your shoulders feel. Notice that it is you who is noticing these sensations. Pay attention to the fact that you are the one making observations and can

choose how to act. Just as you can notice when your breath is happening or how your shoulders feel, you can also notice what thoughts and feelings you have, and you can choose how to respond to them. When you notice thoughts and feelings, be open to what you observe.

Part 2 - Nature environment

These exercises aim to help you learn how to examine and deal with your thoughts and feelings, especially when they are unpleasant and hinder you from acting as you would like. One skill related to this is gaining a new perspective on your own thoughts and feelings. You can think of it this way: just as your breath is just a part of you, certain thoughts and feelings are also just a part of you. Thoughts and feelings are changeable, like clouds in the sky. Your thoughts and feelings, like clouds, can come and go. You can practice noticing and observing what thoughts and feelings arise in different situations, just as you can observe and notice clouds in the sky. Make observations without evaluating what you notice. Learn to observe your thoughts and feelings without judgment. Just notice that you have a certain thought. See it as just a thought. Also, observe what sensations or emotions you have, without evaluating them. Notice the feelings as feelings in specific situations and be open to what you perceive. You have thoughts and feelings in different situations, and they vary. Can you think of yourself as a place where thoughts and feelings occur?

Now, as you observe your environment in this moment, notice that clouds are different from the sky. In the same way, you can think and notice that your thoughts are different from you. Thoughts are different from you, and they come and go within you. Observe how the clouds come and go while you make observations. You can look at them from a distance. Think that you can examine your thoughts and feelings in the same way while also being open and accepting of what you notice.

Examine your surroundings. What do you see, and what do you notice? Recognize that it's you who notices things and can decide what to do. The weather is what it is. You may not like the weather. It may be too hot or too cold. It may be raining, and you might get wet. However, the weather is what it is, and you can adopt an accepting perspective. Similarly, you can think that feelings and thoughts are what they are, and you can take an accepting perspective. You may not like all your feelings and thoughts. You may not want to experience them, especially if they are unpleasant. But just like the weather, unpleasant feelings and thoughts are what they are. It's important to notice and remember that even with unpleasant thoughts and feelings, you can move forward and do things that advance your studies. You can walk in the rain, wind, and snow. Notice that it might not be fun, but you can do it if you choose to. You can also give a presentation or do something else, even if it may not be very pleasant, just as walking in the wind and snow isn't pleasant. We can distinguish two things: first, you, and second, your thoughts and feelings in a specific situation and moment. You can observe your thoughts and feelings, just as you can observe clouds in the sky. You can take the same perspective on your feelings and thoughts as you can on clouds in the sky or the weather. They are what they are, and you can choose to accept what you notice. We hope that through the following exercises, you will learn to be more open to your own thoughts and feelings and that you will learn to act and do things with these thoughts and feelings.

Part 3 - One person

During your studies, as well as in other situations, there are often moments when attention is somehow focused on you, and you feel like you're being watched. Many students experience some level of uncertainty in these situations. In this virtual reality-created scenario, we practice observing what happens in this kind of situation.

Imagine you are in a situation where you are being looked at. Notice what thoughts and feelings arise. You may notice some tension in a part of your body. Pay attention to how your shoulders feel. If you notice tension in your shoulders or elsewhere in your body, make a mental note of it. Say to yourself, "I notice that..." and silently express what you observe. If you notice tension, let go of control. Take a deep breath in and slowly exhale. Continue looking in the

direction of the person looking at you. Be open to any feelings and thoughts that arise. You might feel a bit uncomfortable, uncertain, and perhaps sometimes stressed or anxious. Maybe you should say something or express your opinion. What thoughts and feelings do you notice right now when you're being looked at? Be with those feelings in this moment and keep looking at the other person. Whatever thoughts or feelings you have in this here and now, you can choose what to do. You can choose what to do with these thoughts and feelings. Remember that the skills and abilities you practice in this situation can also be applied in other situations later on.

Look at the person in front of you. What are you thinking right now? What thoughts do you have? Say to yourself silently, "I notice that..." and express what you notice. Now, notice how these thoughts affect you. Would you like to leave the situation? Would you prefer to look elsewhere? Notice that these are also thoughts, and all thoughts are welcome. Also, notice that you can decide how you react to them. Say to yourself silently, "I can choose how I react to these thoughts." Learn to notice how your own thoughts affect you. You can practice this during this exercise.

Look at the person in front of you. For example, you might notice a thought like "Will I be accepted?" or some other thought. How do these thoughts affect you? Do you tend to avoid certain situations? Do you tend to avoid public speaking situations? Are these thoughts or feelings possibly present in this situation right now? Pay attention to whether you often act too much in accordance with what your thoughts and feelings say. Do you believe your thoughts too much? Say to yourself silently, "Thoughts are just thoughts, and I can choose how I respond to them." You can choose how to respond to them right now.

Learn to be open and accepting of the thoughts and feelings you have when you are with others. You can take an accepting perspective on them. Feelings and thoughts are what they are. You may not necessarily like all your feelings and thoughts, but they are what they are. Even with unpleasant feelings, you can be present with others just as you are.

Part 4 - Three people

Next, we'll practice speaking in front of three people. This could be a presentation in a small group, where you are expected to share something you have done or written. What kind of thoughts does this situation trigger in you? ... Remember that thoughts are just thoughts, and you can choose how to respond to them. This could also be a job interview or a similar situation. These individuals might ask you questions, and you should respond while looking at them. Do you notice what feelings or sensations this situation arouses in you? ... Feelings are just feelings, and you can choose how to respond to them.

Look at the people in front of you... You may have a critical or unpleasant thought. For instance, you might think, "I'm not good enough." You might have the thought, "Do I know how to answer or what should I say?" Could you think of these thoughts as just thoughts, understanding that you are not just your thoughts; you are something different from individual thoughts? Say to yourself silently, "In this situation, I have thoughts, I can notice them and look at these people with these thoughts."

Notice that we can distinguish two things here: firstly, you, and secondly, your thoughts in this situation, at this moment. In another situation and moment, you might have a different thought. It might be essential to realize that in this moment, with these people, you have certain thoughts or feelings, and in another moment or situation, you might have a different thought or feeling. Feelings and thoughts are transient. Don't define yourself too much based on the thoughts that arise in individual situations.

Imagine you are in a situation where you need to present and share something related to your studies with this group. What do you notice right now? ... You may have feelings of uncertainty, critical thoughts about yourself, feelings of anxiety, or perhaps fear of what to say, whether you'll be accepted, or what someone thinks of you. Your mind generates all sorts of thoughts. Say to yourself silently, "Thoughts are words and sentences, and I can decide how I relate to them." ... You can be calm in this situation with these thoughts and feelings. Practice these things during your studies and in other situations as well. Remember this experience from this moment later on.

Part 5 – Audience

In the following section, we will practice speaking in front of a group or in a lecture. This could be the final seminar for a course where you present the results of your work. You are sitting at the front of the room, and you need to start your presentation. Notice what thoughts and feelings arise in you right now... Practice being open and accepting of the thoughts and feelings you have. You might be experiencing feelings of uncertainty, critical thoughts about yourself, anxiety, or even fear of being accepted or what someone thinks of you. Examine your thoughts and feelings. Be open to what you notice. Direct your gaze to the back of the room, and you can choose to look and focus on the audience, despite all the feelings and thoughts you have in this moment.

Continue to look at the people in the lecture. You may not necessarily like all the feelings and thoughts you have within you. Notice that they are a part of you, in this moment. You can continue looking at the audience with all the thoughts and feelings you have. Even with uncomfortable thoughts and feelings, you can still speak in front of others. You can be with others, look at them, give a presentation, or do something else that may feel challenging and laborious. Say to yourself silently, "I can choose what I do, no matter what feelings or thoughts I have."

You are at the front of the lecture hall and giving a presentation for your course. Practice being in this situation. You can choose how you respond to your thoughts and feelings. You have the ability to choose. Observe the thoughts you have right now. You might have thoughts like "What do students and teachers think of me?" "I'm afraid to look at those in the front row." Remember that you can choose to look and engage... Look at those sitting at the front of the room. You can choose to look. Remember these experiences you have during this exercise for later.

Also, remember and notice that each individual choice and action takes you closer to a greater goal or objective. Choose to look openly at the people in front of you... Completing the presentation and the course is a step towards a larger whole, and you can do it regardless of the thoughts and feelings you have.

Remember that these things described above can be seen as skills that can be practiced. As you practice and apply these skills, you may have the opportunity to increase your freedom and ability to act. You can choose how you respond to changing thoughts and feelings, and you can choose how you act. Practice these skills over the next week.

SESSION 3

Part 1 - Empty room

The purpose of these exercises is to teach a perspective on thoughts and feelings that research suggests can be beneficial. One key idea in this training is that we learn to act and do things even in the presence of uncomfortable thoughts and feelings and to create some distance from our thoughts. This is not always easy, but the goal is to increase the likelihood that it can happen. The goal is not to change or eliminate thoughts or feelings. This is because controlling thoughts and feelings can be difficult or impossible. Instead, the goal is to change the impact of thoughts and feelings. To achieve this, we need to learn certain skills for handling thoughts and feelings. In the following story, you can practice skills for managing thoughts and feelings in a way that promotes well-being. Note that this exercise teaches you principles and general methods that you can use and practice further in your studies and in your professional life.

One goal of this training is to increase your flexibility in different situations. You can practice functioning in situations where you might experience feelings of uncertainty. You can learn to do meaningful things even when situations evoke uncomfortable feelings or when you're unsure about what to do. Even in those moments, you can be calm and notice that thoughts and feelings are transient and change.

Learn to notice what thoughts are passing through your mind and how they affect you. Also, learn to notice what feelings you are experiencing and how they affect you. Now, pay attention to how your shoulders feel right now. Notice that it's you who observes these

sensations. Pay attention to the fact that you are the one making these observations, and you can choose how to react to what you notice. Just as you can observe when your breath happens or how your shoulders feel, you can also notice what thoughts and feelings you have, and you can choose how to approach them. When you notice thoughts and feelings, be open to what you observe.

Part 2 - Nature environment

These exercises are designed to teach you how to examine and handle your thoughts and feelings, especially when they are uncomfortable and preventing you from acting as you would like to. One related skill is adopting a new perspective on your own thoughts and feelings. You could think of it like this: just as breathing is only a part of you, certain thoughts and feelings are also just a part of you. Thoughts and feelings are transient, like clouds in the sky. Your thoughts and feelings can come and go. You can practice noticing and observing what thoughts and feelings you have in different situations, just as you can observe and notice clouds in the sky. Make observations without judging what you notice. Learn to make observations of your own thoughts and feelings without evaluating them. Just notice that you have a certain thought. Observe it as a thought. Pay attention to what sensations or emotions you experience without judging them. Notice emotional experiences in certain situations and be open to what you observe. You have thoughts and feelings in different situations, and they vary. Could you think of yourself as a place where thoughts and feelings occur?

As you observe your environment in this moment, you may notice that there are clouds in the sky. The clouds are different from the sky itself. There can be various types of clouds in the sky. Similarly, you can think and notice that your thoughts are different from you, and you can have various thoughts. Thoughts are different from you, and they come and go within you. Examine how the clouds come and go. You can also examine your thoughts and feelings in the same way. While doing this, practice being open and accepting of what you observe.

Examine your surroundings. What do you see and notice? Notice that it's you who observes things and can decide what to do. The weather is what it is. You may not like the weather. It might be too hot or too cold. It might be raining, and you might get wet. But still, the weather is what it is, and you can take an accepting perspective on it. Similarly, you can think of your feelings and thoughts as what they are, and you can take an accepting perspective on them. You may not necessarily like all your feelings and thoughts. You might not want to experience them, especially if they are uncomfortable. However, just like the weather, uncomfortable feelings are what they are. The important thing is to notice and remember that even with uncomfortable thoughts and feelings, you can still be and act. Think of it this way: even when you feel a bit anxious, fearful, or uncertain, you can do things that move you forward in your studies. If you choose to, you can also walk in the rain, the wind, and the snow. Notice that it might not necessarily be enjoyable, but you can do it if you choose to. Even with uncomfortable thoughts and feelings, you can also give a presentation or do something else that might not be very pleasant if you choose to. We can distinguish two things: first, you, who are in a particular situation, and second, your thoughts and feelings in that situation and moment. During this exercise, you can take the same perspective on your feelings and thoughts as you can on clouds in the sky or the weather. They are what they are, and you can choose to accept what you notice. We hope that with the help of the following exercises, you will learn to be open to your own thoughts and feelings and learn to act and do things with these thoughts and feelings.

Part 3 - One person

During your studies, as well as in other situations, there are often moments when the focus is on you, and you are being observed. Many students experience at least some level of uncertainty in these situations. In this virtual reality-created scenario, we'll practice observing what happens in a situation like this. You are now in a situation where you are being watched. This could be a pair discussion in class or a job interview. Notice what thoughts and feelings arise... You may notice tension in some part of your body. Notice how your shoulders feel. If you

notice tension in your shoulders or anywhere else in your body, acknowledge it. Quietly say to yourself, "I notice that..." and state what you observe... Learn to be present in this situation without judging what you notice. Breathe in and let the air come out slowly. Continue to look in the direction of the person looking at you. Be open to any feelings and thoughts that arise. Create some distance from them, as if you were observing them from a distance. It's possible that you might feel a bit uncomfortable, uncertain, stressed, or anxious. Imagine you have to say something or express your opinion right now in this situation. What thoughts and feelings do you notice at this moment when you're being watched? ... Be with those feelings in this moment and continue looking at the other person. Whatever thoughts or feelings you have in this moment, you can choose what to do. You can choose what to do with these thoughts and feelings. Notice that the skills and abilities you practice in this situation can also be applied in other situations during your studies.

Look at the person in front of you. What are you thinking right now? What thoughts are you having in this situation? Quietly say to yourself, "I notice that I have a thought that..." and state what you notice. Notice how these thoughts affect you. Would you like to leave the situation? Would you like to look elsewhere? Notice that these are also thoughts, and you can decide how you react to them. Say to yourself quietly, "I can distance myself from my thoughts and choose how I respond to these thoughts."... Learn to notice how your thoughts affect you and practice distancing yourself from them. You can observe your own thoughts from a bit further away. You can practice these things during this exercise.

Look at the person in front of you. Imagine that you have to say something. You might have to express your opinion. In situations like these, many students might have self-critical thoughts, such as "Am I good enough? Can I say something meaningful? What do others think?" ... How do these thoughts affect you? Do you tend to avoid certain situations? Do you avoid public speaking situations? Are these thoughts or feelings possibly present in this situation right now?... Pay attention to whether you are acting too much in line with what your thoughts and feelings say. Are you believing your mind too much? Say to yourself quietly, "Thoughts are just thoughts, and I can choose how I react to them." Say to yourself, "I may have critical thoughts about myself, but I can choose how to respond to them right now."

In public speaking situations and in other situations with other people, practice seeing your thoughts and feelings as a part of you. They don't entirely define what you do or who you are. You can create some distance from your self-critical thoughts and uncomfortable feelings. You can take an accepting perspective on them. They are what they are. You may not necessarily like all your thoughts and feelings, but still, they are what they are. Even with uncomfortable feelings, you can be present with others just as you are.

Part 4 - Three people

Next, we will practice speaking with three people. This could be a presentation in a small group, where you are expected to tell them something you have done or written. It could also be some other educational situation that takes place in a group, where you need to express your thoughts and opinions. What thoughts does this situation evoke in you? ... Remember that thoughts are just thoughts, and you can choose how to respond to them. In this situation, you might have thoughts that are critical, such as "What should I say?" "Will these other students accept me?" This could also be a job interview or a similar scenario. These individuals might ask you questions, and you are expected to respond while looking at them. You can calmly look at these individuals and think that there is room for all these feelings and thoughts within you. In public speaking situations or when you are with others, you may also experience uncomfortable feelings like uncertainty and anxiety. Feelings are just feelings, and you can observe them from a distance and choose how to respond to them.

Look at the people in front of you... You might have a critical or uncomfortable thought. For example, you might think, "These people are staring at me." You might think, "Maybe they can see how uncertain I am." You might think, "Can I answer if I'm asked something, or what would I say?" Could you think of these thoughts as just thoughts? The mind produces all kinds of thoughts. You can think that you are a place or space where these thoughts occur. You can

think, right now, as you look at those people in front of you who are looking at you, that you are something different from any individual thought in this situation. Quietly say to yourself, "In this situation, I have thoughts; I can notice them and look at these people with these thoughts."

Notice that we can distinguish two things here: firstly, you, and secondly, your thoughts in this situation, in this moment. In another situation and moment, you might have a different thought. It's important to recognize that we have a certain thought or feeling in this moment, with these people, and in another moment or situation, we might have a different thought or feeling. Feelings and thoughts are fleeting. Don't define too much of who you are based on individual thoughts that occur in specific situations. Remember these experiences for later.

Imagine that you are in a situation where you need to present and share something related to your studies with this group. They are looking at you, and you need to say something. What do you notice? ... Your mind can produce all sorts of thoughts. Quietly say to yourself, "Thoughts are words and sentences, and I can decide how to react to them." ... You can be calm in this situation with these thoughts and feelings. Practice these things during your studies and in other situations as well.

Part 5 – Audience

In this next section, we will practice speaking in front of a group or during a lecture. This could be the end seminar of a course where you are presenting your work results. You are sitting in front of the room, and you should start your presentation. Notice what thoughts and feelings arise in you right now... Learn to be open and accepting of the thoughts and feelings you are experiencing. You might be feeling uncertain, critical thoughts about yourself, anxiety, or even fear of whether you'll be accepted or what someone might think of you. Examine your thoughts and feelings as if you were examining an object like a table or a chair. Be open to what you observe. Shift your gaze to the back of the room, and you can choose to look and direct your attention towards the audience, all while being aware of the thoughts and feelings you have in this moment.

Continue looking at the audience during the lecture. You might not like all the thoughts and feelings you have. Notice that they are a part of you, in this moment. You can continue looking at the audience with all the thoughts and feelings you have. Even with uncomfortable thoughts and feelings, you can still give a presentation to others. You can look at others or do something else that might feel challenging and difficult. Quietly say to yourself, "I can choose what I do, no matter what thoughts or feelings I have."

You are in front of the lecture hall, giving a presentation for your course. Practice being in this situation. This is all about practice. It's actually interesting to think that you can choose how you respond to your thoughts and feelings. You have the ability to choose. Observe the thoughts you have right now. You might have thoughts like "What do the students and teachers think of me?" "I don't dare to look at those sitting in the front row." Notice that you can choose to look and engage... Now, look at those sitting in the front of the room. Even those sitting in the front row may experience feelings of uncertainty in public speaking situations. In this situation, their role is to be listeners, and your role is to be the speaker. You can be in this situation just as you are. You can be in the role of the speaker because sometimes that's your role. Roles are changing, just like your thoughts and feelings. Remember these experiences from this exercise and apply them later, for example, during your studies. Approach situations like these as practice opportunities where you have the chance to develop your skills.

Remember and notice that every single choice and action takes you closer to a greater goal or purpose. Choose to look openly at the people in front of you... This practice, just like giving presentations and completing courses, takes you toward a larger picture, and you can do it regardless of the thoughts and feelings you have. Remember that these aspects described above can be seen as skills that can be practiced. As you practice and apply these skills, you may have the opportunity to increase your freedom and your ability to act. You can choose how you respond to your ever-changing thoughts and feelings, and you can choose how you act. Practice these skills over the next week.

ORIGINAL PAPERS

I

PSYCHOLOGICAL PROCESSES IN THE SOCIAL INTERACTION AND COMMUNICATION ANXIETY OF UNIVERSITY STUDENTS: THE ROLE OF SELF-COMPASSION AND PSYCHOLOGICAL FLEXIBILITY

by

Simone Gorinelli, Ana Gallego, Päivi Lappalainen & Raimo Lappalainen, 2022

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Psychological Processes in the Social Interaction and Communication Anxiety of University Students: The Role of Self-Compassion and Psychological Flexibility

Simone Gorinelli*, Ana Gallego, Päivi Lappalainen, Raimo Lappalainen

University of Jyväskylä, Finland

Abstract

University students often experience difficulties in social interactions. The current study examined the role of self-compassion and psychological flexibility among university students (*N*= 76) reporting high levels of social interaction and communication anxiety. We observed that high social interaction (SIAS) and communication anxiety (PRCA-24) were associated with low levels of self-compassion and psychological flexibility. Upon further investigating the specific predictors for social interaction and communication anxiety, we found that self-judgment, over-identification and openness to experiences were the key components in self-compassion and psychological flexibility, respectively. However, after examining these components together, only self-judgment and over-identification remained crucial predictors. This suggests that, when training students to manage their anxiety in social situations, attention should be given to promoting skills of self-compassion and psychological flexibility in general. Special attention should be devoted to facilitating a non-critical, accepting and open attitude towards one's thoughts, emotions and negative interpretations.

Key words: social interaction anxiety, communication anxiety, psychological processes, self-compassion, psychological flexibility.

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Novelty and Significance

What is already known about the topic?

- Social interaction and communication anxiety are common among university students.
- Anxiety correlates with psychological flexibility and self-compassion.

What this paper adds?

- What subcomponents of psychological flexibility and self-compassion were associated with and predictors for social interaction and communication anxiety.
- Openness to experiences, self-judgment and over-identification were significant predictors.
- Self-judgment and over-identification were stronger predictor compared to openness to experiences.
- Openness to experiences, especially tackling self-judgment and fixating thoughts, seem to be critical when developing interventions for university students reporting high levels of social anxiety.

Anxiety disorders are considered among the most prevalent and earliest forms of mental disorders, with a wide prevalence ranging from 15% to 20% (Mohr & Schneider, 2013). The most common anxiety disorder is social anxiety disorder (SAD), with a lifetime prevalence of 12% (Ebrahimi, Pallesen, Kenter, & Nordgreen, 2019). SAD is often described as an acute fear of social situations in which a person worries about

* Correspondence: Simone Gorinelli, PO Box 35, Mattilaniemi, FI-40014, University of Jyvaskyla, Jyvaskyla, Finland. Email address: simone.s.gorinelli@jyu.fi. *Acknowledgements*: This work was supported by the Eino Jutikkala Fund (Suomalainen Tiedeakatemia [Finnish Academy of Science and Letters]) for conducting research during 2020. The funding source had no role in the study design, data collection and analysis, writing the article or in the submission of the article. The authors are grateful to Joanna Palén, Katja Mankinen, Jonna Ahvenkoski, Arimo Kerkelä, Marianne Vihervuori and Suvi-Tuulikki Udd for their help in data collection. Technical assistance provided by Petri Kinnunen and statistical assistance provided by Joona Muotka was also appreciated.

being negatively evaluated by others (Leichsenring & Leweke, 2017). SAD is extremely impairing; it can reduce quality of life and influence occupational, scholastic, and social situations (Ebrahimi *et alia*, 2019). Moreover, research found that in a large sample of young people (14-24 years old), those diagnosed with SAD had frequent comorbidities of substance misuse (41.3%), mood disorders (31.1%), and a secondary anxiety disorder (49.9%; Pilling, Mayo-Wilson, Mavranezouli, Kew, Taylor, & David, 2013). Among social anxiety, speech anxiety or, more commonly, public speaking anxiety is the most prevalent subtype (Furmark, Tillfors, Stattin, Ekselius & Fredrikson, 2000), and it commonly refers to the fear of speaking in front of others, which might cause distress or impairment in social, occupational, or other critical areas of functioning (Pull, 2012). These fears might be associated with tremors, blushing, sweating, or the avoidance of social situations (Leichsenring & Leweke, 2017). Public speaking anxiety is a disabling fear, with early onset occurring during adolescence and a prevalence ranging from 21% to 33% (Ebrahimi, Pallesen, Kenter, & Nordgreen, 2019). Social interaction skill difficulties seem relatively frequent among the general adolescent population (e.g., Ranta, Kaltiala-Heino, Rantanen, & Marttunen, 2009), but if left unprocessed, they may have substantial long-term, negative consequences. Even though numerous people with phobias do not seek proper intervention, these situations can impair normal life conditions (Ipser, Singh, & Stein, 2013). According to a recent national survey among Finnish university students (Kunttu, Pesonen, & Saari, 2017), one third of students experience substantial stress and perceive performing in public as the most frequent cause. While this is a considerable problem, university students are aware of the issue, and around 15% of them hope for support in matters related to social anxiety.

An increasing number of studies show how anxiety disorders are negatively associated with psychological flexibility (Kashdan & Rottenberg, 2010; Webb, Beard, Kertz, Hsu, & Björgvinsson, 2016) and self-compassion (Harwood & Kocovski, 2017; Werner, Jazaieri, Goldin, Ziv, Heimberg, & Gross, 2012). Self-compassion is a construct that Neff (2003) describes as being kind and understanding toward oneself when pain or failure arise rather than being self-critical; perceiving one's experiences as part of the larger human experience rather than isolating; and holding painful thoughts and feelings in mindful awareness rather than over-identifying with them. The self-compassion construct can be extensively described as a combination of positive and negative facets (self-kindness versus self-judgment, common humanity versus isolation, and mindfulness versus over-identification) that bundle together into six factors (Neff, 2003). These dualistic factors are not mutually exclusive, so a higher level in one aspect does not necessarily indicate a lower level in the opposite factor. This means that rather than focusing on negative thoughts, it is important to observe how someone chooses to react to them. Self-compassion, therefore, influences how people respond to diverse negative situations and performs as a defense mechanism against negative emotions and experiences (Marshall, Parker, Ciarrochi, Sahdra, Jackson, & Heaven, 2015). If self-kindness, common humanity, and mindfulness entail the definition of self-compassion, in contrast, self-judgment can be defined as a negative evaluation and criticism toward personal aspects and experiences, isolation occurs when a person feels alone in their struggle and separated from others, and over-identification can be observed when a tendency to fixate on negativity and failure occurs. In this context, a fear of both negative and positive evaluations from others is typically associated with social anxiety (Werner *et alia*, 2012). Nevertheless, little is known about the implications of self-judgment and negative evaluations toward individual experiences in social situations.

Psychological flexibility, on the other hand, can be described as fully contacting and mindfully opening up to thoughts and emotional experiences without trying to

avoid or control them (Hayes, Pistorello, & Levin, 2012), and adapting one's behavior to personal valued directions (Ruiz & Perete, 2015; Ruiz, Beltrán, Cifuentes, & Falcón, 2019). Being able to be open to personal experiences regardless of their positive or negative features has also been called acceptance. Acceptance and commitment to value-based actions are central features of Acceptance and commitment therapy (Hayes, Luoma, Bond, Masuda, & Lillis, 2006). Acceptance and commitment therapy (ACT) is a process-based approach founded on relational frame theory (RFT) that aims to increase psychological flexibility skills (Hayes, 2004; Hayes, Strosahl, & Wilson, 2012). ACT provides skills to handle painful events and to facilitate effective actions. ACT promotes psychological flexibility through six core processes: 1) acceptance of difficult experiences and thoughts that might appear when choosing one's values and goals, 2) contact with the present moment, that is, being here and now in the current situation and developing awareness of thoughts and emotional reactions, 3) defusion, or taking distance from one's thoughts, images, or memories, and being able to take action independent of what their mind is saying 4) self-as-context, or taking an observer perspective toward the aware part of the mind that can see emotions, sensations, and feelings taking place in one's mind, 5) description of values or ongoing actions toward what matters in life, and 6) committed actions, or doing what it takes to create a rich, full, and meaningful life in line with one's values (Hayes, 2004; Hayes, Pistorello, & Levin, 2012). Hayes, Villatte, Levin, and Hildebrandt (2011) suggested that psychological flexibility could also be described in terms of three "dyadic" processes or clusters: 1) psychological openness to experience (acceptance and defusion); 2) flexible attention to the now and perspective taking" (present moment awareness and self as context); and 3) motivation to change and meaningful actions (values and committed action) (Francis, Dawson & Golijani-Moghaddam, 2016). Additionally, in recent years, RFT-oriented researchers have reduced the six core processes of psychological flexibility to three key therapeutic strategies (Luciano, 2016; Törneke, Luciano, Barnes-Holmes, & Bond, 2015). The first strategy is to help the client discriminate the relationship between current functional classes of responding and problematic consequences. This refers to the importance in discriminating which behavior cause problematic consequences, or in RFT terms, causal framing where we link specific behaviors to specific consequences (Törneke *et alia*, 2015). The second strategy is to help the client frame their own responses in hierarchy with the deictic I, and to train this repertoire as an alternative functional class. This refers to the idea helping the client reduce the behavioral control functions of verbal responding (e.g. thoughts), and increasing the probability that alternative responses will be produced (Ruiz & Perete, 2015). Lastly, help the client develop alternative repertoires in a way that will specify desirable consequences (appetitive augmental functions) for further behavior. This refers to motivating a behavioral change by clarifying what really matters to the client and linking it to a new behavior (Luciano *et alia*, 2011; Törneke *et alia*, 2015).

One component with large importance in anxiety disorders and especially in social and public speaking anxiety is experiential avoidance (Kashdan & Rottenberg, 2010; Levin, Haeger, & Smith, 2017), which is the opposite of acceptance and refers to psychological inflexibility. Experiential avoidance is an important concept in ACT, and it is defined as an attempt to escape or avoid private events (unpleasant thoughts, emotions, memories) or features of an experience (Hayes, Strosahl, & Wilson, 1999). When this occurs, in clinical practice exposure can be used as a behavioral process to weaken easy access to avoidance (Hayes, Hofmann, & Wilson, 2020).

Among the student population and university context, psychological flexibility shows associations with mental health and academic success (Levin, Krafft, Pistorello, & Seeley, 2019), academic emotions (Asikainen, Hailikari, & Mattsson, 2018), self-efficacy (Jeffords, Bayly, Bumpus, & Hill, 2020), depression, and anxiety (Masuda & Tully, 2012). In accordance with previous studies on the student population, self-compassion shows associations with well-being (Fong & Loi, 2016; Neely, Schallert, Mohammed, Roberts, & Chen, 2009), resilience (Smeets, Neff, Alberts, & Peters, 2014), depression, and distress (Fong & Loi, 2016). Generally, studies demonstrate that psychological flexibility and self-compassion are relevant components for social and public speaking anxiety (Webb, Beard, Kertz, Hsu, & Björgvinsson, 2016; Werner *et alia*, 2012). Social anxiety, described as the fear of one or more social situations, is associated with isolation (Teo, Lerrigo, & Rogers, 2013) and negative impacts on general well-being. Further, the literature suggests how psychological flexibility, self-compassion, and well-being are positively associated and that self-compassion might be a greater significant predictor of well-being compared to psychological flexibility (Marshall & Brockman, 2016).

Given that psychological processes are relevant to anxiety disorders, the current study investigated which psychological processes were associated with anxiety experienced while socially interacting with others among university students. As both psychological flexibility and self-compassion have shown to be associated with wellbeing and psychological symptoms, we were especially interested in sub-components of psychological flexibility and self-compassion and their role in communication anxiety among young adults. Increased knowledge of the key psychological processes associated with social and communication anxiety can be decisive in developing more effective interventions. Psychological processes could also be a key factor toward a treatment goal and guide us toward evidence-based mechanisms of change (Hofmann & Hayes, 2019).

We were especially interested in increasing our understanding of what psychological processes were associated with social anxiety among students who experience high levels of social and interaction anxiety. We expected to observe low levels of psychological flexibility and self-compassion correspond to high levels of social interaction and communication anxiety. According to our previous knowledge regarding public speaking anxiety (Gallego, McHugh, Villatte, & Lappalainen, 2020), we expected the openness to experience sub-skill of psychological flexibility to be a crucial factor in social interaction and communication anxiety. However, studies on the role of self-compassion and its components in social and public speaking anxiety are limited. Finally, to the best of our knowledge, there are no studies among university students that have explored which components of both psychological flexibility and self-compassion are crucial to anxiety when interacting with other people. Findings in the current study could facilitate development of interventions for university students who experience high levels of social and public speaking anxiety.

METHOD

Participants

University students (*N*= 97) were recruited from different faculties of the University of Jyväskylä using newsletters and poster advertisements around campus. The advertisement stated: "Are you nervous before presentations", further, it was stated that student volunteers were being recruited for a Virtual Reality research study aiming to decrease perceived insecurity and anxiety in performing and other social situations. Thus,

the current paper is part of the intervention study, presenting the data collected during the pre-measurement phase. Students using psychogenic medication, participating in a parallel psychological treatment, or those who did not reply or had difficulties fitting the data collection in with their schedule were excluded from the study (*n*= 21). The final sample consisted of 76 participants (*M*age= 24.95, *SD*= 6.50) experiencing anxiety in social situations (see also results). The final sample was predominantly characterized by females (*n*= 53; 69.7%), as males accounted for only one third of the total participants (*n*= 23; 30.3%). The participants came from different fields of study, with an average of nearly three years of study background (Table 1). The study, privacy, and storage of personal data, informed consent, and background data were granted ethical approval by the University Ethical Committee on March 25, 2019.

Table 1. Participants Characteristics (*n*= 76).

Age *M (SD)*		24.95 (6.50)
Female		53 (69.7%)
Male		23 (30.3%)
Year of study		2.81 (3.04)
Faculty/ Education	Humanities and Social Sciences	22 (28.9%)
	Information Technology	16 (21.1%)
	Education and Psychology	15 (19.8%)
	Mathematics and Science	11 (14.5%)
	Sport and Health Sciences	9 (11.8%)
	Business and Economics	3 (3.9%)
Social Interaction Anxiety*	Minimal	30 (39.5%)
	Social Anxiety	46 (60.5%)
Communication Anxiety**	Low	0 (0%)
	Average	22 (28.9%)
	High	54 (71.1%)

Notes: *= Social interaction anxiety scores according to SIAS: cut-off score 34; **= Communication apprehension scores according to PRCA-24: 24-51 low, 51-80 average, 80-120 high.

Measures

Two different self-report scales were used to measure the students' social and communication anxiety: The Social Interaction Anxiety Scale (SIAS) and the Personal Report of Communication Apprehension (PRCA-24). In addition, Visual Analog Scales (VAS) were used to measure anxiety and fear associated with giving presentations. SIAS and PRCA-24 were our primary outcome or dependent variables, while Visual Analog Scales (VAS) were used as an additional measure in purpose to describe the investigated sample.

Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) measured anxiety associated with the initiation and maintenance of social interactions. The SIAS version used in the study is a 20-item scale (e.g., "I have difficulty talking with other people"). Originally, Mattick and Clarke's (1998) version of the SIAS was comprised of only 19

items and differed from the most commonly used 20-item version by the omission of the reversed scored item "I find it easy to make friends of my own age" (Heimberg, Becker, & Van Ameringen, 2004). Each item is rated on a 0 (Not at all characteristic or true of me) to 4 (Extremely characteristic or true of me) Likert scale. Total score ranges from a low of 0 to a high of 80, with higher scores indicating a higher level of social anxiety interaction. A cutoff score of 34 generally identifies a person with clinical social anxiety (Brown, Turovsky, Heimberg, Juster, Brown, & Barlow, 1997). The SIAS is internally consistent. Its alpha reliability originally ranged from .88 to .93 (Mattick & Clarke, 1998). In this study, the SIAS showed excellent internal consistency with a Cronbach's α of .92.

Personal Report of Communication Apprehension (PRCA-24; McCroskey, 1982) investigated anxiety and fear associated with communicating with others across four contexts: speaking in public, speaking in small groups, speaking in meetings, and interpersonal encounters. It is a 24-item scale (e.g., "Generally, I am nervous when I have to participate in a meeting") where higher scores represent greater communication anxiety (CA) in social situations. The PRCA-24 uses a 5 interval (1= strongly agree, 5= strongly disagree) Likert scale. The score among the four contexts can range from a low of 6 to a high of 30, with a total measure score of 24-120. Total scores below 51 represent people with very low CA, scores between 51 and 80 represent people with moderate CA, and scores above 80 represent people with high CA. The scale's internal reliability was estimated at .94 (McCroskey, 1984), with alpha reliability ranging from .93 to .95 (McCroskey, Beatty, Kearney, & Plax, 1985). We reported a Cronbach's α of .91 for the total measure and .71, .91, .91, and .79 for public speaking, group discussion, meetings, and interpersonal conversations, respectively.

Visual Analog Scales (VAS). In this study, the students answered the following questions: "How uncomfortable do you feel to give the speech?", "How stressful do you feel about giving a speech?", "How nervous does speaking make you?" and "How willing are you to give a speech?" The participants were instructed to indicate how they felt by selecting a number ranging from 0 (e.g. not uncomfortable at all) to 10 (e.g. extremely uncomfortable). According to Boonstra, Preuper, Balk, and Stewart (2014), a score ≤3.8 indicates mild symptoms, between 3.9-5.7 moderate, and scores ≥5.8 severe. These scales helped us understanding their subjective feeling when asked to talk or giving a speech.

Two scales were used to assess psychological processes. Self-compassion was measured by The Self Compassion Scale–Short Form, and psychological flexibility by The Comprehensive Assessment of ACT Processes. We selected these scales because they include several sub-scales, and thus, provide more specific information of the processes associated with the anxiety in social situations.

Self Compassion Scale–Short Form (SCS-SF; Raes, Pommier, Neff, & Van Gucht, 2011) was used to measure the self-compassion components self-kindness (SCS-SK), self-judgment (SCS-SJ), common humanity (SCS-CH), isolation (SCS-I), mindfulness (SCS-M) and over-identification (SCS-OI). It is a self-reported 12-item questionnaire (e.g., "I'm disapproving and judgmental about my own flaws and inadequacies") with a 5-point Likert scale ranging from 1 (Almost never) to 5 (Almost always) and higher total scores showing greater self-compassion. Each subscale component is described by two items where higher scores of self-kindness, common humanity, and mindfulness indicate greater self-compassion, and higher scores of self-judgment, isolation, and over-identification indicate lower self-compassion. The SCS-SF showed adequate internal consistency and an almost perfect correlation with the SCS long form (Cronbach's α >.86; Raes, Pommier, Neff, & Van Gucht, 2011). In this study, we observed good internal consistency with a Cronbach's α of .83 for total score and α= .56 for the SCS-SK, α= .78 for the SCS-SJ, α= .60 for the SCS-CH, α= .66 for the SCS-I, α= .65 for the SCS-M, and α= .65 for the SCS-OI.

Comprehensive Assessment of ACT Processes (CompACT; Francis, Dawson, & Golijani-Moghaddam, 2016) measured psychological flexibility, through the openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), and valued action

(CompACT-VA) subscales. The CompACT is a 23-item questionnaire (e.g., "I can keep going with something when it's important to me") with a 7-point Likert scale ranging from 0 (Strongly disagree) to 6 (Strongly agree) and higher scores representing greater psychological flexibility. The total score ranges between 0 and 138, with the CompACT-OE ranging from 0 to 60, the CompACT-BA ranging from 0 to 30, and the CompACT-VA ranging between 0 and 48. In this study, the CompACT showed good internal consistency (Cronbach's α= .83) for total score, with .78 for the CompACT-OE, .65 for the CompACT-BA, and .83 for the CompACT-VA subscales.

Procedure

The university students contacted the research team either by email or phone asking for more information or to inform us of their willingness to take part in the study. Then, any questions were answered, and a screening Webropol survey link containing more detailed information about the research was sent to the potential participants. The same webpage provided a section for the collection of preliminary personal information, inclusion criteria 1) no current intervention for performance anxiety or 2) no possible holidays during the intervention period, and informed consent. Students who met the inclusion criteria were contacted via email with instructions on how to reserve a time for an initial study session using the online scheduling tool Doodle. The meeting was conducted at the Department of Psychology, University of Jyväskylä, where the students were provided more detailed information about the study, privacy and storage of personal data, informed consent, and participant's background, and successively filled in pre-measurement questionnaires on a tablet provided by the researcher.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics 24. The correlations between the variables were investigated using the Pearson correlation test. We considered a small correlation to fall within r= 0.10–0.29, a moderate correlation within r= 0.30–0.49, and a high correlation within r= 0.50–1 (Cohen, 1992; Kraemer *et alia*, 2003). A Shapiro-Wilk's test (Razali & Wah, 2011; Shapiro & Wilk, 1965) and visual inspection of histograms, normal Q-Q plots, and box plots were used to investigate distribution normality among the variables and for detection of possible outliers. After consulting our statistical expert, two data points (one measurement value in CompACT-BA and one in CompACT-VA, respectively) differing significantly from other observations were detected as outliers and therefore removed. For variables that were not normally distributed, a non-parametric statistical analysis (Spearman's correlations) was used to examine correlations. The regression analysis was performed with the SPSS linear and multiple regression (stepwise) method, using significant correlation as a criterion for the selection of the variables. Thus, we selected for the regression analyses only those process variables of SCS-SF and CompACT that significantly correlated with the SIAS and PRCA-24. Further, we tested whether multicollinearity was a problem by calculating tolerance and variance inflation factors (VIF, Kutner, Nachtsheim & Neter, 2004). The selected variables did not represent a problem for multicollinearity having VIF scores under 2.5.

RESULTS

The mean values with standard deviations, min-max values and 95% Confidence intervals of the measures are described in Table 2. A significant number of participants

Table 2. Descriptive table of measurements.

	Mean (*SD*)	Minimum	Maximum	95% confidence interval	
				Lower	Upper
SIAS*	39.00 (15.00)	9	70	35.57	42.43
PRCA-24**	89.28 (14.23)	56	114	86.02	92.53
VAS1	8.29 (1.42)	4	10	7.97	8.61
VAS2	8.53 (1.27)	4	10	8.24	8.82
VAS3	8.46 (1.44)	4	10	8.13	8.79
VAS4	2.93 (2.46)	0	7	2.37	3.50
CompACT Total	83.13 (16.84)	45	118	79.28	86.98
CompACT-OE	30.68 (9.95)	10	51	28.41	32.96
CompACT-BA	18.18 (4.93)	8	30	17.03	19.32
CompACT-VA	35.05 (6.64)	18	47	33.52	36.59
SCS-SF Total	3.09 (0.65)	1.58	4.58	2.94	3.24
SCS - SK	3.65 (0.86)	2	5	3.45	3.84
SCS - SJ	3.19 (1.10)	1	5	2.94	3.44
SCS - CH	3.66 (0.99)	1	5	3.43	3.88
SCS - I	3.51 (1.14)	1	5	3.25	3.77
SCS - MI	4.04 (0.81)	2	5	3.86	4.22
SCS - OI	4.11 (0.82)	1.5	5	3.92	4.30

Notes: SIAS= Social Interaction Anxiety; PRCA-24= Communication Anxiety; CompACT= Psychological Flexibility; CompACT-OE= Openness Experiences; CompACT= Behavioral Awareness; CompACT-VA= Valued Action; SCS= Self-Compassion; SCS-SK= Self-Kindness; SCS-SJ= Self-Judgment; SCS–CH= Common Humanity; SCS-IS= Isolation; SCS-MI= Mindfulness; SCS-OI = Over-Identified; VAS1= "How uncomfortable do you feel to give the speech?"; VAS2 ("How stressful do you feel about giving a speech?"), VAS3= "How nervous does speaking make you?"; VAS4= "How willing are you to give a speech?"; *= Social interaction anxiety scores according to SIAS: cut-off score 34; **= Communication apprehension scores according to PRCA-24: 24-51 low, 51-80 average, 80-120 high.

reported a high degree of social and communication anxiety (Tables 1 and 2). Approximately 60% of the participants were categorized as having social interaction anxiety, and around 70% reported high communication anxiety. The cut-off score (34) for social interaction anxiety scale (SIAS) identifying persons with clinical social anxiety, was within the 95% confidence interval range in the current sample (Table 2). Also, PRCA-24 scale suggested that our sample represented people with high communication anxiety (scores above 80). Moreover, participants reported that they felt uncomfortable, stressful and nervous when giving presentations (Table 2, VAS scales).

As expected, higher levels of social interaction anxiety (SIAS) strongly and positively correlated with higher levels of communication anxiety (PRCA-24; $r(74)= .71$, $p < .001$; Table 3). After examining the process measures, the results showed that social interaction anxiety (SIAS) had a small negative correlation with valued actions (CompACT-VA; $r(74)= -.25$, $p= .029$) and it moderately negatively correlated with openness to experiences (CompACT-OE; $r(74)= -.40$, $p < .001$). The behavioral awareness (CompACT-BA) showed a small and non-significant correlation with the SIAS. Moreover, higher social interaction anxiety (SIAS) was highly correlated with lower self-compassion (SCS-SF total score; $r(76)= -.53$, $p < .001$). The SIAS especially correlated strongly with the SCS subscales self-judgment (SCS-SJ; $r(76)= .55$, $p < .001$) and over-identification (SCS-OI; $r(76)= .54$, $p < .001$), while moderately with isolation (SCS-IS; $r(76)= .46$, $p < .001$). The SCS subscales self-kindness, common humanity and mindfulness showed low and non-significant correlations with the SIAS.

Communication anxiety (PRCA-24) correlated with openness to experiences (CompACT-OE; $r(76)= -.24$, $p= .036$). Correlations between the PRCA-24 and valued actions (CompACT-VA) and behavioral awareness (CompACT-BA) were low and non-

Table 3. Correlations between social interaction anxiety (SIAS), communication anxiety (PRCA-24), psychological flexibility (CompACT) and Self-Compassion (SCS).

	PRCA-24	Comp ACT Total	Comp ACT-OE	Comp ACT-BA	Comp ACT-VA	SCS Total	SCS–SK	SCS-SJ	SCS-CH	SCS-IS	SCS-MI	SCS-OI
SIAS	.71**	-.41**	-.40**	-.13	-.25*	-.53**	-.05	.55**	-.19	.46**	-.20	.54**
PRCA-24	-	-.29*	-.24*	-.11	-.22	-.42**	-.11	.39**	-.18	.32**	-.21	.40**
CompACT Total		-	.87**	.59**	.68**	.55**	.30**	-.49**	.32**	-.50**	.23*	-.26*
CompACT-OE			-	.39**	.40**	.50**	.26*	-.50**	.30**	-.40**	.17	-.31**
CompACT-BA				-	.06	.29*	.16	-.30**	-.00	-.23*	.21	-.17
CompACT-VA					-	.41**	.25*	-.24*	.38**	-.44**	.21	-.07
SCS Total						-	.62**	-.78**	.68**	-.69**	.48**	-.68**
SCS - SK							-	-.40**	.49**	-.23	.30**	-.19
SCS - SJ								-	-.33**	.56**	-.14	.59**
SCS - CH									-	-.22	.34**	-.35**
SCS - I										-	-.17	.48**
SCS - MI											-	-.29*

Notes: SIAS= Social Interaction Anxiety; PRCA-24= Communication Anxiety; CompACT= Psychological Flexibility; CompACT-OE= Openness Experiences; CompACT= Behavioral Awareness; CompACT-VA= Valued Action; SCS= Self-Compassion; SCS-SK= Self-Kindness; SCS-SJ= Self-Judgment; SCS–CH= Common Humanity; SCS-IS= Isolation; SCS-MI= Mindfulness; SCS-OI = Over-Identified; *= The correlation is significant at the 0.05 level; **= The correlation is significant at the 0.01 level.

significant. High communication anxiety (PRCA-24) also moderately correlated with low self-compassion (SCS-SF total; $r(76)= -.42$, $p < .001$). Among the different self-compassion components, PRCA-24 correlated moderately positively with self-judgment (SCS-SJ; $r(76)= .39$, $p < .001$) and over-identification (SCS-OI; $r(76)= .40$, $p < .001$). Additionally, the correlation between isolation and the PRCA-24 was relatively high (SCS-IS; $r(76)= .32$, $p= .006$). The SCS subscales self-kindness, common humanity and mindfulness showed low and non-significant correlations with PRCA-24.

Our second aim was to examine which psychological processes were predictors for social interaction and communication anxiety. We calculated first linear regressions and completed it with the stepwise models to predict social interaction anxiety (SIAS) and communication anxiety (PRCA-24) using psychological flexibility (CompACT) and self-compassion (SCS) as predictors (Table 4). For the analyses, we selected only

Table 4. Regression analyses showing significant predictors for Social Interaction Anxiety Scale (SIAS) and Communication Anxiety (PRCA-24). Standardized β values with 95% confidence intervals and R square (R^2) values are also presented (indicating the percentage of variance explained).

Model		Predictor	SIAS	PRCA-24
CompACT	1	*Total* (Std β)	-.41* (-.55; -.17)	-.29* (-.43; -.06)
		R^2	.16	.08
	2	*CompACT-OE* (Std β)	-.40* (-.92; -.29)	-.24* (-.67; -.02)
		R^2	.15	.06
	3	*CompACT-VA* (Std β)	-.25* (-7.54; -.38)	
		R^2	.06	
	4#	*CompACT-OE* (Std β)	-.39* (-.91; -.26)	
		CompACT-VA	Excluded, p = .273	
		R^2	.15	
SCS-SF	1	*Total* (Std β)	-.53* (-16.73; -7.70)	-.42* (-13.78; -4.62)
		R^2	.28	.18
	2	*Self-Judgment (SCS-SJ)* (Std β)	.57* (5.10; 10.32)	.41* (2.75; 8.77)
		R^2	.32	.16
	3	*Over-Identified (SCS-OI)* (Std β)	.56* (6.62; 13.64)	.44* (3.33; 9.25)
		R^2	.31	.20
	4	*Isolation (SCS-IS)* (Std β)	.46* (3.39; 8.78)	.32* (1.45; 7.70)
		R^2	.22	.10
	5#	*Self-Judgment (SCS-SJ)* (Std β)	.36* (1.79; 8.88)	Excluded, p = .122
		Over-Identified (SCS-OI) (Std β)	.33* (1.42; 8.50)	.44* (3.33; 9.25)
		Isolation (SCS-I)	Excluded, p = .247	Excluded, p = .342
		R^2	.39	.20

Notes: SIAS= Social Interaction Anxiety; PRCA-24= Communication Anxiety; CompACT= Psychological Flexibility; CompACT-OE= Openness Experiences; CompACT= Behavioral Awareness; CompACT-VA= Valued Action; SCS= Self-Compassion; SCS-SK= Self-Kindness; SCS-SJ= Self-Judgment; SCS–CH= Common Humanity; SCS-IS= Isolation; SCS-MI= Mindfulness; SCS-OI = Over-Identified;; Std β= Standardized β values; R^2= R square values; *= Significant predictors; #= stepwise model was applied in purpose to identify the most significant predictors.

those process variables (SCS, CompACT) that significantly correlated with the SIAS and PRCA-24 (see also Table 3).

In relation to social interaction anxiety (SIAS), the CompACT and SCS total scores explained 16% and 28% of the variance in the SIAS, respectively. The CompACT subscales openness to experiences and valued action were both significant predictors, accounting for 15% and 6% of SIAS scores, respectively. When these CompACT subscales were included in the same model, only openness to experiences (OE) remained significant (Model 4, Table 4). Regarding self-compassion (SCS), the subscales self-judgment (SJ, 32% of the variance explained), over-identification (OI, 31%) and isolation (IS, 22%) were significant SIAS predictors (variance explained in the parentheses). When all these SCS subscales were included in the same model, both self-judgment and over-identification remained as significant predictors (Model 5, Table 4).

Regarding communication anxiety (PRCA-24), the significant predictors were similar as for SIAS, but the proportion of variance explained by these predictors was smaller compared to the SIAS. The CompACT and SCS total scores explained 8% and 18% of the variance in the PRCA-24, respectively. The CompACT subscale openness to experiences was the only significant predictor, accounting for 6% of PRCA-24 scores (Table 4). Regarding self-compassion (SCS), the subscales self-judgment (SJ, 16%), over-identification (OI, 20%) and isolation (I, 10%) were significant PRCA-24 predictors (variance explained in the parentheses). When all these SCS subscales were included in the same model, only over-identification remained significant (Model 6, Table 4).

Finally, all subscales (CompACT: openness to experiences, valued actions –only for SIAS; SCS: self-judgment (SJ), isolation (IS) and over-identification (OI)) were included in the regression analyses to identify the strongest set of predictors. In SIAS, the model ($F_{2,72}$= 22.98, p <.001) included both the SCS subscale self-judgment and over-identified as significant predictors with an R^2= .39 (SCS SJ: Std β= .37; *CI*= 1.99, 9.04; SCS OI: Std β= .32; *CI*= 1.21, 8.28). In PRCA-24 instead, the model ($F_{1,74}$= 14.50, p <.001) included only the SCS subscale over-identified (PRCA-24, Std β= .44; *CI*= 3.33, 9.25; R^2= .20).

DISCUSSION

The aim of this study was to obtain a deeper understanding of the psychological processes or factors that are associated with communication anxiety among university students who reported high levels of anxiety when interaction with others. We were especially interested in investigating the role of self-compassion and psychological flexibility sub-components. The results demonstrated that high levels of self-reported anxiety while interacting with others was associated with low levels of self-compassion and psychological flexibility, as measured by SCS and CompACT, respectively. Previous research has also demonstrated negative associations between social anxiety and psychological flexibility (Kashdan & Rottenberg, 2010) and self-compassion, showing that people with social anxiety disorders have significantly lower self-compassion (Werner *et alia*, 2012). This study confirms that the role of self-reported self-compassion and psychological flexibility seems particularly relevant among university students who mean to train their social skills.

There is a growing indication that experiential avoidance plays a crucial role in anxiety related to social situations (Kashdan & Rottenberg, 2010; Levin *et alia*, 2017). In this study, our results suggested that openness to experiences, as measured by CompACT,

was one of the key factors in psychological flexibility that was associated with self-reported social interaction and communication anxiety. The current results present the benefits of being open to thoughts, feelings, or physical sensations without trying to avoid or change them when taking part in social interactions. In line with this, previous studies note the association of the fear of negative and positive evaluations with social anxiety (Weeks *et alia*, 2005), acknowledging the role of self-judgment and how people relate with negative experiences in social interaction. Self-judgement, in this context, refers to thoughts about the self and the critical or negative judgment involved in those thoughts, while over-identification refers to the fixation on these negative thoughts and emotions. They entail the non-accepting view of personal experiences and inadequacies; meanwhile, a compassionate point of view toward negative experiences refers to being understanding and accepting toward failures and painful thoughts, feelings, and emotions. Self-judgment and over-identification appeared to be the predominant component in self-compassion (as measured by SCS), accounting together for almost half of the variance (39%) in social interaction anxiety (SIAS). Additionally, self-reported over-identification with negative thoughts remained the only predictor and it represented one fifth of the variance (20%) in communication anxiety (PRCA). Thus, high levels of self-reported over-identification and self-judgment, and low levels of openness to experiences, were predictors for anxiety when interacting with others. However, when investigating all these components together, only self-judgment together with over-identification remained as a significant predictor of self-reported social anxiety, while only over-identification remained as a predictor of self-reported communication anxiety. These two processes are closely connected and suggest how people could become critical towards their thoughts and feelings, and how they at the same time could fixate on those negative experiences. This finding finally suggested that, when training students to manage their anxiety in situations where social interaction or communication is required, attention needs to be given to their reactions when they are disapproving, judgmental and when they identify themselves with their own thoughts. In other words, students may need to train discriminate that disapproving and judgmental reactions accompanied with identification with thoughts may cause problematic consequences. Further, they might need training in skills reducing the behavioral functions of verbal responding and training of alternative responses in social situations. Overall, these findings highlight the importance of accepting attitude toward one's own physical feelings, emotions, thoughts, and negative interpretations in social situations.

These results are consistent with previous literature that states that both low self-compassion (Leary, Tate, Adams, Batts Allen, & Hancock, 2007) and psychological flexibility (Hayes *et alia*, 2006) can account for impairments in social and personal experiences. Further, earlier studies (Marshall & Brockman, 2016) as well as the current study have shown that self-compassion and psychological flexibility are associated with each other. In the current data, psychological flexibility as measured by self-report measurement CompACT total and self-compassion as measured by SCS total scores were highly correlated (r= 0.55). This raises the possibility that both CompACT and SCS are measuring the same phenomenon. On the other hand, in accordance with our findings, it has been suggested that self-compassion is a greater significant predictor of emotional well-being compared to psychological flexibility (Marshall & Brockman, 2016). The importance of self-compassion has further been shown in a longitudinal study by Marshall *et alia* (2015) exemplifying how self-compassion appears to act as a defense mechanism against negative emotions and experiences.

More studies are needed to confirm that increasing self-compassion and psychological flexibility skills, especially those skills demonstrating acceptance, tolerance, and an approving attitude toward oneself, can lower self-reported levels of anxiety when interacting and communicating with others. Moreover, further research is required to examine which psychological processes are truly involved when a decrease in anxiety is observed. The current study points out possible candidates for these processes.

In this study, however, we also need to take several limitations into consideration. The main limitation concerns the small study sample. The participants involved in this study (*N*= 76) were limited in numbers, but for a few reasons. One reason for the small sample can be attributed to the global coronavirus pandemic (COVID-19) and related national and university safety regulations. The original aim was to recruit more participants during 2020 and early 2021, but we had to stop recruiting because of the university coronavirus directives. Nevertheless, we decided to run another round of data collection during Fall 2021, and we expanded the original sample by 30 participants. Additionally, we were mainly interested in recruiting a specific group of students who wanted to improve their social and public speaking skills. Another limitation was the use of self-reported questionnaires to collect data, which could have influenced the current study's validity. For instance, the self-compassion components were measured through subscales in a short form of the Self-Compassion Scale (SCS), which might deliver low internal consistency. In fact, Raes, Pommier, Neff, & Van Gucht (2011) recommends using the scale's full form for a detailed investigation of the subscales. However, as Raes et alia (2011) also states, reliabilities for all but one subscale (self-kindness) were above 0.60, and Cronbach's alphas of 0.60 and above are generally deemed acceptable. In line with the validation of the short form SCS, in this study, reliabilities for all but one subscale (self-kindness) were above 0.60. Moreover, psychological flexibility was measured with the CompACT, a relatively new scale that has not been predominantly used in the literature. Psychological flexibility, in a recently growing number of studies, has more commonly been measured with the AAQ-II (Acceptance and Action Questionnaire, Bond et alia, 2011). However, the CompACT has good internal consistency, and it allows the investigation of psychological flexibility across three dimensions (openness to experiences, behavioral awareness, and valued actions), which is useful for understanding different components of psychological flexibility in relation to anxiety. An additional limitation involves the study participants, who were university students, which may limit the generalization of these results to the clinical population. Nevertheless, a high prevalence of social and performing anxiety is common among the selected population. Even though the Social Interaction Anxiety scale (SIAS) can be a useful instrument to measure anxiety in social situations, research has found that students may approach some items differently to the clinical population, making them less likely to meet the cutoff (Rodebaugh, Woods, Heimberg, Liebowitz, & Schneier, 2006). Nevertheless, in this study we investigated two outcome measures for social interaction anxiety (SIAS and PRCA-24) and generated comparable conclusions. Finally, one other limitation concerns the results' generalizability. A large part of the participant sample was characterized as female (70%), while males accounted only for around one third of the entire sample. As Neff (2003) describes, women generally report lower self-compassion scores and higher levels of self-judgment, isolation, and over-identification. Therefore, a larger randomized controlled trial with a more balanced gender population is needed.

The current study illuminated how social interaction and communication anxiety were associated with specific components of psychological flexibility and self-compassion.

Therefore, psychological interventions aimed at helping people with social anxiety might benefit if focused on increasing these skills. Specifically, attention should be given to how young adults negatively evaluate or criticize their personal aspects and how they fixate on those negative thoughts and emotions. Young adults with communication anxiety should be trained to promote acceptance, tolerance, and an approving attitude toward themselves. Future research is needed to investigate the role of psychological processes involved in social and communication anxiety. Increased knowledge of psychological processes can help practitioners for establishing effective therapeutic interventions (Hofmann & Hayes, 2019).

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II

VIRTUAL REALITY ACCEPTANCE AND COMMITMENT THERAPY INTERVENTION FOR SOCIAL AND PUBLIC SPEAKING ANXIETY: A RANDOMIZED CONTROLLED TRIAL

by

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

Simone Gorinelli *, Ana Gallego, Päivi Lappalainen, Raimo Lappalainen

Department of Psychology University of Jyväskylä, Finland

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ABSTRACT

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

1. Introduction

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

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

* Corresponding author. Department of Psychology, FI-40014, University of Jyväskylä, Finland.
E-mail address: simone.s.gorinelli@jyu.fi (S. Gorinelli).

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

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

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

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

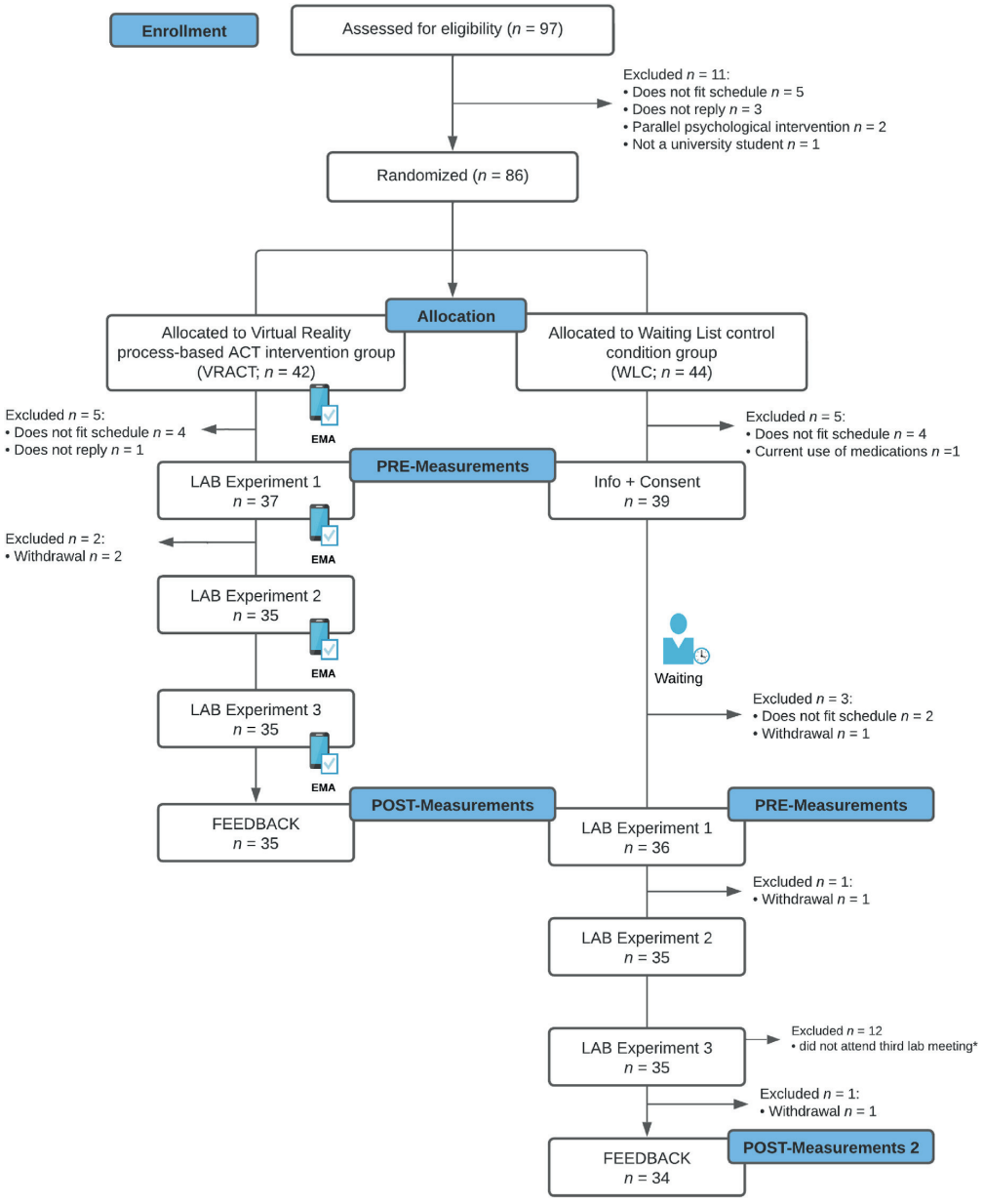
2. Method

2.1. Design

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

2.2. Participants

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



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

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

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

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

2.3. The virtual reality intervention

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

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

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

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

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

Table 1
Participant characteristics.

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

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

2.4. Technical equipment

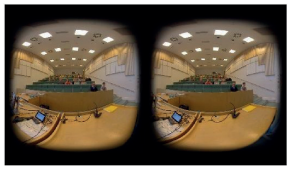
For the virtual intervention, the HTC Vive PRO Virtual Reality HMD was used. It has a resolution of 2880 × 1600 (615 PPI), with a 90 Hz refresh rate, a 110-degree field of view, built-in spatial audio, and an integrated microphone that allows for easy immersion. It is a tethered VR headset connected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

2.5. Measures

2.5.1. Primary outcome measures

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

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

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

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

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

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

2.5.2. Secondary outcome measures

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

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

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

2.5.3. Process measures

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

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

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

2.6. Statistical analysis

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

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

3. Results

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2. Intervention effects: waiting list control group after intervention

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

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

3.3. Avoidance & distress tolerance

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

4. Discussion

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

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

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

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

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

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

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

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

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

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

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Declaration of competing interest

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III

THE IMPACT OF VIRTUAL REALITY-BASED ACCEPTANCE AND COMMITMENT TRAINING ON PSYCHOLOGICAL FLEXIBILITY IN EVERYDAY CONTEXTS: AN ECOLOGICAL MOMENTARY ASSESSMENT STUDY

by

Simone Gorinelli, Ana Gallego, Päivi Lappalainen, Joona Muotka & Raimo Lappalainen, 2023

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ABSTRACT

Objective: as digital innovation advances, technological solutions are likely to play a progressively significant role in the delivery of psychological interventions. Based on this projected future, the aims of this study were (a) to investigate the impact of acceptance and commitment therapy (ACT) delivered via virtual reality (VR) tools on psychological flexibility over time in everyday contexts by using ecological momentary assessment (EMA) and (b) to explore the psychological processes of change that were involved in clinical improvement in social interaction or communication anxiety. **Method**: a sample of university students (N = 37; age: M = 24.03 years, SD = 4.35; 70.3% females) was exposed to three VR-based ACT intervention sessions and asked to simultaneously fill out EMA surveys to measure psychological processes in real-life contexts over time. Additionally, a subsample of participants (n = 8) was observed using a single case design (SCD) to examine the psychological processes of change involved in the clinical improvement of anxiety after the VR-ACT intervention. **Results**: the results showed how psychological flexibility and its subprocesses measured with EMA improved over time and across contexts and, therefore, support the effectiveness of ACT delivered via VR. In addition, the findings revealed substantial variations in the processes of change involved in individuals who showed clinical improvements in anxiety. **Conclusions**: this is the first study to contribute knowledge on how ACT can be successively delivered in the VR format to improve the contextual psychological processes of university students beyond traditional self-reported methods. Furthermore, the study findings underline the importance of paying attention to individual changes in psychological processes when providing ACT-based treatments.

Keywords: virtual reality, ecological momentary assessment, acceptance and commitment therapy, psychological flexibility, processes of change, university students

Introduction

Psychological processes represent a valuable mechanism that can be studied to understand the changes brought about by effective interventions (Hofmann & Hayes, 2019). Further, focusing on the psychological processes of change appears to be important, regardless of the approach used in therapy (Ciarrochi et al., 2010; Rosen & Davison, 2003; Villatte et al., 2016). In acceptance and commitment therapy (ACT; Hayes et al., 1999), the goal is to increase psychological flexibility through six psychological processes of change (Twohig, 2012). ACT cam improve the receiver's ability to fully and openly be in the present moment while mindfully observing their inner experiences without feeling the need to change them, and, based on the context, persuade themselves to reach their personal goals or values (Hayes et al., 2006; Hayes et al., 2012; Hayes et al., 2013). The six core psychological processes are acceptance, defusion, present moment awareness, self-as-context, values, and committed actions, and these have also been described in terms of three "dyadic" processes: (1) psychological openness to personal experiences, (2) flexible attention to the present moment and perspective taking, and (3) valued actions and motivation to change (Francis et al., 2016). Changes in these processes are believed to result in positive life benefits (e.g., Hayes et al., 2011).

ACT is a process-based transdiagnostic approach that has been used to effectively address various psychological issues in diverse samples (A-Tjak et al., 2015; French et al., 2017; Howell & Passmore, 2019). Across multiple studies, psychological flexibility and its related processes have been found to be associated with psychological distress and well-being (Francis et al., 2016), depression (Masuda & Tully, 2012), chronic pain

(McCracken & Morley, 2014), social and public-speaking anxiety (Azadeh et al., 2015; Gorinelli et al., 2022), and psychological and overall mental health (Kashdan & Rottenberg, 2010; Levin et al., 2019). Distinct processes seem to be associated with specific symptoms: for example, cognitive fusion is associated with depressive symptoms (Pinto-Gouveia et al., 2020), and experiential avoidance is associated with depression, anxiety, and related disorders (Akbari et al., 2022). Thus, different components of psychological flexibility might be negatively associated with stress, depression, and anxiety (Brandolin et al., 2023; Flowers et al., 2023; Francis et al., 2016; Kroska et al., 2020; O'Boyle-Finnegan et al., 2022; Rogge et al., 2019). On the contrary, multiple studies seem to suggest that acceptance and openness to experiences is an essential process in anxiety among university students (Gallego et al., 2020; Gorinelli et al., 2022; Morin et al., 2021). Therefore, there is a need for research on identifying the processes of change in mental health while also paying attention to individual differences and using appropriate measurements (Akbari et al., 2022; Hofmann & Hayes, 2019; Morin et al., 2021).

New ways of collecting data, such as single case design (SCD), are providing alternative solutions to traditional methods, such as randomized controlled trials, for investigating psychological interventions and processes of change (Hulbert-Williams et al., 2021; Villatte et al., 2016). Often, traditional self-reported measures are based on participants' recall of past events, which are influenced by an individual's thoughts about their behavior or by their surrounding environment (Schwarz, 2007; Stone & Shiffman, 1994). Thus, there is a risk of retrospective recall bias with these methods; moreover, they do not address how behavior changes over time and across contexts (Shiffman et al., 2008). Thus, there is a need for alternate approaches to collecting data. The increasing usage of mobile technology spurred the development of ecological momentary assessment (EMA), which can overcome the limitations of traditional quantitative methods in psychological science and can be used to monitor a person's experience during daily life (Mitchell et al., 2022; Runyan & Steinke, 2015; Wrzus & Neubauer, 2023) while promoting behavior change (Dao et al., 2021). EMA typically involves the assessment of circumstances or behavior several times per day over multiple days at prompted or random times, or after engaging in a target behavior (Stinson et al., 2022). The "ecological" aspect of EMA refers to the high ecological validity of the assessment, which allows the generalization of results to real-life contexts (Shiffman et al., 2008). Furthermore, previous literature suggests that interventions using EMA measures can be effective and increase engagement in behavioral changes (Heron & Smyth, 2010; Schueller et al., 2017). EMA can be distinguished from other measurements by the following attributes: (1) assessments are done in real time while the phenomena occur; (2) assessments are carefully taken at specific times; (3) assessments are repeated multiple times; and (4) assessments are delivered in the individuals' daily life context (Stone & Shiffman, 1994).

An increasing number of EMA-based studies are being conducted in different fields of psychology (Wrzus & Neubauer, 2023), including ACT (Grégoire et al., 2020; Hulbert-Williams et al., 2021). However, there is a need for further ACT studies (Hayes et al., 2021; Ong et al., 2023) that use EMA or daily assessments of interventions. This could contribute to a better understanding of the effectiveness of ACT and its processes as EMA permits the observation of individuals over time and across contexts. Repeated systematic EMA measurements are well-suited to and strengthen the internal validity of SCD, a methodology often used for examining psychological and behavioral changes in a single or small group of individuals (Bentley et al., 2019). With the ongoing

advancements in technology, EMA can be applied as a standalone intervention (Colombo et al., 2019; Marciniak et al., 2020; Schueller et al., 2017) or in conjunction with other technologies such as virtual reality (Berkhof et al., 2021; Bossenbroek et al., 2020; Geraets et al., 2020; Pot-Kolder et al., 2018) and augmented reality (Marquet et al., 2018; Sayette & Goodwin; 2020). In particular, virtual reality (VR) has already been applied across various psychological interventions and shown promising results as an exposure tool in the treatment of anxiety disorders (Carl et al., 2019; Dellazizzo et al., 2020; Powers & Emmelkamp, 2008). VR allows for the creation of virtual environments as well as control over the intensity and repetition of a fearful situation, making it a possible alternative to imagined or in-person exposure (Gebara et al., 2016). However, only a limited number of studies investigating the effect of VR interventions have included daily momentary assessment of symptoms in young populations (Björling et al., 2022). This could facilitate a better sense of the impact of modern technological interventions in everyday life, beyond traditional self-report measures.

In our previous studies (Gorinelli et al., 2023), we showed how university students immersed in a VR-based ACT (VRACT) intervention experienced a decrease in their self-reported social and public-speaking anxiety and a simultaneous increase in their self-reported psychological flexibility and its subprocesses. However, we were also interested in observing whether psychological flexibility changed over time and across individuals' contextual situations, that is, in everyday living conditions. Therefore, the current study was conducted with the aim of observing whether the VRACT intervention could improve psychological flexibility skills in real-life contexts based on EMA measurements. In our prior research, we observed that openness to experiences, an acceptance sub-component of psychological flexibility, was associated with and possibly predictive of social and public-speaking anxiety in university students (Gallego et al., 2020; Gorinelli et al., 2022). As previous studies have indicated that social anxiety is associated with specific components of psychological flexibility, another aim of the present study was to examine individual psychological flexibility processes of change in everyday life settings among students who showed clinically significant improvements in social interaction and communication anxiety. To this end, we used a SCD approach to observe individual changes in participants using an AB design. To the best of our knowledge, no studies so far have explored the effectiveness of a VRACT intervention on psychological flexibility skills in everyday living contexts or adopted SCD to examine individual differences in changes in psychological flexibility processes among those who have benefitted from the intervention.

The hypotheses that form the basis of this research are as follows: (1) the VRACT intervention increases psychological flexibility over time in everyday contexts based on EMA measurements; (2) the psychological flexibility subdimension openness to experiences significantly increases in individuals who show clinical improvements in their social or communication anxiety after participating in the VRACT intervention.

Methods

Design

The current study was part of a broader intervention study (n = 76; Gorinelli et al., 2023) aimed at decreasing social interaction and communication anxiety by delivering a process-based ACT intervention via VR. As described in our previous study, the VRACT intervention included VR exposure for 20–25 min once a week over a period of three weeks (which added up to less than 2 h of VR exposure) and included different 3D 180-degree neutral and social exposure video scenarios. Through the VR head-mounted

display, participants were simultaneously exposed to five VR scenarios (including one baseline, one neutral, and three social scenarios) while listening to an ACT audio intervention that included openness to experiences exercises, behavioral awareness exercises, as well as hierarchy-based exercises (e.g., "your thoughts and emotions are part of you") and distinction-based exercises (e.g., "you are different from your thoughts"). The intervention promoted acceptance, which may reduce experiential avoidance associated with social interaction and public speaking anxiety. This procedure was repeated three times, once weekly for the duration of three weeks. The exercise was influenced by our previous study (Gallego et al., 2020) and previous literature that suggested the importance of openness to experiences and behavioral awareness when combating fear of public speaking or general anxiety (England et al., 2012; Flowers et al., 2023; Kocovski et al., 2009; O'Boyle-Finnegan et al., 2022). Overall, the intervention was highly "automated" and standardized because it used pre-recorded VR scenarios and ACT audio exercises combined. Thus, there were no individual variations in the delivery of the intervention.

This research was conducted between the autumn of 2019 and the spring of 2020 and during the autumn of 2021. The current study included a group of students (n = 37) who, while participating in the VRACT study, filled in the EMA data during their daily life for one week in the baseline period and for the three weeks of the intervention period. The university's Ethical Committee granted their ethical approval for the study on March 29, 2019. By using identification codes and pseudonyms, students' personal information was made anonymous. The design of the study and more details can be seen in the flowchart presented below (Fig. 1).

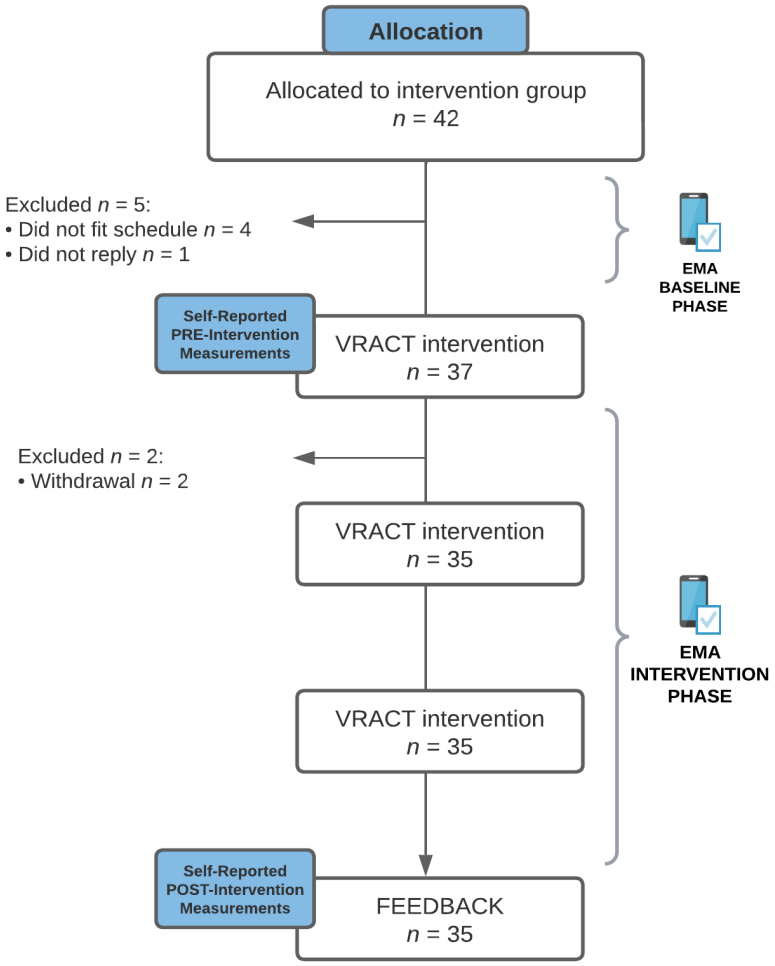


Figure 1 *Flowchart depicting the current study protocol*

Participants

Participants were recruited using newsletters and poster advertisements placed around campus at the University of Jyväskylä, Finland. The advertisement stated that student volunteers were being recruited for a research study to investigate perceived insecurity and anxiety in performing and other social situations. The advertisement included brief information about the study and contact information for enrolling. A sample of 42 participants was allocated to the intervention and asked to download the EMA application to their phones. Students who failed to respond to the emails or had difficulty participating in the intervention due to their schedules were excluded (n = 5). This yielded a final sample of 37 students (age: M = 24.03, SD = 4.35) who provided their baseline EMA data and their informed consent to the researchers. The sample represented university students with social interaction anxiety (n = 22; 59.5%) and high communication anxiety symptoms (n = 28; 75.7%), as measured by the Social Interaction Anxiety Scale (SIAS) and the Personal Report of Communication Apprehension (PRCA-24), respectively. The majority of the participants were females (n = 26; 70.3%), with the remaining 29.7% identifying as males. The students had completed an average of 2.41 (SD = 2.49) years of studies.

Enrollment

University students who were interested contacted the research team by email or phone to request for more information or express their willingness to participate in the study. Potential participants were sent a link to a Webropol survey for screening and for providing detailed information about the research. The webpage contained a section for collecting preliminary personal information that could determine whether potential participants met the following inclusion criteria: (1) no current interventions for performance anxiety and (2) no possible holidays during the intervention period. Another inclusion criterion was provision of informed consent. Students who met the inclusion criteria were emailed instructions on how to download and use the EMA phone application (see details below) and how to reserve a time for an initial intervention session with the online scheduling tool Doodle. Non-students, individuals who were on psychogenic medication, those participating in a parallel psychological treatment, and those who did not reply to the emails or had difficulties fitting the intervention into their schedule were excluded from the study.

Procedure

After the students who met the eligibility criteria were enrolled in the study, an automatic email with instructions on downloading the EMA phone application (https://metricwire.com) for either the Android or iOS operating system was sent. The instructions also guided the participant through the process of registering for the application using their previous email and an additional anonymous identification code. During the baseline phase, participants filled out EMA surveys twice daily for 7 consecutive days. Following this, they were asked to participate in three face-to-face lab intervention sessions once a week for three weeks (Fig. 1). Immediately before the first session was started, participants were asked to provide their informed consent on paper, along with their self-reported anxiety and processes measures. The sessions aimed to improve social interaction and communication anxiety using ACT and exposure exercises that were delivered with the participants immersed in VR (see Gorinelli et al. (2023). During the intervention phase, the participants filled out EMA surveys twice a day for 21 days. Prompts for the survey were scheduled at a random time between 10.00 a.m. and 10.00 p.m. every day. A pop-up reminder would appear on the phone if the survey was not answered within 30 minutes of the prompt, and the survey was made available for the next four hours. The survey would no longer be available beyond this time and would be considered as missed. Additionally, the two daily surveys were scheduled at least four hours apart. Once participants finished the intervention phase, they were asked to join a final face-to-face assessment session with the researchers to fill in post-intervention self-reported questionnaires and provide general feedback on the study.

Measures

Ecological momentary assessment measures

EMA was conducted through the MetricWire mobile application to measure contextualized life satisfaction, daily activities, and psychological flexibility. MetricWire Inc.'s software is a mobile app-based data collection platform that allows researchers to create custom surveys and build EMA studies. Each participant received two phone notifications at random times of the day for 7 days during the baseline period and 21 days during the intervention period; this added up to a maximum of 56 responses. Each survey aimed to measure the present moment situation through five questions. The first question ("How satisfied are you with your life right now?) measured life satisfaction on a Likert

scale ranging from 1 to 10, with higher scores indicating greater satisfaction levels. The second question ("What were you doing?") explored what activity the individual was doing before replying to the survey and provided a list of 18 different activities (e.g., working, eating, and talking) and a final option to indicate activities not present in the list (i.e., "something else"). These two questions, however, fall outside the scope of the present article and are, therefore, not addressed. The last three questions were designed to measure psychological flexibility using the brief acceptance measure (BAM).

Process measures

BAM (Assmann et al., 2018) is specifically designed for daily diary and single case design studies, and it was used as part of the EMA application to measure psychological flexibility and its sub-processes. Three items investigated how participants felt on a Likert scale from 1 to 10, namely, the openness to experiences (struggling with my thoughts, feelings or physical sensations / open to my thoughts, feelings or physical sensations), awareness (acting without awareness / acting with awareness, and engagement in valued actions (not pursuing things that matter to me / pursuing things that matter to me) subscales. The lowest and highest scores are associated with explicit negative and positive statements, respectively: that is, for example in the awareness item, a score of 1 indicates acting without awareness, and a score of 10 indicates acting with awareness. The total BAM score is indicative of psychological flexibility and ranges between 3 and 30, with higher scores suggesting greater psychological flexibility. In previous studies, BAM showed acceptable reliability (Hulbert-Williams et al., 2019). In the current study, we reported an internal consistency alpha score of .59, which was probably influenced by the small number of items and sample (Cortina, 1993; McNeish, 2018), and a test-retest reliability of .79 across the baseline. BAM scores at the baseline strongly correlated to the CompACT self-reported questionnaire scores in other studies (Hulbert-Williams et al., 2019), and it moderately and significantly correlated with the CompACT score in the current study that was determined in the pre-measurement phase ($n = 37$; $r = .43$, $p = .008$).

CompACT (Francis et al., 2016) measures psychological flexibility, and similar to BAM, it is composed of three subscales: openness to experiences (CompACT-OE), behavioral awareness (CompACT-BA), and valued action (CompACT-VA). CompACT is a 23-item questionnaire (containing questions such as "I can take thoughts and feelings as they come, without attempting to control or avoid them") that is scored on a 7-point Likert scale ranging from 0 (*Strongly disagree*) to 6 (*Strongly agree*), with higher scores representing greater psychological flexibility. The CompACT scores in the current study exhibited good internal consistency, with an alpha score of .84.

Anxiety measures

SIAS (Mattick & Clarke, 1998) measures anxiety related to starting and sustaining social interactions. The SIAS is a 20-item scale (which contains questions such as "I feel I'll say something embarrassing when talking") with a cut-off score of 34 for clinical social anxiety (Brown et al., 1997). The Likert scale is scored between 0 (*Not at all characteristic or true of me*) and 4 (*Extremely characteristic or true of me*). The total score can range from 0 to 80, with a higher score indicating higher levels of social interaction anxiety.

PRCA-24 (McCroskey, 1982) investigates anxiety and fear connected with communicating with others. PRCA-24 is a 24-item scale (containing questions such as "I am tense and nervous while participating in group discussions") in which higher scores represent greater levels of communication anxiety in social situations. A Likert scale of 1 to 5 (1 = *strongly disagree*, 5 = *strongly agree*) is used in the questionnaire. A total

score below 51 is considered indicate very low communication anxiety; between 51 and 80, moderate communication anxiety; and above 80, a high level of communication anxiety.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 26, R-4.2.3, and a web-based calculator (Tarlow, 2016). Generalized estimating equations (GEE; Zeger et al., 1988) were used to analyze EMA data for the entire study sample. Here, the autoregressive AR (1) matrix structure was used to show the within-subject dependencies for possible autoregressive effects over the next survey and get a more accurate estimate. This analysis offered the advantage of accurately accounting for both individuals who reported a higher compliance rate as well as those who reported fewer responses. Additionally, SCD analysis was performed using a subsample of eight students (identified using pseudonyms) who reported a clinically significant change in social interaction or communication anxiety after participating in the intervention study (i.e. Gorinelli et al., 2023). Based on the primary outcome measures, clinically significant change was calculated using the Jacobson-Truax method (Jacobson & Truax, 1991). Based on the reliable change index (RCI) and a determined cut-off score, the Jacobson-Truax method classifies individuals into four categories: recovered, improved, unchanged, and deteriorated. Clinically significant change was deemed to have occurred in participants once they had recovered or improved. Only participants with a response compliance rate of at least 50% for both the baseline and intervention phases were included in the analysis. According to the SCD analysis method, visual analysis was first performed using an SCD Package for R (Hussey, 2020), which provided standardized visualization of the data with linear regression trend lines and median absolute deviation. The R SCD package has been used before (Hulbert-Williams et al., 2021; Lavelle et al., 2022; Eswara Murthy et al., 2020) and enabled good visual assessment between the A and B phases of SCD data. After visual inspection, baseline-corrected Tau for single-case analysis (Tarlow, 2017) was used to calculate comparison effect size from the baseline to the intervention phase with an online web-based calculator (Tarlow, 2016). Baseline-corrected Tau is an improved version of the widely used Tau-U statistic for single-case data analysis; it is a modified form of Kendall's rank order correlation Tau (Parker et al., 2011). After several limitations of the Tau-U statistics were reported, baseline-corrected Tau was designed to offer an improved statistic for SCD studies (Tarlow, 2017). If a significant baseline trend is detected, it will be adjusted before a quantitative comparison effect size between the baseline and intervention phases is computed. In this study, a statistically significant positive Tau effect size was considered to indicate an outcome improvement between the EMA baseline period and the EMA intervention period. For accuracy, we also ran Tau-U analyses, which provided similar results. Since the VRACT intervention was expected to increase psychological flexibility over time in everyday contexts as measured by EMA, one-sided p-values were applied when interpreting significant changes from the baseline to the intervention phase.

Results

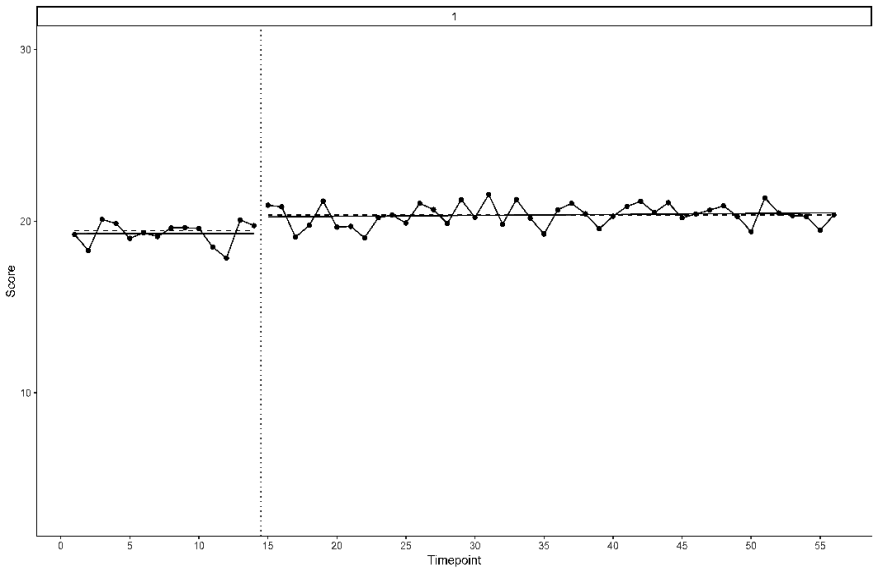
Participant adherence and compliance

Two participants dropped out of the study, and this resulted in a dropout rate of 5.41%. The number of survey entries completed overall for each individual was compared with the expected number of entries to calculate compliance. Compliance was considered 100% when participants entered data twice a day for 7 days during the baseline period and twice daily for 21 days for the intervention period. In the current study, we reported

an average compliance of 77.41% (n = 37; an average of 10.84 entries were made out of a possible total of 14 entries) during the baseline phase and an average compliance of 73.68% (n = 36; an average of 30.94 entries out of 42 possible entries) during the intervention phase. The compliance of the current study is in line with the average EMA compliance reported across other studies, which have an overall compliance rate of 75.06% (Jones et al., 2019).

Effect of the VRACT intervention based on EMA measurements over time

A visual presentation of the overall effect of the intervention can be found in Figure 2. Each data point in this figure represents the mean of all participants' scores at that timepoint. As expected, the baseline phase did not show any change in the total scores of psychological flexibility over time. Preliminary inspection revealed that psychological flexibility improved after the first intervention session and remained stable thereafter, but with a merely slightly increasing trend over the course of the intervention phase.



Note. The x-axis represents EMA responses over time, while the y-axis represents the total score of psychological flexibility. A vertical dotted line marked the baseline phase on the left and the intervention phase on the right. A horizontal dashed line represented the median value for each phase.

Figure 2 *Graphical visualization of the effect of the VRACT intervention on psychological flexibility between the baseline and intervention phase (n = 37)*

GEE modelling of data from the entire sample (n = 37) depicted statistically significant time interactions between the baseline and intervention phases for the total BAM score (p < .001) and its sub-processes openness to experiences (p = .012), behavioral awareness (p = .018), and value actions (p = .013) (Table 1).

Table 1

Generalized estimating equations for modelling change from the baseline to the intervention phase:

	B	95 % *CI*	Wald Chi-Square	*p*-value
BAM-Total	-1.07	[-1.56, -0.58]	18.22	$p < .001$
BAM-OE	-0.33	[-0.59, -0.07]	6.29	$p = .012$
BAM-BA	-0.38	[-0.70, -0.07]	5.61	$p = .018$
BAM-VA	-0.34	[-0.61, -0.07]	6.15	$p = .013$

Note. Baseline-intervention estimated mean difference (beta values) with 95% confidence intervals and interaction change (Wald chi-square test *p*-values). Psychological flexibility (BAM-Total), openness to experiences (BAM-OE), behavioral awareness (BAM-BA), and valued action (BAM-VA).

SCD analyses of individual effects of the VRACT intervention with baseline-corrected Tau

SCD analyses were performed to investigate changes in psychological flexibility among participants who reported a clinically significant improvement in either social interaction anxiety (based on SIAS scores) or communication anxiety (based on PRCA-24 scores) after the VRACT intervention (see Table 2 for changes in SIAS and PRCA-24 scores). Among the 12 students who showed significant improvement, only those with a minimum compliance of 50% were included in the SCD analyses (n = 8). A visual inspection of the BAM total score (Fig. 3) indicated a few concerns with regard to the baseline trends that were controlled in the baseline-corrected TAU analyses, as needed (Table 2). The visual analysis suggested that data patterns differed considerably between participants. Visual inspection of SCD data, based on the median values (represented by the dashed horizontal lines in Figure 2), suggested an improvement in the total scores for psychological flexibility between the baseline and intervention phases in seven of the eight participants (Emma, Monica, Tony, Hannah, Hope, Victor, and Rita). Among them, Monica, Tony, Hannah, and Rita showed a trend toward improvement over time. Baseline-corrected Tau analyses confirmed significant improvements in psychological flexibility (based on the total BAM scores shown in Table 2) for Monica, Tony, and Hannah. In Monica's case, a significant negative trend was observed in the baseline phase, but this was corrected during the analysis.

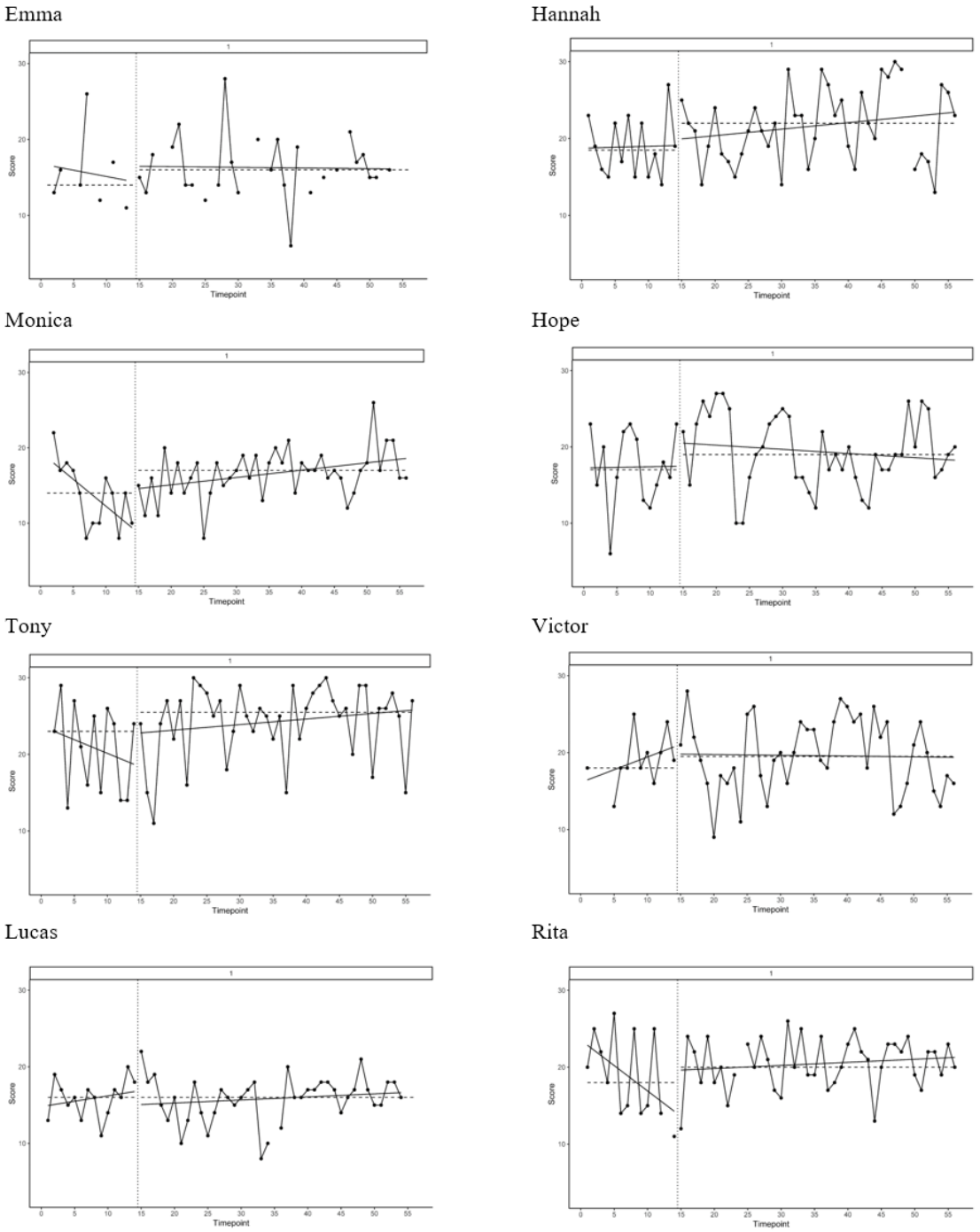


Figure 3 *Graphical visualization of psychological flexibility assessed by SCD analysis of individuals who reported a clinically significant change in social or communication anxiety*

Note. The x-axis represents EMA responses over time, while the y-axis represents the total score of psychological flexibility. A vertical dotted line marked the baseline phase on the left and the intervention phase on the right. A horizontal dashed line represented the median value for each phase.

Baseline-corrected Tau analysis of changes in the three subdimensions of psychological flexibility indicated individual differences among participants (Table 2). Three of the eight participants (namely, Lucas, Victor, and Rita) in the SCD sample showed no significant changes in openness to experiences, behavioral awareness, or valued actions. On the contrary, Emma, Monica, Tony, Hannah, and Hope demonstrated significant changes in these subdimensions: Emma reported a significant change in valued actions; Monica reported a significant improvement in openness to experiences and valued actions (after correcting for the baseline trend); Tony showed an improvement in openness to experiences; and both Hannah and Hope reported significant increases in behavioral awareness (detailed results can be found in Table 2).

Table 2

Baseline-corrected Tau analysis for comparison of psychological flexibility and its sub-processes between the baseline and intervention phases:

	BAM-Total	BAM-OE	BAM-BA	BAM-VA	SIAS	PRCA-24
Emma	τ = 0.15 (0.24) p = .158	τ = -0.02 (0.24) p = .466	τ = -0.12 (0.24) p = .230	τ = 0.28 (0.23) p = .032	-10	-12
Monica	τ = 0.60 (0.15) p < .001	τ = 0.55 (0.16) p < .001	τ = 0.16 (0.19) p = .093	τ = 0.60 (0.15) p < .001	-6	-14
Tony	τ = 0.25 (0.18) p = .017	τ = 0.43 (0.17) p < .001	τ = 0.15 (0.19) p = .106	τ = 0.03 (0.19) p = .413	-12	-13
Lucas	τ = 0.02 (0.19) p = .444	τ = 0.17 (0.19) p = .097	τ = 0.01 (0.19) p = .471	τ = -0.16 (0.19) p = .093	-12	-10
Hannah	τ = 0.22 (0.19) p = .032	τ = 0.13 (0.19) p = .151	τ = 0.30 (0.18) p = .005	τ = 0.04 (0.19) p = .366	-7	-14
Hope	τ = 0.15 (0.19) p = .102	τ = 0.09 (0.19) p = .234	τ = 0.20 (0.19) p = .047	τ = 0.09 (0.19) p = .214	-27	-21
Victor	τ = 0.05 (0.19) p = .350	τ = -0.07 (0.19) p = .297	τ = 0.14 (0.19) p = .134	τ = -0.05 (0.19) p = .356	-9	-16
Rita	τ = 0.11 (0.19) p = .181	τ = 0.12 (0.19) p = .179	τ = 0.15 (0.19) p = .113	τ = -0.13 (0.19) p = .138	-22	-9

Note. Baseline-corrected Tau effect size scores (τ), their standard errors ($SE\tau$), and p values (one-sided) are presented. On the right side, additional changes in the raw scores of self-reported anxiety measures (pre-post) are presented. Psychological flexibility (BAM-Total), openness to experiences (BAM-OE),

behavioral awareness (BAM-BA), and valued action (BAM-VA). SIAS range score 0-80; PRCA-24 range score 24-120.

Discussion

The current study used self-reported EMA data to examine the benefits of a VR-based ACT intervention in improving psychological flexibility skills in real-life contexts among university students experiencing social interaction and communication anxiety. Another important aim of this study was to apply SCD analysis to examine individual differences in changes in psychological flexibility skills observed in everyday life settings among students who showed clinically significant improvements in social interaction and communication anxiety. Specifically, the goal was to identify the main psychological flexibility processes involved in clinical improvement of social interaction or communication anxiety.

The outcomes supported our first hypothesis that psychological flexibility measured in everyday living contexts improves over the course of VRACT training. In line with our results, previous studies have tested the potential of VR applications with daily assessment methods (Bossenbroek et al., 2020; Geraets et al., 2020; Pot-Kolder et al., 2018) and supported the general efficacy of VR-based interventions in improving social or public speaking anxiety (Anderson et al., 2013; Carl et al., 2019; Kampmann et al., 2016). Our earlier study (Gorinelli et al., 2023) was the first one in which an ACT intervention was delivered through a VR headset, and the results demonstrated decreased social interaction and communication anxiety and improved psychological flexibility among university students who received the intervention compared to a no-intervention group. The present study improves on the previous one as it replaces traditional self-reported pre- and post-intervention measures with repeated daily momentary assessments of psychological flexibility skills and supports the increase in psychological flexibility skills resulting from the VRACT intervention.

In this study, while each student underwent the same standardized intervention procedure, there were considerable individual differences in the changes in psychological flexibility among students who showed clinical improvement after the VRACT intervention. This finding underlines the importance of paying attention to individual differences when identifying the processes of change (Hofmann & Hayes, 2019) or when tailoring VR interventions for individual clients to optimize treatment effectiveness (Bossenbroek et al., 2020). Our second hypothesis based on our earlier findings (Gallego et al., 2020; Gorinelli et al., 2022) was that openness to experiences is associated with changes in symptoms of anxiety. However, among the eight students who showed significant improvement and were included in the SCD analysis, only two participants showed a significant increase in the openness to experiences subscale. On the other hand, three participants did not report any significant change in the total score for psychological flexibility. This implies that the observed clinical improvement in anxiety (see Table 2 for changes in anxiety measure scores) may be attributable to factors other than the ACT intervention. Even though levels of acceptance and awareness have been reported to be closely linked to anxiety (Flowers et al., 2023; Gallego et al., 2020; Morin et al., 2021), openness to experience was not the only psychological process of change identified as being involved in clinical improvement in the current study. In addition to the openness to experience exercises, the VRACT intervention also included behavioral awareness exercises and other components. For example, three participants showed psychological flexibility as a central change mechanism associated with clinical improvement in social

or communication anxiety. Further, among two students for whom openness to experiences was identified as a significant process of change, the valued actions component was also found to be crucial for one of them. Moreover, in the case of one participant, valued actions was found to be the only process of change involved. In contrast, behavioral awareness was the only process of change identified in two other participants. Therefore, while openness to experiences was a noteworthy process of change that partly supported our second hypothesis, the findings of this study depict that individuals react differently to the same intervention and that different processes of change are involved even in individuals who exhibit similar levels of improvements in anxiety. This underlines the importance of identifying the processes of change for each individual in order to design customized treatments.

This study has a few limitations that need to be mentioned. The first main limitation is the lack of a control group that used the EMA application without receiving the intervention. The absence of a control group makes it difficult to draw firm conclusions, as participants' processes of change identified from EMA could be attributed to other causes. In our earlier study (Gorinelli et al., 2023), the traditional self-reported pre- and post-intervention measurements of social interaction, communication anxiety, and psychological flexibility significantly improved in the intervention group compared to the waiting list group, in which no change occurred. It could be argued that engaging in the task of filling in EMA data for multiple weeks could also entail a central element of change. However, in the previous study (Gorinelli et al., 2023), we observed that the waiting list (control) group produced similar results in self-reported and behavioral measures when the VRACT intervention was offered without EMA data collection. Therefore, the increase in psychological flexibility occurred without the use of EMA indicating that the EMA measures alone did not affect flexibility. A second limitation is associated with potential factors impacting the intervention's efficacy, as the exercise did not improve psychological flexibility for all participants involved in the SCD analysis. Regrettably, social interaction anxiety and communication anxiety were not measured via EMA. As discussed in previous literature, VR exposure alone can reduce social anxiety and often shows a similar effect to traditional in vivo or imaginal exposure methods (Chesham et al., 2018). Consequently, we cannot exclude the effect of the VR exposure itself on improving self-reported social interaction or communication anxiety, as well as psychological flexibility and its subprocesses. In fact, the current study showed that a brief VRACT training session lasting for less than two hours could decrease social anxiety and increase psychological flexibility skills. A third limitation is that the internal consistency of the BAM scores at the baseline was lower than that reported in previous studies. This may be attributable to the small number of items used in the current study, as it is known that the use of only a small number of items might affect the internal consistency of measures (Cortina, 1993; McNeish, 2018). Nevertheless, the BAM scores for psychological flexibility in the current study were in line with those reported in previous studies (Hulbert-Williams et al., 2019) with CompACT, a commonly used self-reported measure of psychological flexibility (Francis et al., 2016). It is also worth noting that the test-retest reliability at the baseline of the present study indicated the stability of the measures over time. Additionally, the scale of the BAM outcome (psychological flexibility) often showed a small visual range improvement between baseline and post intervention as variations in day to day patterns emerged, making it difficult to draw broad conclusions. These variations could be due to the different time or activity performed prior to responding to the survey. A final limitation concerns the generalizability of the results due to the small sample size, the overrepresentation of female participants, and the

recruitment of participants from a student population. This means that, even though the sample was representative of individuals with high levels of social interaction and communication anxiety, it might not be fully representative of a clinical sample.

Further research is needed to validate the effectiveness of ACT, or other transdiagnostic approaches, delivered via a head-mounted display using traditional self-reported questionnaires or EMA. As technology advances, the application of VR and other mixed-reality alternative applications in psychological approaches needs to be further tested. Moreover, future EMA research using different study designs needs to also be considered. Future research could explore the processes of change involved in recovery from a clinical condition and assess the long-term effect of such interventions. The current findings suggested that a three-session ACT intervention including VR exposure scenarios impacted psychological flexibility skills in students' daily lives. A noteworthy feature of the intervention is that it involved minimal interaction with the therapist, because both the VR scenarios and ACT exercises were recorded beforehand. Although the intervention was highly standardized, large individual differences were observed in changes in the different subcomponents of psychological flexibility. Therefore, the current findings point to the importance of paying close attention to individual processes of change. Although participants reported significant and similar changes in symptoms of social anxiety, different subcomponents of psychological flexibility were found to be involved in these changes. Thus, the current results suggest that there were individual differences in the changes in psychological skills even with similar ACT-based exercises. ACT can be effectively delivered using modern VR technology and can serve as a viable alternative to traditional methods. Furthermore, by examining repeated EMA observations with SCD, knowledge of the VRACT intervention for individuals across time and context was expanded.

Overall, this study provides an overview on how VR-based ACT can positively impact psychological flexibility in everyday contexts based on EMA. In addition, it suggests paying close attention to the effects of the intervention on each individual, as they may react differently to a standardized intervention and acquire different skills.

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