KU LEUVEN

FACULTEIT PSYCHOLOGIE EN
PEDAGOGISCHE WETENSCHAPPEN

VIRTUAL REALITY EXPOSURE IN PUBLIC SPEAKING ANXIETY

The role of expectancy disconfirmation

Masterproef aangeboden tot het
verkrijgen van de graad van
Master of Science in de
psychologie
Door
Julie Roels

promotor: Dirk Hermans
copromotor: Yannick Boddez
Tom Van Daele
m.m.v: Sara Scheveneels

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Summary

Recent advancements in technology have made virtual reality exposure an effective technique in the treatment of anxiety disorders. The treatment success of VRET has been established in numerous studies, however the underlying mechanisms of VRET are still largely unidentified. For in vivo exposure therapy, inhibitory learning theory (ILT) is the leading theoretical account at this moment. The core assumption of this theory is that threat associations in memory are not forgotten or erased, but that conditioned stimulus (CS) becomes ambiguous in meaning, since after exposure both an excitatory CS-US memory and an inhibitory CS-noUS memory exist. According to the ILT the acquirement of the new inhibitory CS-noUS memory is caused by the disconfirmation of dysfunctional expectancies, if the expected feared outcome does not occur (e.g. expectancy violation). Therefore the purpose of this study was to determine the short- and long-term effects of VRET and to examine the role of expectancy violation in VRET. In particular, we tested whether the proportion of testable expectancies predicted VRET outcome.

Participants anxious of public speaking were asked to complete a pre-assessment session with a Behavioural Approach Task (BAT) and self-report questionnaires, two VRET sessions and a post-assessment session with BAT and self-report questionnaires, over four consecutive days. After one week, an online follow-up completed the study. Before VRET, we asked participants which dysfunctional fear expectancies they had in public speaking situations. After VRET, participants indicated which expectancies they felt they could test during VRET. We computed the proportion of testable expectancies for each individual participant.

First, VRET resulted in a significant decrease in self-reported anxiety and heart rate at post-assessment. Second, results were partially retained in the one-week follow-up. Third, it was found that expectancies about one's own reaction were better testable in VRET compared to expectancies about the reactions of the audience and expectancies about being negatively evaluated. Fourth, we did not find evidence that VRET outcome can be predicted by the proportion of testable expectancies.

Acknowledgements

While making the final adjustments to my thesis, I can proudly say that the past two years have been a great learning experience. First of all, I would like to express my gratitude towards professor Dirk Hermans for believing in my research proposal, my curiosity and my ability to contribute to this relatively new field of research within psychology. Next, a special thanks goes out to Sara Scheveneels. Not only did she help me take my first steps in the world of scientific research, she was always on hand for a brainstorm session, answering questions and was also actively involved as a regular confederate in pre- and post-assessment sessions. Further, I am thankful for the guidance of both Sara Scheveneels and Yannick Boddez in helping me develop a scientifically correct working hypothesis and research design, while also giving feedback along the way. Likewise, I would like to thank Tom Van Daele for his willingness to share his expertise within the virtual reality domain, give feedback and his invitation to the symposium regarding virtual reality/augmented reality. This broadened my view of the possibilities and made me even more motivated to get to the core of my research. In addition, I appreciate the opportunity the SMEC-commission was willing to give me in presenting my research ideas and helping me form hypotheses. Throughout these past months, I have also developed an admiration for the hard work and cheerful attitude of my colleague/student, Inez Govaerts. It was a true pleasure working alongside her. I can honestly say that the successful completion of this study had been a lot more difficult without her help and support. Finally, I would like thank my family and friends. Not only have they supported me mentally, but several of them have also acted as confederates in the pre-and post-assessment phases of the study. That is why a special thanks is in order for: Jeroen, Lynse, Kristel, Rob, Zara, Maarten and Sophie.

Approach and own contribution

Even before we had to choose a topic, the prospect of writing a thesis was something I looked forward to. Once I heard that students were allowed to propose a subject of their own choosing, I immediately decided to find something that would be a contribution to psychology research, as well as something through which I could still my scientific curiosity. I first came in contact with virtual reality through an unsuspected demonstration of the technology in august 2016. Immediately, the possibilities of using virtual reality in the treatment of anxiety disorders came to mind. This is when I contacted professor Dirk Hermans of the department of Learning Psychology and Experimental Psychopathology (KU Leuven). Luckily, he was intrigued by my proposal and asked me to write a short essay explaining my interest. Next, came several brainstorming sessions with doctoral student, Sara Scheveneels, in which several possibilities and opportunities were discussed. I decided to go through with the idea of setting up an experimental study in which virtual reality exposure was the key-component. After a few weeks, I got the message that my proposal had been approved. What followed was the hard task of determining a concrete hypothesis and research question, while also figuring out the benefits and downsides of specific virtual reality devices. This involved a lot of investigating, attending a symposium about virtual reality, reading and making contact with other researchers (who were already familiar in the domain of virtual reality). I was also given the opportunity to present my initial ideas in front of the weekly meeting of the research unit Learning Psychology and Experimental Psychology (KU Leuven). The approval and questions I got from this meeting helped me focus and determine a final research question and design. Throughout the actual data collection, I closely worked together with my colleague, Inez Govaerts. We assisted each other in the screening and planning of participants, the preparation of each assessment, the execution of the live pre- and post-assessment sessions, the task division regarding the virtual reality sessions and the analysis of the heart rate data and self-report measures. Throughout, but especially during these last months, I wrote about my findings and research until my daily supervisor, (co-) promotors and myself were proud of the end result.

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Abstract

There is conclusive evidence demonstrating the success of virtual reality exposure therapy (VRET) in the treatment of anxiety disorders. Although previous theories has focused on forgetting fear associations through habituation, research has not yet found a clear explanation for the underlying mechanisms. In this study, 43 participants were therefore asked to complete a four-day series of public speaking tasks; starting with a live BAT pre-assessment, followed by two separate VRET sessions and concluded by a live BAT post-assessment. During these sessions several questionnaires were conducted (e.g. Subjective Units of Distress Scale, Personal Confidence as a Speaker, Self-Statements during Public Speaking and the List of expectations), as well as heart rate measurements during baseline and public speaking (during BAT). In line with our hypotheses, VRET had a significant decreasing effect on public speaking anxiety and this effect was partially retained at a one-week follow-up. Further, we found that the expectancy subtype does influence the amount of expectancy disconfirmation at outcome, but that the proportion of testable expectancies is not a significant predictor of the VRET outcome. These results confirm that VRET is an effective method of exposure, but does not support the ILT, which is currently used as an explanation for the underlying mechanisms of exposure.

Introduction

Throughout the years multiple meta-analyses have demonstrated the efficacy of cognitive and behavioural approaches (CBT) in the treatment of anxiety disorders (Chambless & Ollendick, 2001; Deacon & Abramowitz, 2004; Norton & Price, 2007). One of the most frequently used techniques in CBT is *exposure*, which has shown to be effective on the short- and long-term (Choy, Fyer, & Lipsitz, 2007; Otte, 2011; Trimbos-Instituut, 2013). Division 12 of the American Psychological Association (APA; American Psychological Association Division 12, 2017) describes exposure therapy as a technique to help people confront their fears in a safe environment, whereas they would normally try to avoid them. Throughout the years several variations of exposure therapy have been proposed. For example, in exposure *in vivo* the person is directly confronted with the feared object, situation or activity in real life, whereas in exposure *in vitro* the person is instructed to vividly imagine the feared stimulus (American Psychological Association Division 12, 2017).

However, standard exposure strategies have their limitations. For example, Choy et al. (2007) stated that although exposure in vivo has a large effect in specific phobia, it is also associated with high drop-out rates and low treatment acceptance. Furthermore, the possibility of personalising exposure therapy to the needs and wants of the client is not always possible in standard treatment due to practical limitations. For example, taking a plane is expensive and requires extensive planning. Furthermore Choy et al. (2007) described that long-term follow-up studies indicated that treatment gains can be maintained and even improved by self-exposure. Yet in many cases clients do not have access to the feared stimulus or environment.

A possible solution for these limitations is the use of virtual reality exposure therapy (VRET) (Bouchard et al., 2016; North, North, & Coble, 1997). In the online English Oxford dictionary (Definition of virtual reality in English, 17 January 2018) virtual reality is defined as: “The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.” Furthermore, studies by Freeman et al. (2017), Maples-Keller, Bunnell, Kim, and Rothbaum (2017) and Troendle (2014) also describe VR as a human-computer interface in which a user actively engages in an immersive computer-generated three-dimensional environment.

Key-components in VRET are the amount of *immersion* (an objective measure), the amount of *interaction* with the computer-generated environment and the *sense of presence* experienced (a subjective measure) within VRET (Freeman et al., 2017; Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Schuemie, Van der Straaten, Krijn, & Van der Mast, 2001; Schultheis & Rizzo, 2001). Whereas immersion refers to the capability of the VR device to create a surrounding and a vivid illusion of reality to the senses (for example through the breadth of the field of vison or the quality of the display resolution), presence is described as the subjective feeling of being inside the virtual environment (Sanchez-Vives & Slater, 2005; Schuemie et al., 2001; Slater & Wilbur, 1997).

The advantages of using VRET are diverse. Research has shown that VRET has a lower treatment drop-out than exposure in vivo and that the use of virtual reality technology could provide the necessary stimuli for those patients who would otherwise be unable to confront themselves with their fear (due to the internal fear itself or because of external barriers) (Bouchard et al., 2016; North et al., 1997). Furthermore, simulations made in a virtual reality environment can be tailored to the needs (e.g. difficulty, speed) and fears (e.g. a particular part or the complex whole) of the specific patient. Additionally, the therapist (or the phobic person himself) is able to produce and repeat specific scenarios until the therapeutic benefits become apparent, all in the safe environment of the therapist's room or at home (Freeman et al., 2017; Maples-Keller et al., 2017). All these elements contribute to a highly customised and controlled design for the treatment of fear.

Even though virtual reality provides many advantages, it also has disadvantages. In the past these were the large cost and high chance of technological malfunction. However, more recently VR has become more reliable, available and open for common use (Palmisano, Mursic, & Kim, 2017; Parson & Rizzo, 2007). In addition, some frequently reported side-effects include psychophysiological effects, such as VR-induced sickness (also called cybersickness), behavioural effects, such as dissociation, a misplaced locus of control and health risks, such as flashbacks, panic attacks and epilepsy (Barrett, 2004; LaViola, 2000; Srivastava, Das, & Chaudhury, 2014; Wilson, 1996). Luckily however, Nichols and Patel (2002) demonstrated that, although the symptoms of cybersickness may seem severe, the overall side-effects are mild and, for the most part, will subside quickly.

Furthermore, the effectiveness of VRET has been established extensively. Meta-analyses have confirmed that VRET is as effective in the treatment of several anxiety disorders as standard treatment (such as exposure in vivo or in vitro) and that its effects generalize to real-life (Freeman et al., 2017; McCann et al., 2014[1]; Opris et al., 2012; Parsons & Rizzo, 2007; Valmaggia, Latif, Kempton, & Rus-Calafell, 2016). Likewise, a study by Rothbaum et al. (2006) compared the treatment gains of VRET with standard exposure therapy and a wait list control. The first finding stated that VRET was equally effective as exposure in vivo and superior to the wait list control. The second conclusion was that treatment gains were maintained at follow-up (at 6 and 12 months). The latter was also found in a meta-analysis by Opris et al. (2012). Smaller studies have also confirmed that VRET has a positive treatment effect in specific phobia and social phobia (Bouchard et al., 2016; Klinger et al., 2005; Krijn et al., 2004; Srivastava et al., 2014). But not all research has been this convincing. For example, Wolitzky-Taylor, Jonathan, Horowitz, Powers, and Telch (2008) reported that exposure in vivo was more efficient in reducing anxiety related symptoms than exposure in vitro or VRET in specific phobia. However, the difference in treatment outcome was not maintained at follow-up.

[1] The meta-analysis by McCann et al. (2014) and Freeman et al. (2016) cautioned that early studies on VRET lacked the standard methodological quality preferred in scientific research.

As reported, VRET seems to be an effective treatment for a variety of anxiety disorders. However, the question arises as to '*why'* VRET works (i.e. what are the underlying mechanisms). The most prevailing theories explaining the efficacy of exposure therapy are emotional processing theory (EPT) and, the more recent, inhibitory learning theory (ILT).

EPT was proposed by Foa and Kozak (1986) as an explanation for the working mechanisms underlying exposure therapy. They based their theory upon the memory model of associative nodes and links. When a stimulus activates a node, it will activate numerous others through links formed by experience and learning. For example, seeing a picture of a plane will activate the idea of flying, a pilot, an airport, etc. When fear underlies the associative network and activates a maladaptive way of thinking, it is defined as a fear structure (Lang, 1977/2016). This implies that the associative memory network will be activated through a stimulus (e.g. a plane), which will ignite a response (e.g. a racing heart) and a meaning behind the stimulus and response (e.g. 'the plane will crash'). According to the EPT the (continued) activation of the fear structure and the incorporation of incompatible information about the pathological fear should lead to corrective learning (Craske et al., 2008; Foa & Kozak, 1986). Notably, it is assumed that this is driven by habituation, both within and between therapy sessions (Foa & Kozak, 1986). Therapy progress can be measured through the comparison of the original fear level activation (IFA) and the reduction of fear both within-session habituation (WSH) and between-session habituation (BSH) (Baker et al., 2010; Craske et al., 2008; Craske, Liao, Brown, & Vervliet, 2012).

Hofmann, Alpers and Pauli (2009) proposed that there are two ways of activating and measuring emotion, such as fear. While the first is a perceptual one that is activated through visual cues, the second is a conceptual one, which is activated through the reception of information. Each pathway evokes different reactions. Physiological and behavioural reactions, such as rapid heartbeat, are elicited through the first pathway, while more subjective reactions, such as fear-related thoughts, are activated by the informational pathway. Furthermore, Diemer, Alpers, Peperkorn, Shiban and Mühlerger (2015) described that VRET is often used within EPT because it can help differentiate between the two pathways and assess the subsequent fear reactions, all within a highly controlled setting. For example, VRE can give a visual presentation of a fear-eliciting object (e.g. first pathway) or display information on the VRE screen (e.g. second pathway), evoking the association network and its affiliated emotion.

In view of this research, the importance of the key-components of VRET (immersion, interaction and presence) resurface. For example, a widespread theory is that there is a link between presence and the amount of experienced anxiety in the virtual environment (Price & Anderson, 2007; Robillard, Bouchard, Fournier, & Renaud, 2003). In line with this theory a decline in fear could be interpreted as the consequence of the initial fear activation (IFA) and within-session habituation (WSH), which is directly related to learning and the integration of corrective information (e.g. fear decline) (Baker et al., 2010). Furthermore Peperkorn, Diemer and Mühlberger (2015) concluded in their study that, although presence seems to directly influence the amount of experienced fear in VR, they are mutually dependent over time. In turn, this reflects the idea that higher presence will lead to higher IFA, which can contribute to higher WSH and higher BSH, eventually leading to a greater fear decline.

Yet previous research has shown that the empirical evidence for EPT is inconsistent (Baker et al., 2010). A review by Craske et al. (2008) found that only a limited amount of studies could make an empirically sound and consistent assessment of the main EPT premises and that evidence to support this theory was negligent. For example, no consistent support was found for a relationship between IFA and exposure outcome, nor was there evidence that BSH can only occur when preceded by WSH. In line with these results, Rupp, Doebler, Ehring and Vossbeck-Elsebusch (2016) performed a meta-analysis concerning the predictive value of EPT and its process variables. Their results indicated that the premises of EPT are insufficient predictors of treatment outcome. Furthermore, Bouton (2000, 2002, 2004) presented evidence that extinction does not involve the 'unlearning' of an association, but that the stimulus can evoke multiple meanings, depending on the context and the strength of each memory link.

Over the past decade, the inhibitory learning theory (ILT) became a valid alternative to EPT (Craske et al., 2008; Jacoby & Abramowitz, 2016; Rupp et al., 2016). The core assumption of ILT emphasises the importance of the disconfirmation of dysfunctional expectancies regarding the feared stimulus or situation. Whereas EPT emphasises the importance of habituation in the treatment of anxiety, ILT considers extinction as a mechanism of learning during exposure. Extinction involves the confrontation of a person with the feared stimulus (i.e. conditioned stimulus or CS), in the absence of the unconditioned stimulus (US) (Hermans, Craske, Mineka, & Lovibond, 2006). The repetition of the CS followed by no-US will eventually lead to a diminished conditioned response (CR), which was established by initial learning. This is called inhibitory learning and is regarded essential to extinction (Bouton, 1993). For example, when a person with fear of flying has to fly in an airplane (CS), fear of crashing (CR) will arise. However, when this person is able to repeatedly fly (CS) without crashing (no-US), the fear of crashing will diminish over time, leading to a new CS-noUS inhibitory association that does not elicit fear. The greater the mismatch between the (feared) expectancy and the outcome, the stronger the inhibitory association and the more successful the exposure treatment (Rief et al., 2015). Simultaneously, ILT proposes that the initial excitatory association is not erased, but that, after exposure, the original CS offers two (or more) possible explanations (Bouton, 2002; Craske et al., 2014; Rief et al., 2015). In other words, ILT states that the meaning of the CS becomes ambiguous because of the development of new, secondary pathways instead of changing its predictive message (Bouton, 2002; Craske et al., 2008; Jacoby & Abramowitz, 2016).

Since the maximisation of inhibitory learning is a crucial element in the diminishing of fear, expectancy disconfirmation is seen as an essential factor in exposure therapy (Craske et al., 2014; Rescorla & Wagner, 1972). Research has shown that expectancy disconfirmation can occur when the confrontation with the feared stimulus or situation takes place through imagination, a virtual simulation or in real life. However, some events related to fear expectancies cannot occur, and thus cannot be disconfirmed, through the use of virtual reality. Hence the question: *why does it work?* We will explain this further by using an example of a client with fear of flying. If this person is afraid of having a panic attack while flying, a virtual reality simulation of flying could be sufficient to test the feared expectancy. However, if the client's feared expectancy would be to crash, VRET would not be adequate because the event of a plane crash simply cannot occur. A simulated crash within VRET would not have the same consequences as a crash of a real airplane. Hence, it can be hypothesized that some dysfunctional fear expectancies cannot be disconfirmed using virtual reality technology. This seems to be in contrast to the extensive amount of research showing that VRET is effective in the treatment of fear of flying (Botella, Osma, Garcia-Palacios, Quero, & Baños, 2004; Parsons & Rizzo, 2007; Rothbaum et al., 2006).

This study therefore set out to assess the relationship between fear-related expectations and the effect of VRET. The main issues addressed were (1) the effect of VRET in fear of public speaking, (2) the effects of VRET in the fear level of public speaking after one week (follow-up) and (3) the role of expectancy disconfirmation in VRET. The latter question can be subdivided into (3a) whether certain expectancies are better testable in VRET than others and (3b) the extent to which VRET outcome can be predicted by the proportion of testable expectancies. The findings should contribute to a deeper understanding of the underlying mechanisms of VRET.

Method

Participants

A total of 603 people applied for this study through the online Qualtrics platform. Questions included personal information and the two-question survey on public speaking anxiety, which was also used by Craske, Culver, and Stoyanova (2011) and by Tsao and Craske (2000). The two-question survey consisted of two items measuring anxiety and avoidance in public speaking (1) "how anxious would you feel giving a formal speech before a live audience" and (2) "how likely would you be to avoid taking a class that required an oral presentation". Volunteers were asked to rate these questions on a scale from 0 (not at all) to 8 (very much). The aim was to only select participants who avoided and feared public speaking. If they scored 6 or higher on the first question and 5 or higher on the second question, they qualified to participate. Other selection criteria included the absence of heart problems, respiratory problems, and/or neurological problems. Candidates that met all these criteria were contacted (by email or telephone) to participate in the study. A total of 38 females and 5 males (N = 43) between the ages of 18 and 42 (M_{age} = 22.72, SD_{age} = 4.64) took part in the study. A preliminary analysis of the two-question survey before the start of the experiment showed that participants reported a mean anxiety for public speaking of 6.58 with a standard deviation of 0.66 and a mean avoidance for public speaking of 6.16 with a standard deviation of 1.02. After four consecutive sessions (e.g. a pre-assessment session, two VRET sessions and a post-assessment session), participants were also randomly assigned to one of two conditions. However, because this was not the focus of this thesis, it will not be reported further.

Apparatus and materials

Heart rate.

The Polar RS800CX was used to assess heart rate, a physiological indicator of stress. In this study heart rate was measured before and during the behavioural approach task (BAT) of each assessment session (e.g. at pre and post). This device consists of a strap, which is worn right below the chest area, a wrist unit, which shows and registers the heart rate (amongst other data), and a sensor, which is clicked onto the strap and transmits data from the chest to the wrist unit. Using the additional Polar IrDA USB 2.0, data could be easily transferred to the Polar ProTrainer 5 software on a computer. For the analysis of the mean heart rate the Polar ProTrainer 5 software was used to remove outliers from the recorded data. The Polar RS800CX has been previously used as a valid and reliable method for the measurement of heart rate and heart rate variability (Williams et al., 2016).

Samsung Gear 360° camera.

The Samsung Gear 360° camera was used to film a virtual reality environment. The dual fisheye lenses, both equipped with 15-megapixel image sensors, recorded real life footage. These videoclips were later edited with the ActionDirector computer program, placed on the microSD card of the Samsung S7 and used as public speaking exercises during the second and third virtual reality exposure sessions.

Samsung Gear VR headset.

The Samsung Gear VR (SM-R323) is a portable and wireless virtual reality headset (Figure 1). It was used to immerse the participants into the virtual reality public speaking environments. The device has a 101° field of view, a build in gyroscope/accelerometer, weighs 312 grams and is compatible with Samsung's Galaxy S7 through a USB Type-C connection or microUSB connection.

The edited 360° video clips were displayed inside the headset, by use of a Samsung S7 smartphone. This smartphone has a resolution of 1440x2560 pixels and a 5.1" frame. It contains a 4GB RAM memory and a microSD card slot for extra (video) storage. Furthermore, the Samsung S7 smartphone is compatible with the Samsung Gear VR (SM-R323) headset device and the Oculus virtual reality application. Within the Oculus app we used the 'Oculus Video' and 'Samsung VR' software applications. These allowed us to play the 360° public speaking exercises whilst wearing the Samsung Gear VR headset.

While we opted to use a head mounted display (HMD), other studies have used a desktop personal computer PC, with a standard monitor or an cave automatic virtual environment (CAVE). Because the CAVE system projects the computer display onto the walls, ceiling and floor of the room and the user wears 3D-glasses, the CAVE is able to fully immerse the user into the VE (Kim, Rosethal, Zielinkski, & Brady, 2012). While the CAVE is considered a multi-user VR system, the HMD is only suitable for individual usage. The HMD consists of a display, a headphone and a tracking system. Some versions also include, gesture-sensing gloves and/or a haptic-feedback system. These components allow the user to see and hear virtual images and sounds while disabling sensory information from the real world, leading to the subjective sensation of being inside an alternate environment (Diemer, Mühlberger, Pauli, & Zwanzger, 2014; Krijn et al., 2004; Schultheis & Rizzo, 2001). In addition, a study by Kim, Rosenthal, Zielinski and Brady (2014) indicated that HMD and CAVE devices provoke the same amount of emotional excitation, but that the HMD is able to evoke more unpleasant affect than the CAVE.

The development of the virtual reality environment.

For the purpose of this study five public speaking scenarios were created. The Gear 360° camera was placed in front of a neutral, but attentive, audience. During each fragment the audience had to act as if the camera was a person giving a presentation. One or two attendants were also instructed to lose interest (for example look at their watch or phone).

The first day of virtual reality exercises consisted of three scenarios. The first scenario lasted for two minutes and was recorded in an empty classroom. It was used to get the participants acquainted to the virtual reality environment and handling of the headset. The second scenario was five minutes long and was filmed at the office of a faculty member. The audience consisted of four male professors, one of which was asked to play uninterested. The second day of virtual reality exercises consisted of virtual reality exposure to the fourth and fifth recorded scenario. The third video was nearly six minutes long and was set to resemble a professional meeting. It had a mixed audience of approximately 15 people. The fourth video was nearly seven minutes long and the scenery was an actual classroom, attended by 20-25 university students. The fifth video was made inside a university auditorium. Approximately 150 students were present and, additionally, two professors were seated in the front row. This last exercise was nine minutes long and several of the audience members were asked to act uninterested.

Subjective Assessments

Personal report of confidence as a speaker (PRCS; Paul, 1966).

This 10-item instrument was used to assess if any changes, in regard to feelings of confidence as a speaker, occurred. It consists of 30 items and two answer alternatives, ‘true’ and ‘false’. To get an indication of the score, items 1, 4, 6, 9, 10, 11, 12, 14, 16, 17, 21, 22, 23, 27 and 30 had to be reversed. Afterwards, all 'true'-responses were summed. The higher the score, the higher the indication of doubt as a speaker. Paul (1966) described this instrument as a measure of interpersonal-performance anxiety with an internal consistency of .91 (Cronbach's alpha) and a test-retest correlation of .61.

Self-statements during public speaking (SSPS; Hofmann, & DiBartolo, 2000).

This 10-item instrument measures the person's self-statements during public speaking on a scale from 0 ('I don't agree at all') to 5 ('I highly agree'). The SSPS contains two five-item subscales, the 'Positive Self-Statements' (SSPS-P) and the 'Negative Self-Statements' (SSPS-N) subscale. While high scores on the SSPS-P subscale stand for 'non-negative thinking', high scores on the SSPS-N subscale give an indication of heightened anxiety and fearful thoughts associated with public speaking. Additionally, Hofmann and DiBartolo (2000) indicated that the SSPS-N is clinically useful, as it is sensitive to short-term treatment change. Hofmann and DiBartolo also gave an overview of different studies investigating the preliminary psychometric properties. A first study found an internal consistency of .94 (Cronbach's alpha). In another study, the subscales were evaluated separately. The Cronbach's alpha for the SSPS-P and the SSPS-N were .80 and .86, respectively. A three-month follow-up found a test-retest reliability of .78 for the SSPS-P subscale and established a test-retest reliability of .80 for the SSPS-N subscale.

Subjective units of distress scale (SUDS; Wolpe, 1973).

The Subjective Units of Distress (SUDS) is a one-item scale to assess the amount of fear or distress experienced at a particular moment in time. The scale ranges from 0 ('no distress at all') to 100 ('most severe distress ever experienced'). The SUDS is a frequently used and valid instrument in exposure treatment, as well as in research on phobias and other anxiety disorders (Baker et al., 2010; Culver, Stoyanova, & Craske, 2011; Tsao & Craske, 2000).

List of expectations (general and VR specific) (unvalidated).

The 'List of expectations' is a checklist of 50 expectations that people might have when exposed to public speaking situations. Two separate versions were created. The first version asked about participants' expectancies in public speaking situations in general and was used during the first assessment session (see Appendix 2). Questions include: "I will faint", "they are going to think I am weak", "the audience will yawn as a reaction to my presentation". The second version focused on whether it was possible to test certain expectancies during the virtual reality exercises (see Appendix 3). Questions include: "I will blush, turn red", "they will think I'm ridiculous", "people from the audience will ask difficult questions". This version was used during the third and fourth meeting. Each version contained a global score and three different subscale scores (e.g. 'Expectations towards Your own reactions, 'Expectations towards the Audience reactions' and 'Expectations about Negative evaluation'). The goal of creating these questionnaires was to evaluate our third and fourth hypotheses regarding the role of fear disconfirmation within VRET: (3a) VRET can test certain subtypes of expectancies better than others, (3b) the outcome of VRET can be predicted by the proportion of testable expectancies. This was done by computing a new variable 'proportion of testable expectancies' for each subtype (e.g. self, audience and negative evaluation) and using it in further analyses.

Behavioral Approach Task (BAT)

The behavioural approach task (BAT) was adopted from Culver et al. (2011) and completed during the pre- and post-assessment sessions. Each participant had to perform a two-minute speech in front of a neutral audience, during which they wore a Polar RS800CX to measure heart rate. Furthermore, each participant was asked to fill in the SUDS right before the presentation, at the 1-min mark during the presentation and at the 2-min mark of the presentation. This was signalled by a piece of plasticized paper that was held up by the experimenter. If they preferred, participants were allowed to continue their speech for another two minutes, during which all the BAT measured variables (e.g. heart rate, SUDS) continued being monitored. The live audience was invited by the researchers and consisted of one man and two women. These confederates differed from the pre- to the post-assessment to minimize the potential effects of repeated exposure. The only exception was the appointed experimenter, who returned for both sessions. Participants randomly picked one topic for their pre-assessment speech out of two possibilities. The other topic was used in the post-assessment session. The two possibilities were: "should Muslims be able to wear their hijab everywhere and/or at all times" and "what do you think about the wages people in high functions are earning". Participants were not allowed to prepare their speech and were instructed to start the presentation immediately after picking a topic. They were told that they could stop the speech at any given time. They were also instructed that interaction with the audience (e.g. discussing the topic) was not permitted. They were also told that their speech would be recorded by a camera, although it was not. This instruction merely served to elevate the feeling of being evaluated.

Experimental Manipulation

Feedback-sheet.

At the start of the post-assessment session a feedback-sheet was used to assign participants to the non-interactive or interactive condition. However, because this was not the focus of this paper, the part of the procedure will not be reported here.

Procedure

Voluntary study participants were screened for speaking anxiety by means of the two-question survey (Craske et al., 2011; Tsao & Craske, 2000). Other selection criteria included the absence of heart problems, respiratory problems and/or neurological problems.

The four sessions were conducted over consecutive days, with each session lasting on average one hour. The first and the last session were used as pre- and post-assessment, which included the live BAT procedure and several questionnaires (such as the PRCS, SSPS, List of expectations). The second and third sessions were used as public speaking training through means of virtual reality exposure.

Day 1: Pre-assessment.

During the first session a group of six participants were asked to fill in the informed consent, followed by a 10-minute heart rate baseline, in the same room. The participants were not able to see each other, nor were they permitted to talk or use any other material, except for the magazine provided by the researcher. Additionally, the researcher left the room during this time period to ensure no secondary stressors would influence the anxiety level of each participant. After this baseline each individual participant was guided to the next room (in which they would perform the BAT). While giving the 2-min presentation, each participant was asked to stand in front of a table, camera and a 3-person audience. They also wore the heart rate monitor and filled in the SUDS scale at three separate time intervals. After their two-minute presentation, they were asked if they wanted to continue the presentation for another two minutes, during which heart rate and SUDS-scores continued to be evaluated. After the BAT procedure participants were asked to fill in the PRCS, SSPS and the List of expectations – general version. Later they were asked to remove the Polar RS800CX and were allowed to leave.

Day 2 & 3: Virtual reality exposure.

Each participant was received individually for the completion of the virtual reality exposure exercises. In total, they were asked to complete five virtual reality public speaking exercises. For each of these exercises the participants had to randomly pick a (controversial) topic out of a bag. Before the start of each presentation they got five minutes of preparation time. The four available topics were "should there be more strict boundaries to immigration", "in which situation is abortion justified", "which attitude should we assume towards long-lasting unemployment" and "are we spending too much time on social media? Which effect does this have on our daily lives, for example on social contact". After a participant discussed a certain topic, that topic was excluded from future exercises. If the participants endured difficulties during the speech, the researcher encouraged them to keep going for as long as possible, but participants were allowed to terminate the exercise prematurely.

The VR public speaking training during the second session contained the two-minute ‘empty room’, in which the participant learned how to handle the virtual reality headset (such as starting the exercise, adjusting the image, …) and get accustomed to the virtual reality environment. Next came two VR exercises during which the participants had to present a speech on a previously unknown topic. The first virtual reality exercise was created to mimic a five minute ‘office’ environment, followed by the second exercise that lasted six minute and portrayed a ‘meeting’ scenario. The participant was asked to return the next day for the next exposure session, during which he/she had to complete the last two VR public speaking exercises (e.g. the seven minute ‘classroom’ and nine minute ‘auditorium’ scenario’s) and fill in the SSPS, IPQ and List with expectations – Virtual Reality version. All exercises were given in a hierarchical order of difficulty (audience size, duration of the presentation, …). Furthermore, a different topic had to be chosen for each exercise.

Day 4: Post-assessment.

The last session contained the post-assessment of fear of public speaking. While it followed a similar procedure to the pre-assessment session (e.g. BAT, heart rate as physiological measure and the PRCS, SSPS and the List of expectations), the experimental manipulation was also implemented. The manipulation took form in the debriefing of participants before the start of the session. This was done by giving participants a feedback-sheet by which they were categorized into one of two conditions. In the non-interactive condition participants were told that the virtual audience was not able to react to their presentation. Conversely, in the interactive condition, they were told that the experimenter had the ability to manipulate the reaction of the virtual audience to the presentation. Next, the 10-minute heart rate baseline was measured while the participants sat in the same room. Afterwards each participant was guided to the three-person audience to complete the behavioural approach task (BAT). Participants filled out the PRCS, SSPS, manipulation check and the List of expectations - Virtual Reality version.

One-week follow-up.

One week after completion of this four-day study, participants received a link with the PRCS and SSPS via email.

Results

The Immediate Effect of VRET in Fear of Public Speaking

The immediate effect of the virtual reality exposure sessions on public speaking anxiety was tested using a paired-samples t-tests. Prior to the analysis a couple of adjustments were made. First of all, the results of the second 2-minute speech task were not included in the analysis because only few participants performed this task. Second, a new variable, named ‘mean baseline-corrected heart rate’, was computed to exclude any pre-existing differences in heart rate. This variable was calculated by subtracting the mean heart rate measured during baseline from the mean heart rate during BAT in each pre- and post-assessment. Before we could test whether the VRET outcome at post-assessment could be predicted by the amount of testable expectancies, the 'proportion of testable expectancies' was computed. The first step in calculating this variable was determining the overlap between expectancies at pre-assessment and virtual reality assessment. The second step was dividing each expectancy subtype overlap with the amount of expectancies at pre-assessment.

The paired-samples t-test showed that the baseline-corrected heart rate during BAT was significantly lower at post-assessment (M_{post} = 22.80, SD_{post} = 11.36), than at pre-assessment (M_{pre} = 31.90, SD_{pre} = 13.59), $t(42) = 5.64$, $p < .001$ (Figure 2). Further, a significant decline between pre- and post-assessment (M_{pre} = 59.20, SD_{pre} = 17.23; M_{post} = 44.10, SD_{post} = 17.22) for the SUDS during BAT was found, $t(42) = 7.27$, $p < .001$ (Figure 3). In addition, the comparison between the pre- and post-assessment of the PRCS (M_{pre} = 21.49, SD_{pre} = 4.66; M_{post} = 16.12, SD_{post} = 6.72) was found to be significant, $t(42) = 6.39$, $p < .001$ (Figure 4). In addition, the SSPS-N at post-assessment (M_{post} = 11.51, SD_{post} = 5.03) was significantly lower than at pre-assessment (M_{pre} = 13.33, SD_{pre} = 5.26), $t(42) = 4.64$, $p < .001$ (Figure 5). To conclude, a significant increase in the SSPS-P, $t(42) = -5.92$, $p < .001$, from pre- to post-assessment (M_{pre} = 13.02, SD_{pre} = 4.23; M_{post} = 15.91, SD_{post} = 4.41) showed that participants reported more positive self-statements regarding public speaking than before the training (Figure 5).

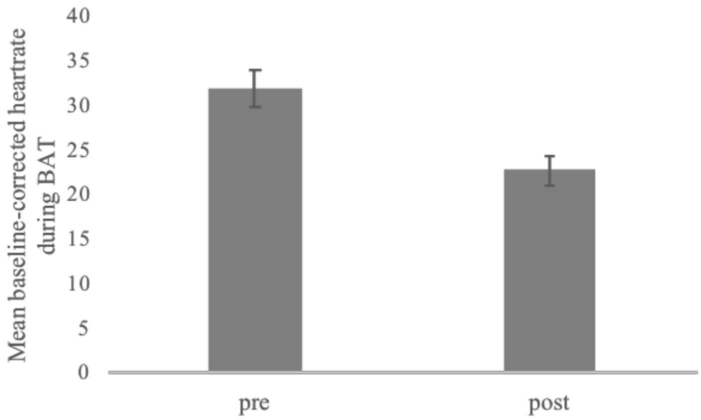

Figure 2. Mean baseline-corrected heat rate during BAT at pre- and post-assessment. Error bars represent standard error of the mean.

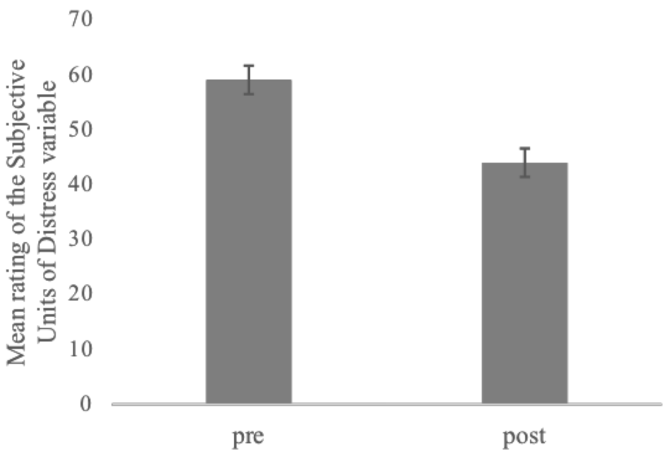

Figure 3. Mean SUDS ratings during BAT at pre- and post-assessment. Error bars represent standard error of the mean.

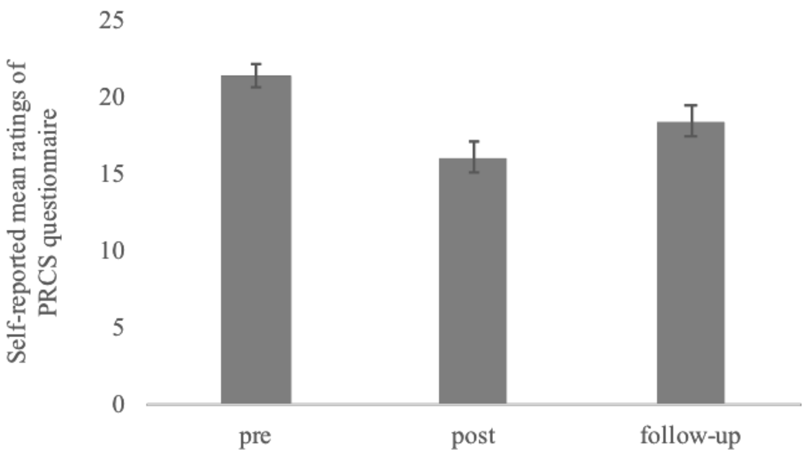

Figure 4. Mean PRCS scores at pre-, post-, and follow-up assessment. Error bars represent standard error of the mean.

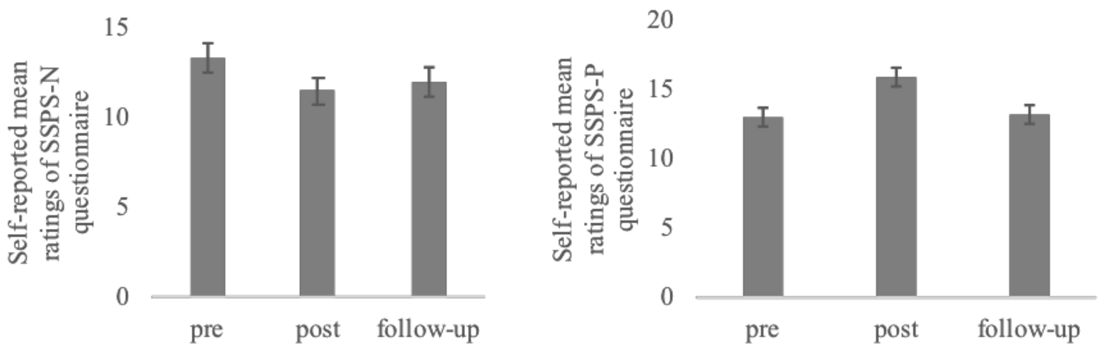

Figure 5. Mean SSPS scores at pre-, post-, and follow-up assessment. The SSPS-N subscale is depicted left and the SSPS-P subscale is depicted in the right panel. Error bars represent standard error of the mean.

The Effects of VRET in Fear Level Public Speaking After One Week (Follow-Up)

To test whether the immediate effects of the virtual reality exposure treatment were retained after one week, paired-samples t-tests were performed. The results showed that, although visual inspection of Figure 4 and 5 suggests the self-reported anxiety levels of the PRCS and SSPS-N questionnaires increased from post-assessment (M_{post} = 16.12, SD_{post} = 6.72) to follow-up ($M_{follow\text{-}up}$ = 18.51, $SD_{follow\text{-}up}$ = 6.63), only the increase in PRCS scores was statistically significant, $t(42) = -3.37$, $p < .01$. Moreover, Figure 5 indicates a decrease in SSPS-P scores between post-assessment (M_{post} = 15.91, SD_{post} = 4.41) and follow-up ($M_{follow\text{-}up}$ = 13.28, $SD_{follow\text{-}up}$ = 4.68), which was confirmed to be statistically significant, $t(42) = 4.53$, $p < .001$. These results suggest that there was a return of fear in the PRCS and SSPS-P.

In addition, a comparison was made between pre-assessment and follow-up of the PRCS and SSPS subscales through paired-samples t-tests. These analyses were performed to test whether, despite the observation of return of fear, there was still an effect of VRET after one week. Results demonstrate that after one week VRET had a significant decreasing effect on self-reported anxiety as measured by the PRCS, $t(42) = 3.99$, $p < .001$, and the SSPS-N, $t(42) = 2.54$, $p = .015$. However, no significant increase in the SSPS-P subscale between post-assessment (M_{post} = 11.51, SD_{post} = 5.03) and follow-up ($M_{follow\text{-}up}$ = 12.05, $SD_{follow\text{-}up}$ = 5.55) was observed, $t(42) = -0.48$, $p = .636$.

In conclusion, a significant immediate effect of VRET was observed in all outcome variables. However, these effects were not fully retained at follow-up, since a return in reported fear was observed in the PRCS and SSPS-P. The comparison between pre-assessment and follow-up shows that, despite the observed return in fear responding, the decrease in the PRCS and SSPS-N was still significant. Furthermore, a visual inspection suggests that there was an increase in positive self-statements between pre-assessment and follow-up, but this effect was not statistically significant.

The Effect of the Expectancy Subtype on the Amount of Expectancy Disconfirmation

To test the hypothesis that expectancies about one's own reaction can better be tested in VRET than expectancies about the (overt) reactions of the audience and about being negatively evaluated, the proportion of testable expectancies was computed for each expectancy subtype (e.g. self, audience and negative evaluation). Subsequently, a repeated measures ANOVA was performed. Mauchly's test of sphericity indicated that the variances of the differences between levels differed significantly, $W = 0.85$, $X^2(2) = 6.38$, $p < .05$, therefore the Greenhouse-Geisser correction was applied. Analysis showed a significant effect of subtype on expectancy disconfirmation, $F(2, 82) = 6.18$, $p < .005$. Figure 6 indicates that expectancies regarding the own reactions are the most testable, $M_{self} = 0.658$, $SD_{self} = 0.646$, followed by expectancies towards negative evaluations, $M_{neg\text{-}ev} = 0.478$, $SD_{neg\text{-}ev} = 0.467$, and expectancies towards the audience, $M_{aud} = 0.469$, $SD_{aud} = 0.469$. A Bonferroni post-hoc comparison revealed that expectancies towards the own reactions (e.g. 'self') differ significantly from expectancies towards the audience, $p = .011$, and negative evaluations, $p = .041$, but that expectancies towards the audience versus negative evaluation did not, $p = 1$. These results confirm that expectancies regarding the own reactions are better testable in VRET than expectancies towards an audience or negative evaluations.

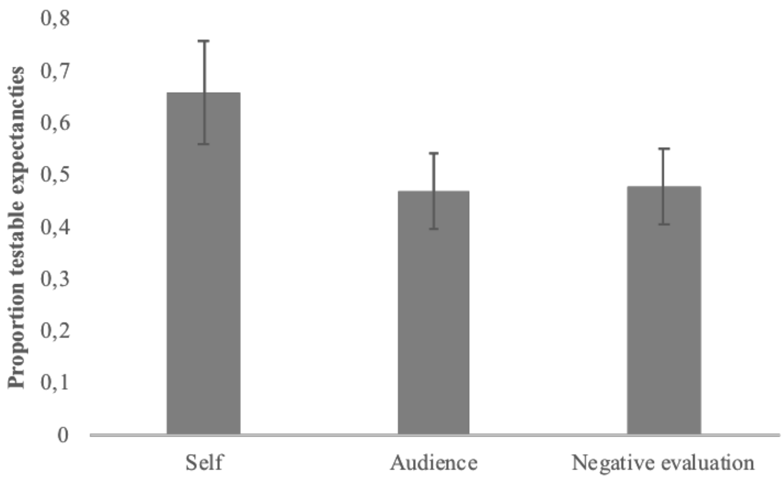

Figure 6. Mean proportion of testable expectancies per subtype. Error bars represent standard error of the mean.

The Effect of the Proportion Testable Expectancies on VRET Outcome

Finally, multiple linear regression analyses were performed to test whether VRET outcome at post-assessment could be predicted by the proportion of testable expectancies. This was performed for the different subtypes of expectancies (i.e., self, audience, negative evaluation). Results indicated that for all outcome variables the pre-assessment levels significantly predicted the post-assessment outcome (Table 1). However, for none of the subtypes, the proportion of testable expectancies were predictive for post-assessment outcome when controlled for pre-assessment levels (Table 2-4).

Table 1

Multiple linear regression analyses with mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at pre-assessment and each proportion of testable expectancy subtype as predictor variables and mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at post-assessment as outcome variables.

Measures	Exp. Subtype	R^2	*F*	df1	df2	*p*
Mean-SUDS	Self	.473	17.962	2	40	<.001
	Audience	.504	19.779	2	39	<.001
	Neg. Ev.	.488	19.091	2	40	<.001
Mean baseline-corrected Heart Rate	Self	.470	17.765	2	40	<.001
	Audience	.446	15.703	2	39	<.001
	Neg. Ev.	.434	15.340	2	40	<.001
PRCS	Self	.339	10.278	2	40	<.001
	Audience	.387	12.306	2	39	<.001
	Neg. Ev.	.342	10.415	2	40	<.001
SSPS-P	Self	.530	22.559	2	40	<.001
	Audience	.547	23.592	2	39	<.001
	Neg. Ev.	.534	22.909	2	40	<.001
SSPS-N	Self	.769	66.500	2	40	<.001
	Audience	.787	72.182	2	39	<.001
	Neg. Ev.	.777	69.751	2	40	<.001

Note. Abbreviations: SUDS = Subjective Units of Distress Scale, PRCS = Personal Report of Confidence as a Speaker; SSPS = Self-Statements During Public Speaking, SSPS-P = subscale Positive self-statements, SSPS-N = subscale Negative self-statements, Exp. Subtype = Expectancy subtype (e.g. towards the participants own reactions, towards the audience or towards negative evaluation).

Table 2

Multiple linear regression analysis with mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at pre-assessment and the expectancy towards the own reaction (or self) as predictor variables and mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at post-assessment as outcome variables.

	B	SEB	β	*t*	*p*
Mean-SUDS					
Intercept	2.707	8.455		0.32	.751
Pre level	0.686	0.115	0.686	5.96	< .001
Exp. Self	1.240	7.990	0.018	0.16	.877
Mean Diff. Heart rate					
Intercept	12.534	5.210		2.41	.021
Pre level	0.516	0.098	0.617	5.28	< .001
Exp. Self	-9.589	5.354	-0.209	-1.79	.081
PRCS					
Intercept	-1.327	4.495		-0.30	.769
Pre level	0.842	0.186	0.585	4.53	< .001
Exp. Self	-1.018	3.493	-0.038	-0.29	.772
SSPS-P					
Intercept	1.560	2.031		0.77	.447
Pre level	0.695	0.104	0.725	6.67	< .001
Exp. Self	0.621	1.852	0.036	0.34	.739
SSPS-N					
Intercept	0.071	1.409		0.05	.960
Pre level	0.837	0.073	0.876	11.50	< .001
Exp. Self	0.435	1.544	0.021	0.28	.779

Note. Abbreviations: SUDS = Subjective Units of Distress Scale, PRCS = Personal Report of Confidence as a Speaker; SSPS = Self-Statements During Public Speaking, SSPS-P = subscale Positive self-statements, SSPS-N = subscale Negative self-statements, Exp. Self = Expectations towards the own reactions.

Table 3

Multiple linear regression analysis with mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at pre-assessment and the expectancy towards the audience as predictor variables and mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at post-assessment as outcome variables.

	B	SEB	β	*t*	*p*
Mean-SUDS					
Intercept	-3.946	8.234		-0.48	.634
Pre level	0.741	0.118	0.735	6.29	< .001
Exp. Aud.	8.873	5.172	0.200	1.72	.094
Mean baseline-corrected Heart rate					
Intercept	4.498	4.052		1.11	.274
Pre level	0.564	0.101	0.673	5.58	< .001
Exp. Aud.	1.166	3.536	0.040	0.33	.743
PRCS					
Intercept	-3.938	4.350		-0.91	.371
Pre level	0.904	0.183	0.629	4.93	< .001
Exp. Aud.	0.772	2.188	0.045	0.35	.726
SSPS-P					
Intercept	1.737	1.710		1.02	.316
Pre level	0.663	0.107	0.692	6.20	< .001
Exp. Aud.	1.528	1.219	0.140	1.25	.218
SSPS-N					
Intercept	-0.280	1.097		-0.26	.799
Pre level	0.836	0.070	0.883	11.95	< .001
Exp. Aud.	1.184	0.952	0.092	1.24	.221

Note. Abbreviations: SUDS = Subjective Units of Distress Scale, PRCS = Personal Report of Confidence as a Speaker; SSPS = Self-Statements During Public Speaking, SSPS-P = subscale Positive self-statements, SSPS-N = subscale Negative self-statements, Exp. Aud. = Expectations towards the audience.

Table 4

Multiple linear regression analysis with mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at pre-assessment and the expectancy towards negative evaluations as predictor variables and mean-SUDS, mean baseline-corrected heart rate, PRCS, SSPS-P and SSPS-N at post-assessment as outcome variables.

	B	SEB	β	*t*	*p*
Mean-SUDS					
Intercept	-0.611	7.867		-0.08	.938
Pre level	0.712	0.115	0.713	6.18	< .001
Exp. Neg. Ev.	5.438	4.935	0.127	1.10	.277
Mean baseline-corrected Heart rate					
Intercept	3.851	4.135		0.93	.357
Pre level	0.561	0.102	0.671	5.51	< .001
Exp. Neg. Ev.	2.258	3.434	0.080	0.658	.515
PRCS					
Intercept	-2.831	4.457		-0.64	.529
Pre level	0.857	0.189	0.595	4.545	< .001
Exp. Neg. Ev.	1.125	2.184	0.067	0.52	.609
SSPS-P					
Intercept	2.151	1.742		1.24	.224
Pre level	0.706	0.104	0.736	6.77	< .001
Exp. Neg. Ev.	-0.759	1.141	-0.072	-0.67	.510
SSPS-N					
Intercept	-0.225	1.115		-0.20	0.841
Pre level	0.840	0.071	0.878	11.76	<0.001
Exp. Neg. Ev.	1.174	0.932	0.094	1.26	0.215

Note. Abbreviations: SUDS = Subjective Units of Distress Scale, PRCS = Personal Report of Confidence as a Speaker; SSPS = Self-Statements During Public Speaking, SSPS-P = subscale Positive self-statements, SSPS-N = subscale Negative self-statements, Exp. Neg. Ev. = Expectations towards negative evaluations.

Discussion

The aim of this study was to investigate the underlying mechanisms of virtual reality exposure therapy (VRET). Although research has established that VRET reduces anxiety in the treatment of public speaking anxiety (Harris, Kemmerling, & North, 2002; Wallach, Safir, & Bar-Zvi, 2009), the underlying mechanisms as to *why* it works are still unclear. One proposition is the inhibitory learning theory (ILT), which emphasises the importance of disconfirming dysfunctional fear expectancies in order to achieve a significant fear decline (Craske et al., 2008). In line with this theory our hypotheses stated that (1) VRET would diminish the fear of public speaking at post-assessment, (2) treatment effects would be retained at a one-week follow-up, (3a) the expectancy subtype would play a role in the amount of disconfirmation, i.e. expectations regarding the own fear reactions would be better testable than feared expectancies regarding others (e.g. the audience) or negative evaluations and (3b) the proportion of testable expectancies would have an predictive effect on VRET outcome.

We examined these hypotheses by recruiting participants with a high fear of public speaking. The participants were asked to complete four consecutive sessions. During the first and last session participants had to perform a live BAT, while wearing a heart rate monitor. At the end of these sessions they were also asked to fill in the PRCS, SSPS and List of expectations. During the third and fourth session, participants were asked to complete five virtual reality exposure exercises in which they had to present a previously unknown topic. At the end of the fourth session participants were also requested to fill in the PRCS, SSPS and List of Expectations. One week after completion of the last session, participants were asked to fill in an online follow-up of the PRCS and SSPS.

Results of this study provide partial support for our hypotheses. First, our results confirm that VRET has an overall and immediate decreasing effect on public speaking anxiety. Second, this effect is partially retained at a one-week follow-up. The comparison between pre-assessment and follow-up indicated that there was a significant decrease in public speaking anxiety for the variables PRCS and SSPS-N, but no significant change was found for the SSPS-P questionnaire. Although, the comparison between post-assessment and follow-up showed that there was a significant increase in anxiety for the PRCS questionnaire, the degree of fear did not return to its original level. Third, results confirm that some expectancies can better be tested in VRET than others. More precisely the results indicate that expectancies regarding the own fear reactions are more testable than expectancies towards the audience or negative evaluations. Finally, the results did not conform the fourth hypothesis that the VRET outcome could be predicted by the proportion of testable expectancies.

Our findings are in line with previous research in which significant decreases in anxiety after VRET for public speaking were found, in both self-rated questionnaires and physiological measures (Harris et al., 2002; Wallach et al., 2009). Furthermore, other studies have demonstrated follow-up effects of VRET. A meta-analysis by Vanni, et al. (2013) showed that the decrease in public speaking anxiety was sustained at a three month follow-up. Likewise, a follow-up study by Safir, Wallach and

Bar-Zvi (2012) showed that treatment gains were maintained after one year. However, our study was subject to a number of limitations. The first limitation with regard to the follow-up assessment in this study is the limited number of variables used to assess the anxiety level at follow-up. The second limitation is that we only used a brief one week time period between post-assessment and follow-up, which might be too short to determine long-term effects. Alternatively, it is possible that the (limited) fear increase found in this study's follow-up is part of a natural process. Future research should examine if treatment effects are still retained after an expanded time period or whether the observer increase leads to a complete reinstatement of fear.

Further, we assumed that the disconfirmation of dysfunctional beliefs would be a significant predictor of the VRET outcome and that the various expectancy subtypes would each influence the treatment outcome to a different extent. However, our results only partially confirmed these hypotheses. This is in contrast with a study by Schumm, Dickstein, Walter, Owens and Chard (2015) who found that change in negative beliefs about the self, but not changes in dysfunctional beliefs about the world, preceded changes in PTSD-related symptoms. Although, our data showed that expectations regarding the own reactions are more testable than other beliefs, the effect of testable expectancies on top of pre-levels was found to be non-significant. This is in contrast to research by Botella et al. (2004), that found that VRET stimulates the dysfunctional fear and avoidance memory structures and leads to a significant decrease in fear, avoidance and catastrophic beliefs. A possible explanation for our outcome is that this study did not take into account the necessary social (e.g. peers, partners, media, stereotypes,…) and attentional (e.g. the detection of stimulus valence and stimulus probability, allocation of attention, preparation of anticipatory reactions and application of coping mechanisms) processes, previously mentioned by Rief et al. (2015), to optimally violate dysfunctional beliefs. Another option is that the expectancy violation in this study was insufficiently adjusted to the individual fear beliefs of the participants (Craske et al., 2014), thus not maximally disconfirming dysfunctional fear expectancies. As Craske et al. (2014, p. 12) stated: "Clinically, it is important that the client identify the US when predicting the expectancy to be violated". For example, the fear expectancy of a person with social anxiety might be that they will get ignored while giving a presentation. Therefore, the mere disconfirmation of "the belief of getting anxious while speaking", will not be a disruptor of the whole fear belief (e.g. social anxiety). Consequently, future research should be more adaptable to the fears and expectancies of the participant. For example, it would be interesting to look at the treatment effect of VRET when the virtual events and environment are adjusted to the specific dysfunctional fear expectancies of the participant.

To recapitulate, the key-components of VRET were interaction, presence and immersion (Freeman et al., 2017; Krijn et al., 2004; Schuemie et al., 2001; Schultheis & Rizzo, 2001). As mentioned by Maples-Keller et al. (2017) a downside of early research regarding VRET is that many of these studies did not entail all three components. As reported, participants in this study were also unable to interact with the virtual audience because our VRET exercises were filmed rather than programmed. However, our instructions were formulated to deceive participants into believing that the VRET was interactive, until they were randomly assigned to one of two conditions (e.g. interactive group and non-interactive group) at the end of the fourth session. Because the focus of this study was not the impact of the manipulation on anxiety, we will not report on this outcome. Nonetheless, we recommend future researchers to create a virtual reality setting with whom the participant can interact.

Another shortcoming is that our participants were not allowed to move around the virtual reality environment because the video of our environment was made using a static 360° camera. Therefore, it is possible that, if our participants moved while inside the simulation his or her perspective of the room would not change, which, in turn, could lead to the development of cybersickness (Kolasinski, 1995; Smart, Stoffregen, & Bardy, 2002). In addition, it is possible that the continued presence of the experimenter during the VRET sessions lead to a diminished sense of realness (Powers et al., 2013). However, because we did not have a measure to determine the amount of experienced presence it was not possible to determine if this lead to a diminished sense of realness.

Further, we can assume that this study did fulfil the third key-component of immersion, as each participant was completely surrounded by a non-physical, simulated world, through the use of the VR headset (Sanchez-Vives & Slater, 2005; Schuemie et al., 2001; Slater & Wilbur, 1997). This assumption was supported by a study by Baños et al. (2004), which demonstrated that the presence of immersion is more important when dealing with a non-emotional environment than an emotional one. More specifically they concluded that when the goal of the virtual reality exposure is to reduce or modify an emotion, a coordinated content design is more important than the level of immersion. Since this study only used participants with a fear of public speaking and the virtual reality exposure sessions were all made up to simulate public speaking situations, we can assume that this key-component was fulfilled.

Additionally, the expectancy violation approach continues exposure until the disconfirmation of the dysfunctional believe, contrary to previous exposure approaches which continued until an apparent fear decline (Craske et al., 2014). Thus, it can be suggested that the differences in the structure of this study and the expectancy violation approach may also play a part in our findings. An interesting set-up for future research would be the following: an experimental design with two conditions, one in which the VRET sessions are pre-determined in time and one in which the VRET sessions are concluded once a significant change in dysfunctional fear expectancies is established. The downside to this arrangement is that the participants in the second condition will repeatedly be reminded of their participation in an experimental study because they have to reflect on their (changing) fear expectancies.

Next, some smaller limitations will be discussed. Future research should try to use the same confederates for every pre-assessment and post-assessment. In this study we used different volunteers because of practical reasons, in which one person was the same at pre- and post-assessment. However, using the same confederates for every pre-assessment and others for every post-assessment would further optimize the standardisation.

Yet, there have also been a couple of strengths of this study. First of all, we used the two-question survey as a screening method before admission to this study. The two-question survey has previously used in research regarding public speaking anxiety by Craske et al. (2011) and, Tsao and Craske (2000). Further, real life exposure sessions were used as indicators of fear levels before and after the virtual reality exposure training. Both physiological and self-report measures were used, as to attain an objective measure of fear. We completed a comprehensive study of the pro's and con's of available virtual reality technology. We opted for the Samsung VR because this allowed us to create our own virtual reality environment, which was compatible with a Samsung virtual reality headset and was easy in use. More specifically, the Samsung headset is not attached to extension cords, thus not limiting head movement or weighing down the participant. In addition, multiple contexts were used for the virtual reality exposure sessions (Vansteenwegen et al., 2007; Balooch, Neumann, & Boschen, 2012; Bandarian-Balooch, Neumann, & Boschen, 2015). Even though we did not find evidence for the inhibitory learning model, this study is one of the first that explores the underlying mechanisms of VRET.

This study has demonstrated that VRET is useful in the treatment of public speaking anxiety. However, we did not find evidence for the role of expectancy violation in VRET, the mechanism at work in exposure according to ILT. An alternative explanation for the underlying mechanisms of VRET is the cognitive processing therapy (CPT). This theory is based on the information processing theory (Lang, 1977/2016) and social cognitive theories of PTSD (Resick, Monson, & Chard, 2008). Although the CPT is currently only used in the treatment of trauma, the theory regarding the working mechanisms may also be applicable to anxiety disorders in general. In line with the EPT and the ILT, the CPT states that a person's memory can store fear structures, which elicit avoidance or fear behaviour (Moser, Hajcak, Simons, & Foa, 2006). The theory states that the fear structures come from a traumatic event, which evokes primary and secondary emotions. While primary emotions refer to feelings directly related to the traumatic event, secondary emotions are the cognitive appraisals behind other emotions. The CPT states that the core of exposure is not habituation, but the restoration of emotion and cognition within memory, which have an effect on behaviour (Resick et al., 2008). The change in trauma-related cognitive distortions through CPT based exposure has been confirmed by Sobel, Resick and Rabalais (2009) and Schumm, Dickstein, Walter, Owens and Chard (2015) . In other words, it is important to identify the dysfunctional fear expectancies and the emotional affect connected to the cognitive structure in order to achieve treatment success (Resick et al., 2008). In line with our findings, a study by Foa and Rauch (2004) and a study by Moser et al. (2006) found that negative beliefs about oneself are related to PTSD symptom severity, but not negative cognitions about the world.

In conclusion, results of this study suggest that VRET immediately reduces anxiety for public speaking and that these effects are partially retained at follow-up. Furthermore, the underlying mechanisms were explored. Based on the ILT, we hypothesized that the more an expectation could be tested, the more it could be disconfirmed. In addition, we expected that certain expectancy subtypes would be easier to test (and thus violate) than others. We found that the expectancy subtype does influence the amount of expectancy disconfirmation. However, results also showed that the proportion of testable expectancies did not statistically influence the overall outcome. In other words, no evidence for the inhibitory learning theory was found. A first premise for future research and theory was made with the proposition of the theory of cognitive processing therapy, often used in the treatment of PTSD. It is possible that a combination of information processing theories and social cognitive theories can address the underlying mechanisms of (virtual reality) exposure.

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Appendix 1: Head Mounted Device (HMD)

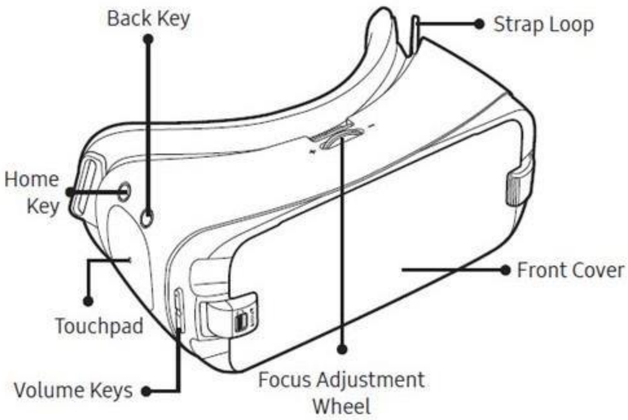

Figure 1. Device layout. Retrieved of “Interactive guide: Front View of the Device”, from Samsung Support, 2016 (http://www.samsung.com/us/support/owners/product/gear-vr-2016). Copyright 2017, SAMSUNG

Appendix 2: List of expectations (general version) (unvalidated)

LIST OF EXPECTATIONS, PRE-ASSESSMENT

This questionnaire is about the expectations that people might have when they speak or bring a presentation in front of an audience. Please select for each of the following expectations if the expectation applies to you in general during situations in which you speak or bring a presentation.

Pp-nr: …………..
Gender: M / F
Date: …………….
Session: PRE

1. I will not know what to say	YES - NO
2. They will think I am incompetent	YES - NO
3. I will perspire a lot	YES - NO
4. I will have palpitations	YES - NO
5. They will think I am not interesting	YES - NO
6. I will lose control over myself	YES - NO
7. They will think I am weird	YES - NO
8. I will start blushing, turn red	YES - NO
9. People of the audience will start asking difficult questions	YES - NO
10. The fear will be unsufferable	YES - NO
11. I will not be able to handle the situation	YES - NO
12. They will think I am ridiculous	YES - NO
13. They will think I am boring	YES - NO
14. I will freeze	YES - NO
15. I will escape from the situation	YES - NO
16. People of the audience will sigh as a response to my presentation	YES - NO
17. Suddenly, I will not know what to say	YES - NO
18. They will think I am weak	YES - NO

19. I will vomit YES - NO

20. People of the audience will look disapprovingly as a response to my presentation YES - NO

21. I will start to cry YES - NO

22. I will not be able to think YES - NO

23. People of the audience will start yawning as a response to my presentation YES - NO

24. I will feel dizzy YES - NO

25. I will start hyperventilating YES - NO

26. People of the audience will start to laugh because of what I am saying YES - NO

27. I will get overwhelmed by fear and I will not be able to speak anymore YES - NO

28. People of the audience will criticize me YES - NO

29. I will feel nauseous YES - NO

30. They will think I am unintelligent YES - NO

31. I am going to stutter YES - NO

32. I will fail (I will not pass the presentation) YES - NO

33. People in the crowd will use their cellphone when they think I am not interesting YES - NO

34. I will faint YES - NO

35. People of the audience will roll their eyes as a response to my presentation YES - NO

36. People of the audience will frown as a response to my presentation YES - NO

37. They will think I am stupid YES - NO

38. I will become hysterical YES - NO

39. They will think I say dumb things YES - NO

40. I will make a bad impression YES - NO

41. I will shake and/or tremble YES - NO

42. They will think I look like foolish YES - NO

43. I will start to panic YES - NO

44. People of the audience will start talking to each when they think my presentation is uninteresting YES - NO

45. I will lose my mind YES - NO

46. They will notice that I am anxious and nervous YES - NO

47. I will become aggressive YES - NO

48. I will talk weird YES - NO

49. They will think I am a “loser”/idiot YES - NO

50. People of the audience will leave as a response to my presentation YES - NO

Do you have expectancies concerning about speaking/bringing a presentation in front of an audience which are not listed in the previous list? Please write these expectancies down:

- …………………………………………………………………………………………………… ……………………………………………

- …………………………………………………………………………………………………… ……………………………………………

- …………………………………………………………………………………………………… ……………………………………………

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Appendix 3: List of expectations (VR specific version) (unvalidated)

LIST OF EXPECTATIONS, VR SESSION AND POST-ASSESSMENT SESSION

Pp-nr: …………..
Gender: M / F
Date: …………….
Session: EXP4 / POST

This questionnaire is about the expectations that people might have when they speak or bring a presentation in front of an audience. Please select for each of the following expectations if it was possible for you to test the expectation whether or not during the virtual reality exercises.

Pay attention, this is about whether the following statements could happen during the speech in front of the virtual audience, regardless of the actually happening of the expectation. If you have the feeling that a statement/ expectation could happen during the virtual reality exercises, you can answer "yes", even when the statement/expectation did not occur. Only if you have the feeling it was not possible that the statement/expectation could occur during the virtual reality exercises you can answer "no".

1. I will not know what to say — YES - NO
2. They will think I am incompetent — YES - NO
3. I will perspire heavily — YES - NO
4. I will have palpitations — YES - NO
5. They will think I am not interesting — YES - NO
6. I will lose control over myself — YES - NO
7. They will think I am a weird person — YES - NO
8. I will start blushing, turn red — YES - NO
9. People of the audience will start asking difficult questions — YES - NO
10. The fear will be unsufferable — YES - NO
11. I will not be able to handle the situation — YES - NO
12. They will think I am ridiculous — YES - NO
13. They will think I am boring — YES - NO
14. I will freeze — YES - NO
15. I will escape from the situation — YES - NO

16. People of the audience will sigh as a response to my presentation YES - NO

17. Suddenly, I will not know what to say YES - NO

18. They will think I am weak YES - NO

19. I will vomit YES - NO

20. People of the audience will look disapprovingly as a response to my presentation YES - NO

21. I will start to cry YES - NO

22. I will not be able to think YES - NO

23. People of the audience will start yawning as a response to my presentation YES - NO

24. I will feel dizzy YES - NO

25. I will start hyperventilating YES - NO

26. People of the audience will start to laugh because of what I am saying YES - NO

27. I will get overwhelmed by fear and I will not be able to speak anymore YES - NO

28. People of the audience will criticize me YES - NO

29. I will feel nauseous YES - NO

30. They will think I am unintelligent YES - NO

31. I am going to stutter YES - NO

32. I will fail (I will not pass the presentation) YES - NO

33. People in the crowd will use their cellphone when they think I am not interesting YES - NO

34. I will faint YES - NO

35. People of the audience will roll their eyes as a response to my presentation YES - NO

36. People of the audience will frown as a response to my presentation YES - NO

37. They will think I am stupid YES - NO

38. I will become hysterical YES - NO

39. They will think I say dumb things YES - NO

40. I will make a bad impression YES - NO

41. I will shake and/or tremble YES - NO

42. They will think I look like foolish YES - NO

43. I will start to panic YES - NO

44. People of the audience will start talking to each when they think my presentation is uninteresting YES - NO

45. I will lose my mind YES - NO

46. They will notice that I am anxious and nervous YES - NO

47. I will become aggressive YES - NO

48. I will talk weird YES - NO

49. They will think I am a "loser"/idiot YES - NO

50. People of the audience will leave as a response to my presentation YES - NO

Write *down your own extra expectations and ascertain if you were (un)able to test them during the virtual reality exercises:*

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AFDELING
Straat nr bus 0000
3000 LEUVEN, BELGIË
tel. + 32 16 00 00 00
fax + 32 16 00 00 00
www.kuleuven.be