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A Meta-Analysis of the Efficacy of Virtual Reality and In Vivo Exposure Therapy as Psychological Interventions for Public Speaking Anxiety

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Abstract

Public speaking anxiety (PSA) is a prevalent condition with disabling occupational, educational, and social consequences. Exposure therapy is a commonly utilized approach for treating PSA. Traditionally, this intervention has been delivered as in vivo exposure therapy (IVET). Limitations inherent to in vivo as a mode of delivery have been identified and studies have increasingly explored the use of Virtual Reality Exposure Therapy (VRET) as an alternative. Understanding the efficacy of both VRET and IVET as psychological interventions for PSA is important. A systematic search identified 11 studies with 508 participants. Meta-analysis yielded a large significant effect wherein VRET resulted in significant reductions in PSA versus control of −1.39 ($Z=3.96$, $p<.001$) and a similar large significant effect wherein IVET resulted in significant reductions in PSA versus control of −1.41 ($Z=7.51$, $p<.001$). Although IVET was marginally superior to VRET, both interventions proved efficacious. Given the advantages of utilizing VRET over IVET future research and clinical practice could explore VRET as a treatment option for PSA.

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Public speaking Anxiety (PSA), where individuals experience high levels of discomfort when speaking to an audience (O'Hair et al., 2011), is recognized as the most prevalent social fear in both clinical (Furmark et al., 2000) and non-clinical samples (Stein et al., 1996); with prevalence rates estimated between 20% (Leary & Kowalski, 1997) and 85% (Motley, 1995) in community samples. PSA describes the experience of individuals who converse easily in every-day social interactions but experience physiological, behavioral, and cognitive symptoms when delivering or anticipating the delivery of a speech in-front of a group of people (Bodie, 2010). As with other anxiety disorders, individuals with PSA often avoid or escape from situations (Maner & Schmidt, 2006) which involve public speaking. This can result in negative consequences for occupational and educational progression wherein public speaking is often a requisite (Raja, 2017) and is recognized as a desirable professional skill (Ulinski & O'Callaghan, 2002).

Arguably the most problematic aspect of PSA is the associated social consequences (Blöte et al., 2009). Individuals with PSA have a significantly increased risk of developing Social Anxiety Disorder (SAD) (Blöte et al., 2009) characterized as an enduring fear of at least one social or performance situation in which the individual is exposed to unknown people or to possible scrutiny (American Psychiatric Association, 2013). It is estimated that 97% of individuals with SAD experience PSA (Beidel & Turner, 2007) and approximately 40% of individuals with SAD experience severe and debilitating PSA (Ruscio et al., 2008). Although PSA is a dominant feature of SAD, some individuals report experiencing PSA without broader SAD symptomatology. Consequently, PSA is recognized as a distinct "performance only" SAD subtype (Pull, 2012). The American Psychiatric Association's (2013) Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5) recognizes this subtype as anxiety restricted to performing or public speaking. This can be distinguished from generalized SAD which encompasses both interaction and performance anxiety.

In acknowledgment of its potentially debilitating impact, several interventions aiming to reduce PSA have been trialed. The majority of PSA interventions are based upon cognitive or behavioral principles (Ebrahimi et al., 2019) which is unsurprising given CBT is the National Institute for Health and Care Excellence (NICE) (2013) recommended intervention for SAD. A recent meta-analysis found CBT interventions to be equally as efficacious as

interventions based upon other modalities (insight therapy, psychodynamic, visualization therapy, EMDR) for treating PSA (Ebrahimi et al., 2019). Each CBT intervention included in said meta-analysis utilized a form of exposure therapy. Established as an effective intervention for treating anxiety disorders (Rodebaugh et al., 2004); exposure therapy involves individuals systematically progressing through a hierarchy of situations which are graded according to the level of fear they evoke. A number of major theories attempt to explain the psychological mechanisms of exposure therapy (e.g., Craske et al., 2008; Foa & Kozak, 1986). The widely accepted emotional processing theory (Foa & Kozak, 1986) purports that emotions, including fear are stored within associative information structures in memory. The activation of escape and avoidance information structures serves as both a precipitating and perpetuating factor for anxiety. Exposure therapy enables participants to overcome this avoidance by directly exposing them to feared situations.

Exposure Therapy has been traditionally delivered In Vivo (IVET) with participants directly confronting their fears in reality (Abramowitz et al., 2019). For individuals with PSA this involves completing a hierarchy of public speaking tasks in front of a live audience. As proposed by Foa and Kozak (1986), through directly confronting these fearful stimuli, in the absence of escape, avoidance and ritualizing, the relationship between the fear stimulus and memory structures is modified and the fear elicited by the stimulus can decrease. Subsequently the therapeutic process of habituation results in a decrease in anxiety (Benito & Walther, 2015). Studies have demonstrated the efficacy of IVET for treating PSA (Lawm et al., 1994; Newman et al., 1994). However, IVET has several limitations. IVET may be difficult to instigate when the cause of anxiety is inaccessible (e.g., flying) or less tangible (e.g., death anxiety). In the case of PSA the practicalities of gathering audiences of increasing sizes is particularly problematic. Moreover, IVET is considered time-consuming, expensive, cumbersome for therapists and difficult to control in order to adhere to traditional exposure hierarchies (Bouchard et al., 2017). When rated as a treatment option, it has low acceptability for client's (Garcia-Palacios et al., 2007) and therapist's (Pittig et al., 2019).

In recognition of IVET's limitations, attempts have been made to deliver exposure therapy through different modalities (Maples-Keller et al., 2017). Of note, is the recent drive to utilize technologically delivered exposure interventions (Pull, 2012). Virtual Reality (VR) is a technological intervention currently receiving considerable attention in healthcare research (Wiederhold & Riva, 2019). VR is an interactive computer environment that enables individuals to experience a sense of presence within pre-recorded environments. Visual VR stimuli are presented via VR glasses or projection-based systems

like CAVE (Cave Automatic Virtual Environment) systems. Through using VR Exposure Therapy (VRET) a participant can confront their fears in a virtual world and experience responses similar to those experienced in confrontation with feared stimuli in reality (Krijn et al., 2004).

VRET overcomes some of the aforementioned limitations of IVET. It is less time consuming and cumbersome (Emmelkamp, 2005), has lower treatment costs (Miloff et al., 2016) and facilitates easy access to stimuli which can be controlled by the therapist (Hartanto et al., 2014). As VRET can take place within a practitioner's office it maintains client confidentiality (Carl et al., 2019). Furthermore, it is a scalable tool that may increase accessibility of therapeutic interventions for clients who are unwilling or unable to attend more traditional forms of psychological interventions (Boeldt et al., 2019). From a client's perspective, VRET is a more acceptable treatment option, with lower refusal rates than IVET (Garcia-Palacios et al., 2007).

Due to the benefits of VRET, significant advancements in VR technology (Miloff et al., 2016) and increased affordability of VR equipment (Freeman et al., 2017); VRET has become an increasingly popular option in the treatment of mental health disorders. VRET has been evidenced as an effective intervention for anxiety disorders (Carl et al., 2019) including but not limited to; specific phobias (Miloff et al., 2016), SAD (Bouchard et al., 2017), PTSD (Reger et al., 2016), and panic disorder (Pelissolo et al., 2012). Meta-analyses have demonstrated the comparable efficacy of VRET and IVET for anxiety disorders (Carl et al., 2019), SAD (Chesham et al., 2018; Powers & Emmelkamp, 2008) and Agoraphobia, Specific Phobia and Social Phobia (Wechsler et al., 2019).

The efficacy of VRET has been demonstrated in studies incorporating participants with PSA (Heuett & Heuett, 2011; Lindner et al., 2019; Wallach et al., 2009). Yet, the efficacy of VRET for PSA has not yet been explored through meta-analyses. Ebrahimi et al. (2019) investigated the efficacy of technology delivered interventions (Video, Internet, VR) in comparison to face-to-face and telephone delivered interventions for PSA. Although this meta-analysis evidenced both modes of delivery were equally efficacious, only three of the incorporated technology delivered interventions employed VRET (Anderson et al., 2013; Harris et al., 2002; Wallach et al., 2009). Given the small number of VRET studies and the combination of different technology delivered interventions in this meta-analysis, further research is required to draw conclusions on the efficacy of VRET for PSA.

When investigating the efficacy of VRET as a psychological intervention, it seems important to also consider the efficacy of the traditional and long-established mode of delivering exposure therapy; IVET. Although both

VRET and IVET contain common features inherent to the category of exposure-based behavioral interventions, the mode of delivery differs. Mode of delivery can impact treatment outcomes in social anxiety, with some reports of VRET being superior to IVET (Bouchard et al., 2017) and dissimilar findings that VRET and IVET are equally efficacious (Klinger et al., 2005).

To date no meta-analysis which can draw a conclusion on the efficacy of either VRET or IVET for treating PSA has been conducted. The objective of the current study is to fill this gap in the literature. The study aims to examine through meta-analysis the efficacy of VRET and IVET as psychological interventions for reducing symptoms of PSA. The study will provide effect size estimates for VRET, IVET, and control conditions.

Method

Registration and Systematic Search Strategy

The protocol for the meta-analysis was preregistered on PROSPERO International Prospective Register of Systematic Reviews (Reeves et al., 2019) and can be accessed at https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=132587. Relevant studies were identified through systematic searches in four major bibliographical databases: Web of Science, PsycINFO, Scopus and Medline in January 2020. The databases were searched using Boolean operators to link the search terms "virtual reality" or VR or VRT or VRET or exposure or CBT or "behavio* therapy," and "public speaking anxiety." As several phrases and terms can be utilized to describe public speaking anxiety, the PSA search utilized the following search terms: "public speaking anxiety" or "public speaking phobia" or "public speaking fear" or "presentation anxiety" or "presentation phobia" or "presentation fear" or "speech anxiety" or "speech phobia" or "public speaking apprehension" or "communication apprehension," or (fear and ["public speaking" or "speaking in public"]). Specific search strategies differed slightly in accordance with the criteria for the database employed. When searching Web of Science search terms were searched as Topics. In both PsycINFO and Medline subject headings for the intervention were exploded and search terms related to PSA were mapped to subject headings. The Scopus database involved searching Titles, Abstracts and Keywords (TITLE-ABS-KEY) for each search term. No date restrictions were applied to the search. Database searches were supplemented by completing a manual reference list search of similar meta-analyses, systematic reviews, and studies identified for inclusion in the meta-analysis, yielding ($n = 2$) papers.

Eligibility Criteria

Utilizing the Participants, Interventions, Comparators, Outcomes (PICO) framework (Schardt et al., 2007) the present meta-analysis included studies where: Participants had elevated levels of PSA as identified through:

(1) Participants scoring above the clinical cut-off on a PSA measure, for example, Personal Report of Confidence as a Speaker.
(2) Participants with a significantly elevated score on a PSA measure (scoring one standard deviation higher than the mean).
(3) Participants who self-report PSA as a significant difficulty.
(4) Participants with a diagnosis of SAD with a noted anxiety for public speaking as identified through self-report or the researcher.

There were no age limit restrictions for participants. Interventions of IVET and/or VRET delivered either as a stand-alone intervention or within a wider intervention package where the primary target of the intervention was PSA were included. Studies were included if the intervention group was compared to a wait list control, no treatment control or non-active control group. Included studies were required to report outcomes utilizing a quantitative measure of PSA. Studies were required to be published in a peer reviewed academic journal or book chapter.

Studies were excluded if:

(A) They did not meet the aforementioned inclusion criteria,
(B) Were duplicate or follow-up studies,
(C) Were published in a non-English language,
(D) Did not include effect size and information required to calculate effect size was not available after contacting the author,
(E) The primary target of the intervention was Social Anxiety not PSA,
(F) The primary target of the intervention was another speech disorder not directly related to anxiety.

Study Selection

A PRISMA flow diagram (Moher et al., 2009) depicts the number of studies screened and excluded during the screening process (Figure 1). Systematic searches in four major databases resulted in a total of 779 studies. A reference list search yielded two studies. Following removal of duplicates, 481 studies remained. Titles and abstracts of all 481 studies were reviewed by the first author and 441 studies were excluded. Where required, authors were

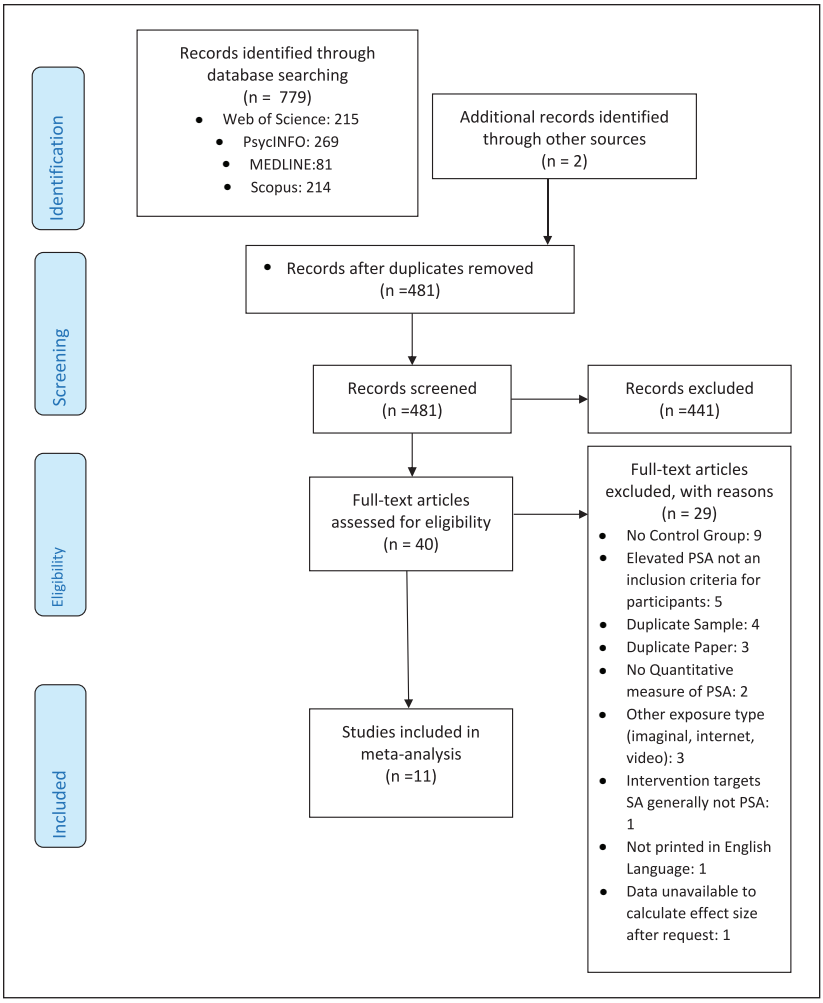

Figure 1. Selection of studies.

contacted for further information. Authors North et al. (1998) confirmed that the Trivial VR scene utilized for the comparator group was a walk through a virtual park and did not involve any PSA environments or active interventions. Thus, this study was deemed eligible for inclusion. Despite attempts the author was unable to receive clarification from Heuett and Heuett (2011) regarding participant inclusion criteria. Participants are termed "students

with high public speaking anxiety," however, the manner in which PSA was measured is poorly defined. Thus, although this study has met inclusion criteria the findings should be interpreted with caution. The authors Lindner et al. (2019) were contacted as a corrigendum to their paper was released due to a phrasing error in the PSA measure utilized. Updated means and standard deviations were provided. Lister et al. (2010) paper was excluded as the corresponding author could not provide the information required to calculate the effect size for the control group. Finally, authors of Wallach et al. (2009) study provided post scores for the subgroups in their study. The original article reported post-change scores. Once the aforementioned information was received the first author and a second independent reviewer independently reviewed the abstracts and full texts of all remaining studies ($n = 40$) to determine studies eligible for inclusion. Concerning inclusion of full text articles, the disagreement between the two independent reviewers occurred four time across 40 studies, yielding a substantial agreement (90%) with a Cohen's Kappa of 0.75. Where a decision could not be made between the first and second reviewer regarding studies eligibility for inclusion, this was discussed with a third researcher who provided a final decision. This resulted in a final total of 11 studies to be included in the meta-analysis.

Data Extraction

The following data were extracted from all 11 studies included and are displayed in Table 1: participant sample (diagnostic/non-diagnostic), conditions (VRET/IVET/Control), format (individual or group), exposure type (IVET, VRET) any additional interventions (exposure only/CBT package), number of participants, number of intervention sessions and the instrument measuring PSA. To determine the effects of the interventions on PSA; means and standard deviations for the intervention and control conditions post intervention were collected. For the five studies that included mixed methods of measuring PSA (i.e., physiological anxiety measures, speech length, behavioral assessment) only quantitative questionnaire data was extracted. Three papers included multiple questionnaire based PSA measures. For these studies data was only extracted from a single measure. Selecting a single outcome measure which provides data which best represents the focus of the meta-analysis, is a recommended statistical method (Card, 2012). In Harris et al. (2002) The Personal Report of Confidence as a Speaker (PRCS) data was extracted as this measure was widely used across other studies included within the meta-analysis. In Heuett & Heuett (2011) the Personal Report of Communication Apprehension (PRCA) was extracted as it was identified by the authors as the primary PSA scale within the study. Similarly,

Table 1. Study Characteristics Table.

Author (date)	Country	Pop	Conditions and format	Exposure type	Intervention package/additional interventions (VR and In vivo conditions)	N	N Ses	PSA measure
Anderson et al. (2013)	USA	D	Exposure Group Therapy	In vivo		39	8	PRCS
			Individual Virtual Reality Exposure	Virtual Reality	**CBT for Social Anxiety** Psychoeducation, realistic goal setting for social situations (cognitive preparation, challenging of cost and probability biases), relapse prevention, homework (daily mirror task, daily record of social situations, identification of cognitive bias)	28	8	
			WL			30		
Harris et al. (2002)	USA	ND	Individual Virtual Reality Exposure	Virtual Reality	Exposure only	8	4	PRCS
			WL			6		
Heuett and Heuett (2011)	USA	ND	Individual Virtual Reality Exposure	Virtual Reality	Exposure only	40	1	PRCA
			No Treatment Control			40		
Lawm et al. (1994)	USA	ND	Group graded exposure plus feedback	In vivo	Exposure only	9	5	PRCS
			WL			4		
Lindner et al. (2019)	Sweden	ND	Therapist-led Virtual Reality Exposure	Virtual Reality	Psychoeducation, extraction of catastrophic beliefs that could be tested during exposure.	25	1	PSAS
			WL			25		
Newman et al. (1994)	USA	D	Exposure Group Therapy	In vivo	Exposure only	16	8	PRCS
			WL			17		
North et al. (1998)	USA	ND	Individual Virtual Reality Exposure	Virtual Reality	Exposure only	8	5	ATPSQ
			No Treatment Control			8	5	

(continued)

Table 1. (continued)

Author (date)	Country	Pop	Conditions and format	Exposure type	Intervention package/additional interventions (VR and In vivo conditions)	N	N Ses	PSA measure
Price and Anderson (2012)	USA	D	Individual Virtual Reality Exposure	Virtual Reality	**CBT for Social Anxiety** Targets self-focused attention, negative perceptions of self and others, perceptions of lack emotional control, realistic goal setting for social situations	33	8	PRCA-SF
			Exposure Group Therapy	In vivo		34	8	
			WL			25		
Schoenberger et al. (1997)	USA	ND	Group CBT	In vivo	**CBT for Social Anxiety:** Cognitive restructuring and progressive relaxation.	17	5	PRCS
			WL			10		
Trussell (1978)	USA	ND	Group GBR	In vivo	Exposure only	15	8	PRCS
			No Treatment Control			13		
Wallach et al. (2009)	Israel	ND	Individual Virtual Reality Exposure	Virtual Reality	**CBT** Presentation of cognitive and behavioural model of social phobia, training in cognitive restructuring (CR). CR role plays and homework assignments.	28	12	SSPS-N
			WL			30		

Note. ATPSQ = attitudes toward public speaking questionnaire; CBT = cognitive behavioral therapy; D = diagnostic; GBR = graduated behavior rehearsal; ND = non-diagnostic; N ses = Number of Intervention Sessions; POP = Population; PRCS = personal report of confidence as a speaker; PRCA = personal report of communication Apprehension; PRCA-SF = personal report of communication apprehension- short form; PSAS = public speaking anxiety scale; SSPS-N = self statements during public speaking- negative scale; WL = waitlist.

the PRCA was selected in Price & Anderson (2012) as it is identified as giving a more global measure of PSA. Finally, data was extracted from the negative subscale of the SPSS utilized within Wallach et al. (2009). The negative subscale is a more direct measure of PSA, which is more highly correlated with PSA and shows more sensitivity to change than the positive scale (Hofmann & DiBartolo, 2000).

Statistical Analysis

All analyses were conducted using RevMan Version 5.3, developed by the Cochrane Collaboration (Review Manager, 2014). The Generic Inverse Variance Method was employed, and a random effects model was utilized due to the variance in the type of interventions included in the meta-analysis (Borenstein et al., 2010). I^2 was employed to assess heterogeneity across studies with I^2 values of 30% representing mild heterogeneity and values exceeding 50% representing large heterogeneity (Higgins & Thompson, 2002). A 95% confidence interval and a p value were computed for each model and overall effects were computed using z-scores. Funnel plots were created and inspected to check for publication bias, asymmetrical funnel plot areas are indicative of publication bias (Sutton, 2009).To calculate the effects of VRET and IVET on PSA, the effect size demonstrating the difference between the intervention and control group at post-treatment was calculated.

Results

Study Characteristics

Table 1 provides an overview of the study characteristics for all 11 studies included in the current meta-analysis. Of these five utilized VRET (Harris et al., 2002; Heuett & Heuett, 2011; Lindner et al., 2019; North et al., 1998; Wallach et al., 2009), four utilized IVET (Lawm et al., 1994; Newman et al., 1994; Schoenberger et al., 1997; Trussell, 1978) and two directly compared VRET to IVET (Anderson et al., 2013; Price & Anderson, 2012). A total of 508 participants were included across the 11 studies. Of these ($n = 300$) were allocated to a psychological intervention group (VRET $n = 170$ and IVET $n = 130$) and ($n = 208$) were allocated to a control group. The number of treatment sessions ranged from one to twelve with 6.4 being the mean number of treatment sessions. The mean number of sessions was marginally higher for the IVET group (7) than the VRET group (6.3).

Of note is certain studies exclusively used exposure therapy (i.e., VRET or IVET) (Harris et al., 2002; Heuett & Heuett, 2011; Lawm et al., 1994;

Newman et al., 1994; North et al., 1998; Trussell, 1978). Others adopted exposure therapy as the primary therapeutic intervention while including additional accompanying interventions such as CBT for Social Anxiety (Anderson et al., 2013; Price & Anderson, 2012; Schoenberger et al., 1997; Wallach et al., 2009) and Psychoeducation (Lindner et al., 2019). In the two studies that compared VRET and IVET (Anderson et al., 2013; Price & Anderson, 2012) the same accompanying intervention was delivered in both conditions. IVET was delivered in a group format across all studies. VRET was delivered individually. In Lindner et al. (2019) the study comprised two VRET groups (Therapist-Led and Self-Led). The Self-Led group did not have a comparator group, thus only data from the Therapist-Led group was analyzed.

The VR equipment and visual stimuli differed across studies. Regarding visual stimuli six studies utilized Computer Generated Image (CGI) audience scenes (Anderson et al., 2013; Harris et al., 2002; Heuett & Heuett, 2011; North et al., 1998; Price & Anderson, 2012; Wallach et al., 2009). A single study Lindner et al. (2019) utilized video recordings of real-life audience members animated on a continuous loop over a static background image. The use of real life recordings may have instilled a different level of spatial presence, involvement and experienced realism for the participant (Seyama & Nagayama, 2007) than CGI. All studies used HMD devices but image resolution and field of view differed. Harris et al. (2002); Heuett and Heuett (2011) and North et al. (1998) utilized a Pentium-based™ computer (100 MHZ, HMD and Head-Tracker (Virtual I/O™). Wallach et al. (2009) utilized an Intel Pentium 4 computer and the HMD was VFX3D from Interactive Imaging Systems, Inc. Anderson et al. (2013) utilized a VFX headset with 640 image resolution and 480/35° field of view. Lindner et al. (2019) utilized a Samsung Gear VR headset (1st generation) running on a Samsung Galaxy Note 4. The information regarding VR equipment reported by Price and Anderson (2012) is limited and requests for further information were unsuccessful. Some studies also incorporated auditory elements. Heuett and Heuett (2011) and North et al. (1998) utilized an amplifier enabling participants to hear their own voice. Other specifications reported included the incorporation of audience audio clips (e.g., laughing), the ability to manipulate audience size (North et al., 1998) and the ability to manipulate audience members expressions (Anderson et al., 2013; Wallach et al., 2009).

Quality Assessment

Two reviewers both independently completed a risk of bias assessment for each study using The Revised Cochrane risk-of-bias tool for randomized

Figure 2. Estimated risk of bias of the included studies.

trials (RoB 2) (Sterne et al., 2019). Risk of bias was assessed across four main domains and is depicted in Figure 2; risk of bias arising from (1) The randomization process, (2) missing outcome data, (3) measurement of the outcome, and (4) selection of the reported result. Domain 2 which assesses risk of bias due to deviations from the intended interventions was omitted as the questions are not relevant to the methodologies examined in this review.

As per the guidance provided by Sterne et al. (2019) the risk of bias in each domain was rated as either "Low" (+), "High" (–), or "Some Concerns" (×). All quality assessment decisions were based on the information provided in the selected articles. As depicted in Figure 2, of the 11 included studies: eight studies had low risk of bias arising from the randomization process, one was judged to have some concerns and two studies were judged to have high risk of bias. All 11 studies were judged to have a low risk of bias in the domain assessing bias due to missing outcome data. In the domain assessing bias due to measurement of the outcome three studies were rated to have a low risk of bias and eight were rated to have some concerns. Finally, in the fourth domain assessing risk of bias in selection of the reported result all studies were judged to have a low risk of bias. The outcome of each domain was then combined to derive an overall risk of bias judgment. Two studies were judged as low risk of bias, seven were evaluated to have some concerns and two studies had a high risk of bias. Substantial overall agreement was achieved by the two

reviewers (81.82%), yielding a Cohen's Kappa of 0.69. Disagreements were settled by consensus.

Analysis 1: VRET versus Control Conditions

Seven studies reported results relevant to a comparison of VRET and control conditions. The analysis of the studies which included 341 participants (Figure 3) yielded a significant large effect favoring VRET over control on PSA reduction of −1.39 (95%CI = −2.08, –0.70; $Z = 3.96$, $p < .001$). Six studies significantly favor the VRET condition with effect sizes ranging from −1.14 to −2.73. One study marginally favors the control condition with effect size of 0.19. This analysis indicates large and significant heterogeneity (X^2 [6, $N = 341$] = 42.84, $p = <.001$; $I^2 = 86\%$).

The Wallach et al. (2009) study was identified as a single study which seems to marginally favor the control condition. A possible explanation for this, is this study utilized the SSPS scale, which is split into positive and negative scales. However, only data from the negative subscale was included within the current meta-analysis. Thus, a sensitivity analysis was conducted to determine if removal of this data resulted in any significant change. The analysis of six studies which included 280 participants yielded a significant large effect favoring VRET over control on PSA reduction of −1.59 (95%CI = −1.92, −1.27; $Z = 9.72$, $p < .001$).

Subgroup analysis VRET versus Control Conditions

Subgroup analysis indicated a similar large and significant effect favoring VRET over control on PSA reduction in both Diagnostic (−1.32 [95%CI = −1.73, –0.91; $Z = 6.29$, $p < .001$]) and Non-Diagnostic (−1.46 [95%CI = −2.54, −0.38; $Z = 2.65$, $p = .01$]) samples. There was also a large and significant effect favoring VRET over control on PSA reduction when VRET was delivered with additional psychological interventions (i.e., CBT or Psychoeducation) (–1.01 [95%CI = −1.87, −0.15; $Z = 2.30$, $p = .02$]) or when delivered as a stand-alone intervention (–1.95 [95%CI = −2.42, −1.48; $Z = 8.12$, $p < .001$]). Finally, when considering the number of intervention sessions, five studies utilized multiple intervention sessions (4–12) and two studies utilized a single session. A large and significant effect favoring VRET over control on PSA reduction was found in both multiple session (–1.24 [95%CI = −2.14, –0.34; $Z = 2.71$, $p = .01$]) and single session (−1.78 [95%CI = −2.20, −1.37; $Z = 8.38$, $p < .001$]) interventions. The number of studies included in each subgroup analysis was small, thus these findings should be interpreted with caution (Oxman & Guyatt, 1992).

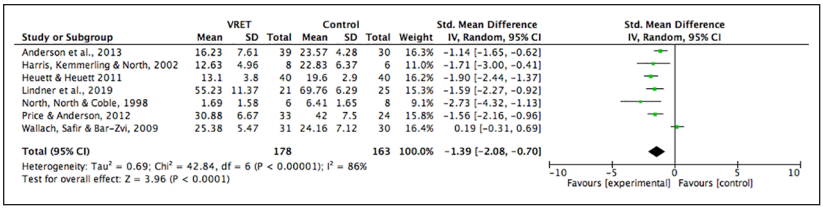

Figure 3. Forest plot. Post PSA scores VRET V Control.

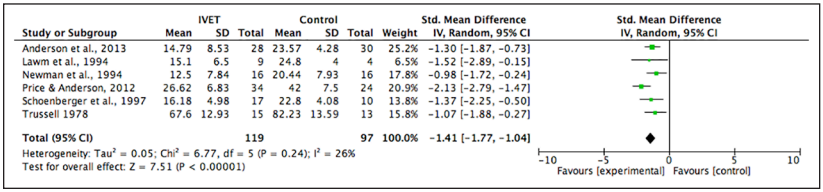

Figure 4. Forest plot. Post PSA scores IVET V Control.

Analysis 2- IVET versus Control Conditions

Six studies reported results relevant to a comparison of IVET and control conditions. The analysis of the studies which included 216 participants (Figure 4) yielded a significant large effect favoring IVET over control on PSA reduction of −1.41 (95%CI=−1.77, −1.04; $Z=7.51$, $p<.001$). All studies significantly favor the IVET conditions with effect sizes ranging from −0.98 to −2.13. The analysis indicates low and non-significant heterogeneity (X^2 [5, $N=216$]=6.77, $p=.24$; $I^2=26\%$).

Subgroup Analysis IVET versus Control

Subgroup analysis indicated a similar large and significant effect favoring IVET over control on PSA reduction in both Diagnostic (–1.48 [95%CI=–2.13, –0.83; $Z=4.47$, $p<.001$]) and Non-Diagnostic (–1.26 [95%CI=–1.80, –0.72; $Z=4.54$, $p<.001$]) samples. There was also a large and significant effect favoring IVET over control on PSA reduction when IVET was delivered with additional psychological interventions (i.e., CBT or Psychoeducation) (–1.61 [95%CI=–2.16, –1.06; $Z=5.71$, $p<.001$]) or when delivered as a stand-alone intervention (–1.09 [95%CI=–1.60, –0.59; $Z=4.23$, $p<.001$]). The number of studies included in each subgroup analysis was small, thus these findings should be interpreted with caution (Oxman & Guyatt, 1992).

Publication Bias

Publication bias was assessed by generation and inspection of two separate funnel plots for VRET versus control and IVET versus control. Visual inspection of both funnel plots indicated asymmetry. This would indicate that there is a potential issue of publication bias in the current meta-analysis as the majority of included studies in both the IVET and VRET condition had significant findings in favor of the intervention group. Rosenthal (1991) proposed that studies with significant findings have a greater probability of publication than studies with non-significant results leading to a potential file-drawer problem. The detection of publication bias indicates the findings should be interpreted with caution.

Discussion

The present meta-analysis included 11 studies which investigated the efficacy of VRET and IVET for reducing PSA. The results of the first meta-analysis indicated that VRET was significantly more efficacious than control with a large effect size. VRET is an effective intervention for reducing the symptoms of PSA. Results of the second meta-analysis indicated that IVET was significantly more efficacious than control in reducing PSA with a large effect size. Although findings demonstrated that IVET was marginally superior to VRET, both interventions can be considered effective interventions for reducing PSA. These findings are consistent with similar meta-analysis which have been conducted which reported that VRET and IVET are comparably efficacious for treating other anxiety disorders including anxiety disorders (Carl et al., 2019), SAD (Chesham et al., 2018) and phobias (Wechsler et al., 2019).

The reductions in PSA as a result of VRET and IVET were found across studies which utilized general assessments of public speaking anxiety (e.g., PRCS, PRCA-24). As these measures did not assess anxiety related to a single public speaking task, they best represent measures of public speaking trait anxiety. Trait anxiety represents a personality trait which remains relatively stable over time (Spielberger et al., 1970). Thus, the findings raise the question as to why significant change was found in this stable construct following a short period of VRET and IVET. A possible explanation is that anxiety is a unidimensional construct, with positive correlations found between state and trait anxiety (Spielberger et al., 1970). Numerous studies have demonstrated a significant positive correlation between trait and state public speaking anxiety (Mladenka et al., 1998; Pörhölä, 1997; Roberts et al., 2005). The PRCA-24 has also been evidenced to correlate significantly with state anxiety, as

measured by the Spielberg State Anxiety measure (McCroskey & Beatty, 1984), suggesting that this measure can be appropriately utilized as a cross-situational predictive instrument.

PSA presents in both clinical and non-clinical samples, and sub-group analysis indicated that both VRET and IVET are significantly more efficacious than control with large effect sizes when delivered in both diagnostic and non-diagnostic samples. Thus, VRET should be considered as a treatment option for those presenting with distressing but subclinical or mild anxiety symptoms. This will reduce pressure on clinicians and clinical services and facilitate increased therapist time for working with more severe anxiety presentations. For those individuals with clinical PSA, VRET could be utilized to prepare individuals for engagement in therapy and to support out of session exposure practice.

Subgroup analysis also indicated that both VRET and IVET are significantly more efficacious than control with large effect sizes when delivered as stand-alone interventions or as part of a wider intervention package. This is in-keeping with previous findings that exposure therapy as a stand-alone intervention is as effective as a combination of exposure therapy and cognitive therapy for reducing social anxiety (Powers et al., 2008). Furthermore, findings of this meta-analysis indicate VRET is effective when delivered as a single session, or over multiple intervention sessions. These benefits indicate that VRET can be used as a specific and direct, yet effective intervention for PSA.

VRET may be a potentially attractive treatment option for clinicians working with individuals with PSA as conducting IVET with this population is inherently problematic due to the requirement to gain access to and control audiences of increasing sizes for exposure tasks. Further advantages associated with the VRET approach include: reduced cost (Miloff et al., 2016), increased scalability (Boeldt et al., 2019) and that the mode of delivery is preferred by patients (Garcia-Palacios et al., 2007). Given these advantages and the findings of the current study that VRET is not substantially inferior to IVET for treating PSA, VRET should be considered a valuable treatment option. Clinical skills are a key factor to the effective use and implementation of VRET (Nascivera et al., 2018), so VRET will not eradicate the requirement for trained practitioners. However, its use may have several advantages for practitioners aiming to treat clients with PSA.

Limitations

The current meta-analysis had a number of limitations which should be considered when interpreting the findings. Only published studies were included. This may have resulted in publication bias as positive results are more

frequently published in scientific literature (Duyx et al., 2017). This positive publication bias may have impacted the effect sizes in the current meta-analysis (Mlinaric et al., 2017). However, recent studies have indicated that including unpublished literature has a minimal effect on effect sizes in meta-analysis (Hartling et al., 2017; Schmucker et al., 2017). Secondly, a number of the IVET studies included in the meta-analysis may be considered outdated as four studies were published between 1978 and 1997. This poses several limitations as the quality, transparency and reporting of scientific studies has improved in recent years (Plint et al., 2006) due to the widespread dissemination of reporting guidelines (Simera et al., 2010). Furthermore, the delivery of exposure therapy may have changed somewhat in recent times due to advancements in understanding and changes in clinical practice guidelines (Abramowitz et al., 2019). The fact that significantly more VRET studies have been conducted recently demonstrates the new drive to utilize more innovative methods of delivering exposure therapy (Maples-Keller et al., 2017). All IVET studies included were conducted in a group format whereas all VRET studies were conducted on an individual basis. This contrast in format may have impacted upon the outcomes of the current study as some research has indicated that individual cognitive therapy has a superior treatment effect for individuals with SAD than the same therapy delivered within a group format (Stangier et al., 2003). Contrastingly, a meta-analysis demonstrated that there was no significant difference in treatment gains for individuals with SAD who were treated on a group or individual basis (Powers et al., 2008). Nonetheless, these results should be interpreted with caution. Further limitations arise from the sample of participants included within the meta-analysis. Firstly, only three studies utilized a diagnostic sample, thus the applications of the interventions for clinical settings are not clear. Secondly, the findings are limited to a working-age adult population. Although there were no limits placed on participant age range for inclusion, research on VRET and IVET for children and older adults is significantly limited, and existing papers did not meet other inclusion criteria. For example, Kahlon et al. (2019) reported that VRET reduced PSA in adolescents, however this pilot study did not utilize a control group and was not eligible for inclusion. Finally, the results of the study are limited to post-treatment effects as no follow-up analyses was conducted. Follow-up analyses was not possible as the majority of included studies did not include this information.

Future Directions

As the current meta-analysis demonstrated the potential benefits of VRET for reducing PSA, further high-quality studies are required to strengthen this

evidence base. Future studies should prioritize methodological rigor, adopt a randomized control trial design, reliable and valid measures of PSA, and transparent and replicable reporting. Recruitment of larger sample sizes, which are adequately powered should be prioritised to facilitate more precise estimates of effect size (Lipsey & Wilson, 2001). Furthermore, additional studies wherein the intervention is standardized and identical across both the VRET and IVET condition aside from the mode of exposure would be advantageous to draw more robust comparisons between the two modes of delivering in treating PSA. Future research would also benefit from investigating the impact of treatment adherence. Treatment adherence, which predicts outcome from CBT in anxiety disorders (Glenn et al., 2013) was only measured in a small number of studies included within this meta-analysis.

A number of recommendations relate to forthcoming research employing VRET. Firstly, presence should be measured via a reliable and valid quantitative measure. Presence, which refers to the level of connection a participant feels with a virtual environment is associated with fear rating and treatment response during VRET for PSA (Price et al., 2011). Secondly, relating to the VR technology, VR employing CGI images, and avatars is often rated as unrealistic by participants (Pertaub et al., 2002). VR employing 360° video recordings of real life footage can reduce the "uncanny valley" effect associated with animated VR (Seyama & Nagayama, 2007). As 360° VR equipment is becoming increasingly affordable and accessible (Lindner et al., 2017) future research should utilize this equipment.

Preliminary evidence demonstrates that self-led VRET is equally as efficacious in reducing PSA as the same therapist-led intervention (Lindner et al., 2019). Given the increasing access to technology including smartphones, tablets, and computers in the general population, further investigations into the efficacy of self-led VRET for PSA would be interesting. The development of an evidence base for self-led VRET interventions would further reduce waiting lists, treatment costs and increase accessibility for both clinical and non-clinical samples. Future research should incorporate more diverse participant groups. For example, since PSA is associated with negative educational and occupational consequences; an investigation into the efficacy of VRET and IVET for children and adolescents should be prioritised. Furthermore, as public speaking is highly prevalent in both generalized and non-generalized Social Anxiety (Blöte et al., 2009) future research investigating whether VRET and IVET targeting PSA is effective in reducing social anxiety is warranted, but was beyond the scope of the current meta-analysis. Finally, to investigate whether treatment gains made in VRET and IVET for PSA generalize to the real world context as found in studies investigating other anxiety disorders (Morina et al.,

2015) the use of follow-up studies and behavioral assessments would be advantageous.

Conclusion

In conclusion, this is the first meta-analysis to investigate the efficacy of VRET and IVET as psychological interventions for PSA. Both VRET and IVET had large, significant effects on PSA compared to control conditions, with analysis demonstrating IVET was marginally more efficacious. These results were consistent across clinical and non-clinical populations and when VRET and IVET were delivered as stand-alone interventions or within wider intervention packages. Due to the advantages of VRET it could be considered a more preferable, accessible and tangible alternative to IVET for treating PSA. These findings, although promising are based on a small number of studies. Nonetheless, this adds to the growing literature base suggesting VRET should be explored as a psychological intervention for PSA.

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*studies included in the meta-analysis are denoted with an asterisk.

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