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A meta-analysis of the effect of virtual reality on reducing public speaking anxiety

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Abstract

The fear of public speaking is a prevalent phobia that has a damaging impact on the lives of many phobic patients. One method to treat this phobia is the use of virtual reality (VR). A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol was used to report how the publications that have examined the role of VR in treating public speaking anxiety were identified. A meta-analysis of 92 non-review publications published by January 15, 2021 was conducted. In this meta-analysis, the effectiveness of the treatment of public speaking anxiety refers to the degree of reduction in the participants' public speaking anxiety from pre-test to post-test. This meta-analysis consisted of an examination of the homogeneity of the studies (the I^2 indexes), publication bias (Kendall's tau and Egger's regression values) and an estimation of the grand effect size for all studies. The three major findings of this meta-analysis are: (1) Overall, VR had a statistically significant effect on reducing public speaking anxiety, which suggests that VR is a useful and promising therapeutic tool for the treatment of public speaking anxiety; (2) Studies that found VR to be effective in the treatment of public speaking anxiety conducted an average of approximately six VR sessions, with each session lasting around 37 minutes; and (3) VR is statistically as effective as other treatment methods such as cognitive behavioral therapy. Therefore, rather than completely replacing other treatment methods, VR should be used to complement other treatment methods to compensate for some of their disadvantages.

Keywords Public speaking anxiety · Virtual reality · PRISMA protocol · Meta-analysis

Virtual reality (VR) has attracted researchers' attention for nearly 20 years (Lan, 2020). VR refers to a "transformative service designed to build a synthetic virtual environment to mimic the real world, and subsequently, immerse participants in highly realistic virtual worlds" (Hu et al., 2020, p. 105). By donning stereoscopic head-mounted displays, visual sensory information from the outside world is filtered out and users experience a computerized version of a three-dimensional real-like virtual world (Slater et al., 1999). These displays are sensitive to the users' head movement, creating a perception of depth when they look around the virtual environment (Lindner et al., 2019). VR also allows for complete control over the settings, designs and stimuli in the virtual world (Lindner et al., 2017).

Many past review papers on VR concluded that VR is beneficial for the treatment of fears and phobias (Botella et al., 2000; Vanni et al., 2013; Vincenti, 2009; Hinojo-Lucena et al., 2020). Botella et al.'s (2000) narrative review enumerated numerous benefits of VR such as providing a protected environment for patients to explore and act without feeling threatened, the flexibility of VR to tailor to individuals' specific needs and allowing users to experience different situations at their own pace with a high degree of control over time and space. Similar to Botella et al.'s review (2000), both Vanni et al.'s (2013) and Vincenti's (2009) narrative reviews provided evidence of the effectiveness of VR for the treatment of fears and phobias. Vanni et al. (2013) found that VR environments can trigger realistic anxiety responses from patients and decrease patients' public speaking anxiety for over three months. Comparably, Vincenti's narrative

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review (2009) found that VR therapy can increase patients' calmness when flying and reduce the debilitating effect of the fear of flying. This is evident from patients' self-report questionnaires and increased air travel in real-life following VR treatments. Hinojo-Lucena et al.'s systematic review (2020) reviewed 13 publications and their results supported Botella et al.'s (2000), Vanni et al.'s (2013) and Vincenti's findings (2009) that VR treatments are generally effective in treating fears and phobias. However, they posited that effective VR therapies usually require at least one week of treatment and up to 12 treatment sessions.

Furthermore, past review papers also corroborated that VR is useful in treating a wide range of fears and phobias (Gregg & Tarrier, 2007; North et al., 2002). Both Gregg and Tarrier's meta-analysis (2007) and North et al.'s systematic review (2002) described the uses of VR to treat a myriad of psychological disorders. Gregg and Tarrier (2007) reviewed 17 publications, some key case studies, and pilot studies, which found that VR therapy can help patients reduce their fear of heights, flying phobia, driving phobia, spider phobia, social phobia, panic and agoraphobia, post-traumatic stress disorder and body image disturbance. Similarly, North et al. (2002) found that VR is effective for the treatment of fear of flying, agoraphobia, acrophobia and fear of public speaking.

Public Speaking Anxiety

While VR has had many salient applications, one application of VR is in the treatment of public speaking anxiety (Kimani & Bickmore, 2019). Seinfeld (1993) famously said that "according to most studies, people's number one fear is public speaking. Number two is death …. This means that to the average person, if you go to a funeral, you are better off in the casket than doing the eulogy." It has been estimated that about 20% to 85% of individuals are afraid of giving speeches (Katz, 2000). Delivering a public speech can easily induce anxiety regardless of how well-versed and experienced the speakers are (Khan et al., 2015). This anxiety is prevalent among individuals, including actors and politicians who voluntarily choose to work in their professions which require them to interact frequently with live audiences or the general public (Khan et al., 2015).

The anxiety caused by public speaking can be accompanied by physical and psychological symptoms such as perspiration and a feeling of helplessness (Ibrahim & Devesh, 2019). For some people, public speaking anxiety has a deeper cause and is caused by a condition called glossophobia (fear of public speaking) (Rahma, 2018). Additionally, a fear of public speaking can negatively impact oral presentation performance across different contexts (Overholser, 2002). To avoid awkward moments, many individuals with a fear of public speaking try to avoid it, which can result in a loss of opportunities. As public speaking skills are essential in everyday life such as in schools and workplaces (Gupta et al., 2019), having a fear of public speaking can be detrimental to one's social relationships and educational and career success (Wang et al., 2020).

While traditional treatments for public speaking anxiety are useful, they have major limitations. For example, cognitive behavioral therapy and imaginary exposure therapy, which are common treatments for public speaking anxiety, require presenters to imagine feared social situations. This may be difficult for presenters who are unable to imagine these feared social situations (Wallach et al., 2009). These treatments also do not allow them to experience a real or real-like environment with audiences (Šalkevičius et al., 2019), which makes it less effective. Only 35.4% of students surveyed by Hauck and Hurd (2005) felt that imagining themselves having a friendly informal chat when presenting in a language classroom helps them reduce their oral presentation anxiety. Additionally, in in-vivo exposure, presenters are exposed to feared social situations in the real world. One disadvantage of in-vivo exposure is that it is difficult to control the anxiety-producing stimuli in the environment and the stimuli cannot be replayed many times to achieve habituation (Rothbaum et al., 2006). Moreover, highly anxious presenters may be too afraid to try it (Emmelkamp et al., 2001) and it may compromise their privacy (Lear, 2020).

Using VR in Treating Public Speaking Anxiety

The aforementioned limitations can be overcome using VR. VR therapy for public speaking anxiety relies on anxiety habituation, where prolonged exposures to feared public speaking situations in simulated virtual environments will result in systematic desensitization to such scenarios (Zacarin et al., 2019). VR therapy for public speaking anxiety can provide exposure therapy practice for patients to experience simulated real-like feared social situations without having to imagine them (Yuen et al., 2019, p. 51). By wearing a VR headset, patients can deliver public speeches to reactive virtual audiences in virtual environments (Šalkevicius et al., 2019). The therapist can modify the number of virtual listeners, their looks, and behaviors to cater to an individual patient's needs (Mostajeran et al., 2020). Moreover, unlike in-vivo exposure, VR therapy can be performed in the therapist's office with just a head-mounted display, thus protecting the patients' confidentiality (North et al., 1997) and avoiding public embarrassment (El-Yamri et al., 2019, p. 350).

Research Gap

While there have been 11 review papers written on VR, there are no meta-analyses that investigate the current application of VR for the treatment of public speaking anxiety. Among the 11 review papers, 10 are narrative reviews and systematic reviews, and only Gregg and Tarrier (2007) conducted a meta-analysis. However, their meta-analysis broadly focused on the use of VR to treat mental health disorders in general and did not focus specifically on public speaking anxiety.

Therefore, the present study aimed to perform a meta-analysis of all publications that investigate the effectiveness of VR in alleviating public speaking anxiety. In this study, the effectiveness of public speaking anxiety treatment refers to the degree of reduction in public speaking anxiety from pre-test to post-test. The research questions for this review are as follows:

Research question 1: Is VR effective for the treatment of public speaking anxiety?
Research question 2: What is the average number and length of VR sessions for studies that found VR to be effective for the treatment of public speaking anxiety?
Research question 3: Is VR more effective than other treatment methods for the treatment of public speaking anxiety?

Methodology

Dataset

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Stovold et al., 2014) was used to report the findings of this meta-analysis. This framework has four stages, consisting of identification, screening, eligibility and included stages (Figure 1). Accordingly, publications that met all of the following inclusion criteria were included in the meta-analysis: 1. Related to virtual reality and public speaking anxiety, 2. Non-review publication, 3. Non-duplicated publication, 4. Peer-reviewed publication and 5. Publication that the authors have access to. Publications that did not meet these criteria were excluded. In the identification stage, a search for publications on the use of VR for the treatment of public speaking anxiety was conducted in Scopus on 15th January 2021. "Public speaking" and "virtual reality" were entered into the search engine for article title, abstract and keywords. The data range was set from all years to present and the search identified 146 publications. However, in the screening and eligibility stages, 54 publications were removed from the dataset because they were either review publications, duplicate publications, non-peer-reviewed publications, publications unrelated to the topic or publications that the authors did not have access to. Lastly, in the included stage, the final dataset

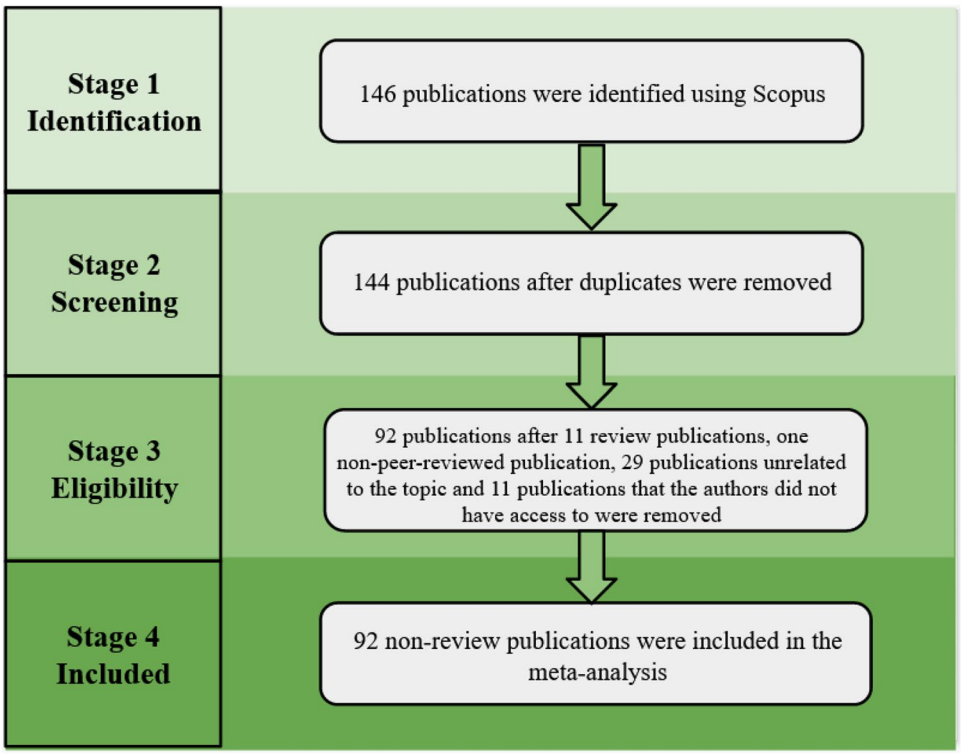

Fig. 1 PRISMA Flow Diagram

consisted of 92 publications published between 1999 and 2020. These included 72 experimental, 11 quantitative non-experimental, seven qualitative, and two descriptive studies.

Coding Schemes for the 92 Non-Review Papers

The coding scheme for the non-review papers included references, research question(s) or purpose of the study, research design, data analysis, reliability analysis, country where the study was conducted, sample size, gender distribution, number of VR session(s), length of each VR session, VR location(s), number of virtual audiences, behaviors of virtual audiences and whether the authors determined VR to be effective for the treatment of public speaking anxiety.

Data Analysis

Descriptive Statistics

All research questions were answered using only data from the 92 non-review papers. The reasons for not using data from the 11 review papers were because 1. Many of the 92 non-review papers were already examined in the 11 review papers; thus, the inclusion of the review papers may overstate the findings and 2. Most of the 11 review papers were not closely relevant to the use of VR for the treatment of public speaking anxiety. Many of these papers either broadly focused on the use of VR to treat mental health disorders in general (Gregg & Tarrier, 2007; Repetto & Riva, 2011; North et al., 2002) or did not focus mainly on VR (Pull, 2012; Lipsitz & Marshall, 2001). Of the 11 review papers, only Hinojo-Lucena et al.'s (2020), Daniels et al.'s (2020) and Vanni et al.'s reviews (2013) focused specifically on the use of VR for the treatment of public speaking anxiety.

Meta-Analysis

A meta-analysis was conducted using Jamovi (2020). Jamovi is a statistical software based on the R statistical language. To conduct this meta-analysis, we examined the heterogeneity, publication bias, and combined effect of VR in the separate studies. First, heterogeneity is defined as a variability in the data that can be accounted for by the differences between the estimates of the studies that are included in a meta-analysis and is usually measured using I^2 (Thorlund et al., 2012). I^2 ranges from 0% to 100%, with lower values indicating more similarity in the degree of variability in the studies that are included in a meta-analysis and the sample it is compared to if the sample of studies is taken from the same population (Sedgwick, 2012, p. 2). Percentages of I^2 below 25%, around 50% and more than 75% indicate low, moderate and strong heterogeneity, respectively (Ahn & Kang, 2018). Hence, low I^2 values are desirable as they indicate consistency in results of separate studies.

Moreover, publication bias occurs when studies that found large and significant results are disproportionately more likely to be included in a meta-analysis than studies that found small and insignificant results. This is unrepresentative of all studies that were conducted (Gage et al., 2017, p. 428) and can undermine the validity and generalizability of the findings of a meta-analysis (Lin et al., 2018). Publication bias will be measured using funnel plots, Kendall's tau and Egger's regression tests. Funnel plots are scatterplots of the estimates of each study included in a meta-analysis after accounting for the sample size used in each study. Symmetrical funnel plots indicate no identifiable publication bias while asymmetric funnel plots indicate the presence of publication bias (Sterne et al., 2005, p. 75). Kendall's tau is used to determine whether the correlation between the effect estimates and the variances of the studies included in a meta-analysis is significant (Begg & Mazumdar, 1994). Similarly, the Egger's regression test compares standardized regression estimates with standard errors (Egger et al., 1997). For both the Kendall's tau and the Egger's regression tests, if the p-values obtained are significant, it indicates potential publication bias (Van Enst et al., 2014). The combined effect of VR examines whether the aggregate findings of all studies are statistically significant which can be analyzed graphically using forest plots (Lewis & Clarke, 2001).

Regarding research question 1, the number of studies that found VR to be effective for the treatment of public speaking anxiety was compared with the number of studies that found VR to be ineffective for the treatment of public speaking anxiety. An examination of the homogeneity of the studies (the I^2 indexes), publication bias (Kendall's tau and Egger's regression values) and an estimation of the grand effect size for all studies were also conducted in the analysis. Research question 2 was answered by calculating the average number and length of VR sessions for studies that found VR to be effective for the treatment of public speaking anxiety. Lastly, for research question 3, the numbers of studies that found that VR is more, equally and less effective than other treatment methods were compared. This comparison allowed us to determine the relative effectiveness of VR compared to other treatment methods for the treatment of public speaking anxiety. An examination of the grand effect size for all studies was also conducted to examine whether there were statistically significant differences between the effectiveness of VR and other treatment methods for the treatment of public speaking anxiety.

Results

Descriptive Statistics (92 Non-Review Papers)

Table 1 shows the descriptive statistics for the 92 non-review studies. The most commonly adopted research design was experimental study (72 studies). There were only 11 quantitative non-experimental, seven qualitative and two descriptive studies. The studies were conducted in 23 different countries. 14 studies did not mention the country where the study was conducted. The top three countries where the most number of studies were conducted were the United States of America (23 studies), Germany (10 studies) and the Netherlands (seven studies). The United Kingdom had the fourth highest number of studies (four studies). There were three studies conducted each in Sweden, Norway and Israel. Countries with two studies included Austria, Turkey, France, Portugal, Lithuania, Spain, India, China and Japan. Australia, South Korea, Canada, Costa Rica, Belgium, Greece and Brazil had one study each. About two-thirds of the studies (63 studies) had fewer than 50 research participants. 15 studies had 50 to 100 research participants and six studies had more than 100 research participants.

65 studies conducted fewer than five VR sessions. Only nine studies conducted five to 10 VR sessions and six studies conducted more than 10 VR sessions. The length of each VR session for 54 studies was less than 30 minutes. Only eight studies had VR sessions that were between 30 minutes and one hour and only seven studies had VR sessions that were longer than one hour. The VR sessions took place in various virtual locations, including classrooms or lecture rooms, auditoriums, conference rooms, offices, meeting rooms, streets, elevators, shops, bars, as well as a therapy room. The top three places were classrooms or lecture rooms (28 studies), auditoriums (16 studies) and conference rooms (12 studies). The number of virtual audiences used varied for different studies. There were more studies (30 studies) that used fewer than 15 virtual audiences. Nine studies used 16 to 30 virtual audiences and seven studies used 31 to 50 audiences.

Furthermore, the virtual audiences displayed diverse behaviors. The behaviors of the virtual audiences can be classified into positive, neutral and negative. Some examples of positive behaviors were leaning forward and nodding encouragingly. Neutral behaviors were neither supportive nor distracting and negative behaviors included yawning, falling asleep and laughing loudly. Many studies (42 studies) used virtual audiences that displayed a combination of positive, neutral and negative behaviors. Virtual audiences in five studies displayed positive behaviors only and virtual audiences in four studies displayed negative behaviors only. Seven studies used virtual audiences that displayed neutral behaviors only.

Research Question 1 (92 Non-Review Papers)

Is VR Effective for the Treatment of Public Speaking Anxiety?

27 individual studies compared participants' levels of public speaking anxiety during post-test with their levels of public speaking anxiety during pre-test. Of the 27 studies, 26 studies found that VR is effective for the treatment of public speaking anxiety while only one study found that VR is not effective for the treatment of public speaking anxiety.

The most commonly employed measures of public speaking anxiety used in the 27 studies were the Fear of Negative Evaluation scale (FNE) (seven studies), the Liebowitz Social Anxiety Scale - Total (LSAS) (five studies), and the Personal Report of Confidence as a Speaker scale (PRCS) (four studies). Hence, one analysis each was conducted for studies that used these three measures of public speaking anxiety. The pre-test means, post-test means, pre-test standard deviations, post-test standard deviations, and the sample sizes of studies that measured public speaking anxiety using FNE, LSAS and PRCS were obtained directly from the studies and presented in Table 2.

We examined heterogeneity, publication bias, and combined effect of VR in the separate studies using forest plots. First, we examined the heterogeneity for publications that measured public speaking anxiety using FNE, LSAS and PRCS. The heterogeneity statistics for PRCS indicated that the data were homogenous, as the I^2 was 0% (Tau = 0.000; $Tau^2 = 0$; $H^2 = 1.000$; df = 3; Q = 0.996; $p = 0.802$). In addition, the I^2 for FNE (Tau = 0.351; $Tau^2 = 0.1231$; $H^2 = 1.981$; df = 6; Q = 11.648; $p = 0.70$) and LSAS (Tau = 0.428; $Tau^2 = 0.1833$; $H^2 = 1.927$; df = 4; Q = 7.690; $p = 0.104$) were 49.53% and 48.09% respectively, which suggests moderate degrees of heterogeneity. In interpreting these results, we should take into account the small sample sizes of studies that measured public speaking anxiety using FNE and LSAS, which may be a contributory factor in the slightly higher heterogeneity estimates (IntHout et al., 2015).

Next, funnel plots, Kendall's tau and Egger's regression values were used to detect any potential publication bias. The overall symmetrical distributions of effect sizes in the funnel plots for publications that measured public speaking anxiety using FNE, LSAS and PRCS indicated that there was no identifiable publication bias (Figure 2). The p-values of the Kendall's tau ($p = 1.000$ for FNE, 0.083 for LSAS and 0.750 for PRCS) and Egger's regression tests ($p = 0.882$ for FNE, 0.012 for LSAS and 0.839 for PRCS) were also insignificant at the .01 level, further attesting no publication bias.

Finally, we used forest plots to statistically determine whether the combined findings of all individual studies

Table 1 Descriptive Statistics for the 92 Non-Review Studies

	Categories	Number of publications
Research designs	Experimental studies	72
	Quantitative non-experimental studies	11
	Qualitative studies	7
	Descriptive studies	2
Countries where the study was conducted	The United States of America	23
	Germany	10
	Netherlands	7
	The United Kingdom	4
	Sweden, Norway and Israel	3 each
	Austria, Turkey, France, Portugal, Lithuania, Spain, India, China and Japan	2 each
	Australia, South Korea, Canada, Costa Rica, Belgium, Greece and Brazil	1 each
	Not mentioned	14
Number of research participants	Fewer than 50	63
	50 to 100	15
	More than 100	6
	Not mentioned	8
Number of VR session(s)	Fewer than 5	65
	5 to 10	9
	More than 10	6
	Not mentioned	12
Length of each VR session	Less than 30 minutes	54
	30 minutes to one hour	8
	More than one hour	7
	Not mentioned	23
Virtual locations	Classrooms or lecture rooms	28
	Auditoriums	16
	Conference rooms	12
	Offices	5
	Meeting rooms	5
	Streets	2
	Elevators	2
	Shops	2
	Bars	2
	Therapy room	1
Number of virtual audiences	Fewer than 15	30
	16 to 30	9
	31 to 50	7
	Not mentioned or unclear	46
Behaviors of virtual audiences	Positive only	5
	Neutral only	7
	Negative only	4
	Mixed	42
	Not mentioned	34

would indicate that VR had a significant effect on reducing participants' public speaking anxiety from pre-test to post-test. Three separate forest plots were generated from the studies that measured public speaking anxiety using FNE, LSAS and PRCS, respectively (Figure 3). The diamond in each forest plot represents the overall combined effect of all individual

Table 2 Means, Standard Deviations, and the Sample Sizes of Studies Using FNE, LSAS and PRCS

ID of the study	Pre-test means	Post-test means	Pre-test standard deviation	Post-test standard deviation	Effect sizes (Cohen's d)	Sample size for pre-test	Sample size for post-test
FNE							
Anderson et al. (2013)	40.32	36.96	10.01	9.65	0.34	25	25
Anderson et al. (2017)	40.31	38.77	10.93	8.54	0.15	13	13
Bar-Zvi (2011)	21.80	18.90	3.58	5.02	0.64	10	10
Güleç et al. (2019)	41.29	36.57	7.97	7.55	0.57	7	7
Robillard et al. (2010)	25.64	18.00	6.13	8.21	1.02	14	14
Safir et al. (2012)	21.04	17.30	7.54	8.30	0.47	28	28
Wallach et al. (2009)	16.36	3.71	7.86	9.00	1.48	28	28
LSAS							
Güleç et al. (2019)	56.86	51.43	11.99	9.88	0.46	7	7
Harris et al. (2002)	52.25	37.75	18.61	23.29	0.65	8	8
Klinger et al. (2005)	89.70	47.60	20.60	20.40	2.01	18	18
Klinger et al. (2004)	83.90	45.50	23.50	22.40	1.64	18	18
Robillard et al. (2010)	82.93	47.50	32.23	17.83	1.32	14	14
PRCS							
Anderson et al. (2005)	21.40	12.00	5.89	6.32	1.47	10	10
Anderson et al. (2013)	24.36	14.92	2.68	7.55	1.64	25	25
Anderson et al. (2017)	24.61	17.38	3.25	7.11	1.27	13	13
Harris et al. (2002)	22.63	12.63	4.66	4.96	1.96	8	8

studies. Individual studies with larger sample sizes were represented by larger boxes and contributed more to the results of the meta-analysis. The rightmost column of the forest plots provides point estimates and confidence intervals where the "true" effect probably lies. The middle of the diamonds represents the mean effect estimates of all studies combined. Additionally, the length of the diamonds indicates the length of the confidence intervals and the two ends of the confidence intervals were indicated by each end of the diamond. If the diamonds cut the vertical dotted line called the "line of null effect", which corresponds to the effect size value of 0, it would indicate that VR is neither statistically effective nor ineffective for the treatment of public speaking anxiety. As the three diamonds for studies that measured public speaking anxiety using FNE, LSAS and PRCS lie on the right of the "line of null effect" entirely, the findings of all the three analyses indicate that VR is statistically effective for the treatment of public speaking anxiety.

Research Question 2 (92 Non-Review Papers)

What Is the Average Number and Length of VR Sessions for Studies that Found VR to Be Effective for the Treatment of Public Speaking Anxiety?

As the foregoing meta-analysis in research question 1 showed that VR had a statistically significant effect on reducing participants' public speaking anxiety, a descriptive analysis of the number and length of VR sessions was conducted. The 26 studies that found that VR is effective for the treatment of public speaking anxiety conducted an average of 6.33 VR sessions (SD = 4.29; median = 4.75; min = 1; max = 16 VR sessions). Thirteen studies conducted fewer than five VR sessions. The number of studies that conducted five to 10 VR sessions and 10 to 15 VR sessions were six each. There was only one study that conducted more than 15 VR sessions. The average length of each VR session was 37 minutes. The range was 175 minutes, where the shortest VR session was five minutes and the longest VR session was 180 minutes. The standard deviation and median were 41 minutes and 20 minutes respectively.

Research Question 3 (92 Non-Review Papers)

Is VR more Effective than Other Treatment Methods for the Treatment of Public Speaking Anxiety?

While research question 1 compared the participants' levels of public speaking anxiety during pre-test with their levels of public speaking anxiety during post-test, research question 3 compared the effectiveness of VR in treating public speaking anxiety with other treatment methods. Both an analysis of the individual studies and the forest plots showed that VR is as effective as other treatment methods for the treatment of public speaking anxiety.

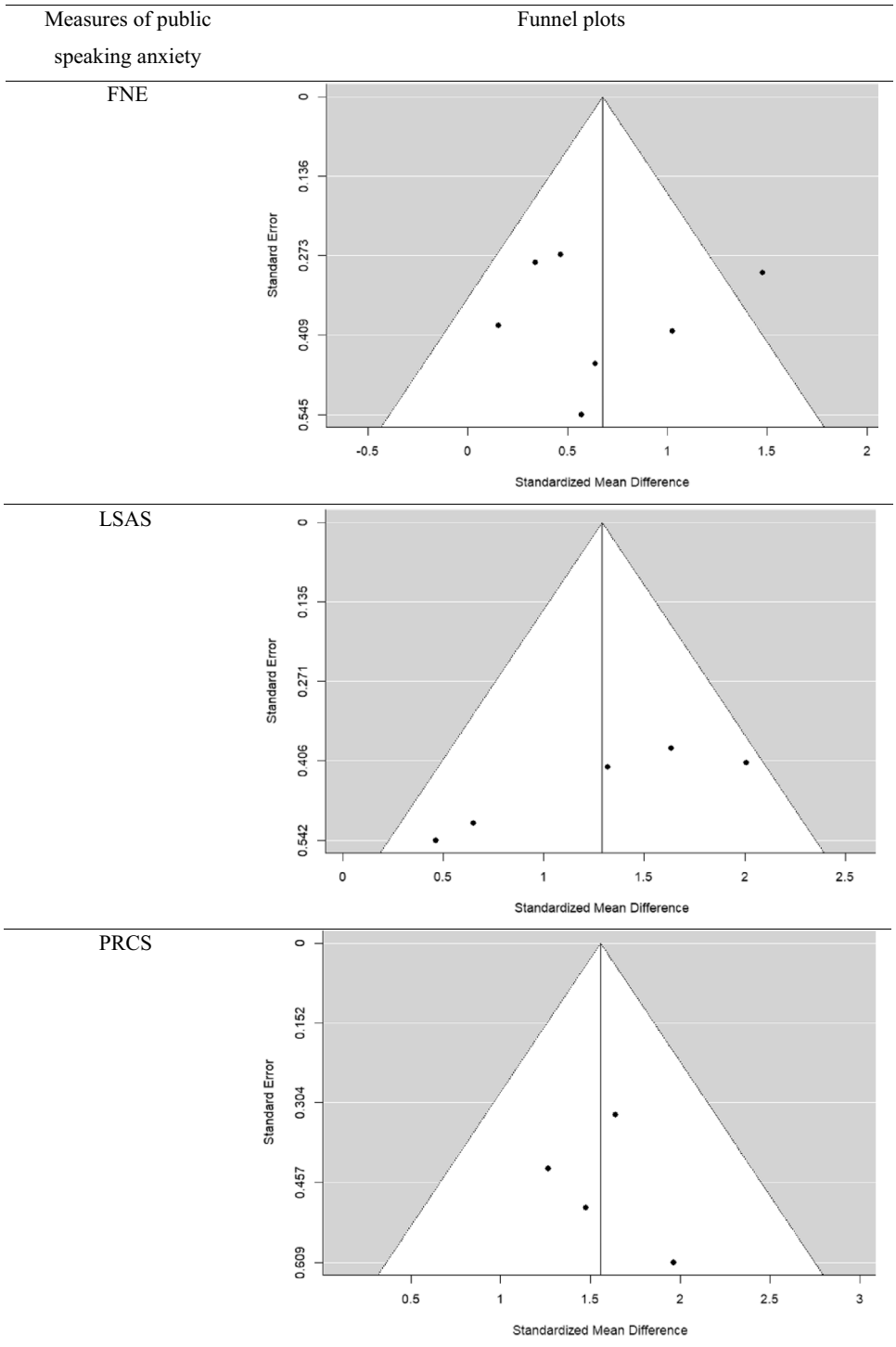

Fig. 2 Funnel Plots of Studies Measuring Public Speaking Anxiety Using FNE, LSAS and PRCS. *Note*. All three funnel plots indicate no publication biases

Overall, 12 studies (13%) compared the effectiveness of VR with other treatment methods such as exposure group therapy, psychoeducation and cognitive behavioral therapy. A descriptive analysis of these studies found that VR is generally as effective as other treatment methods. Ten studies found that VR is as effective as other treatment methods. While no study found that VR is less effective than other treatment methods, only two studies found that VR is more effective than other treatment methods.

Of the 12 studies that compared the effectiveness of VR for the treatment of public speaking anxiety with other treatment methods, two of the most common measurements of public speaking anxiety were FNE (seven

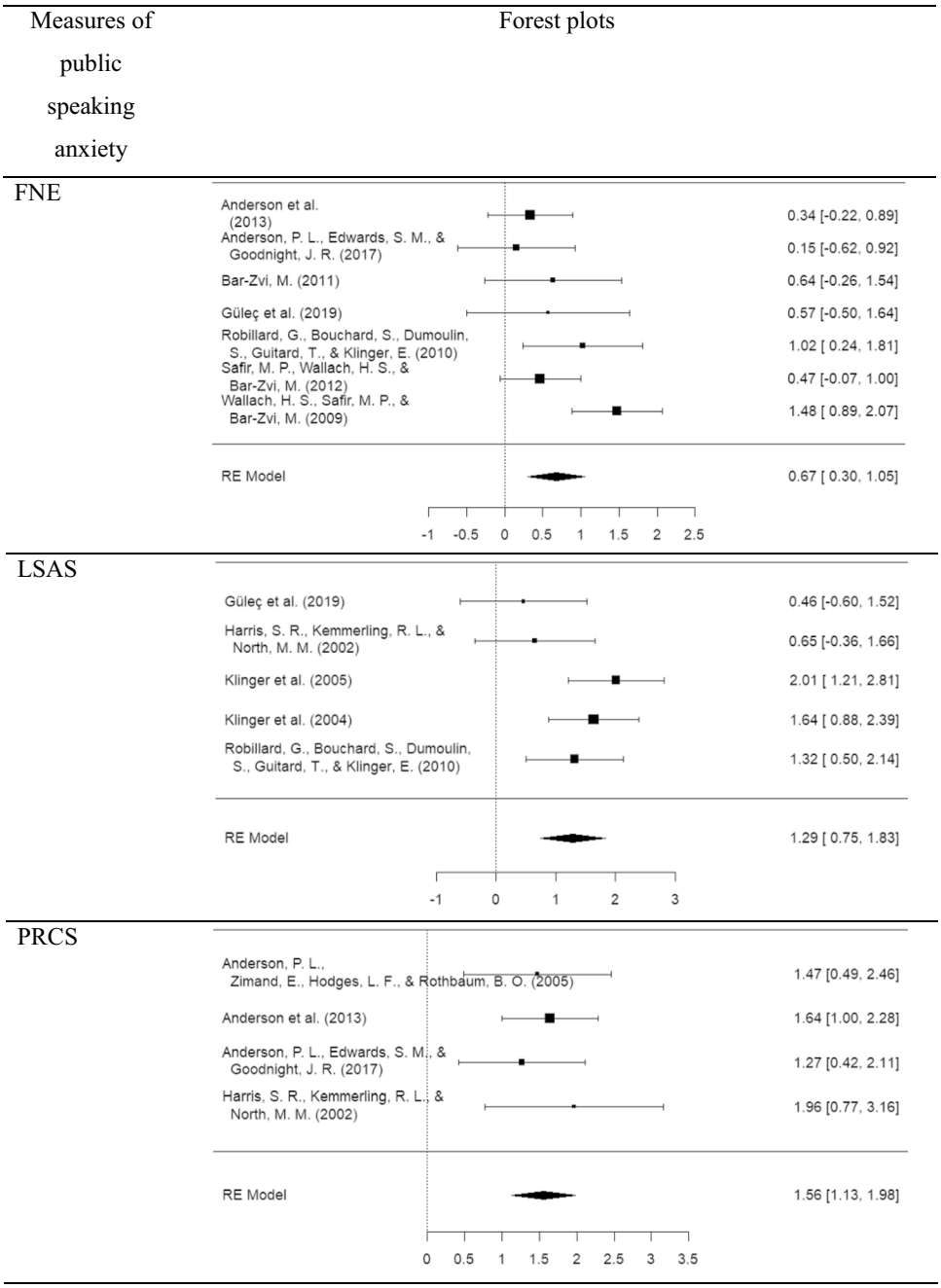

Fig. 3 Forest Plots of Studies that Measured Public Speaking Anxiety using FNE, LSAS and PRCS. The forest plots indicate that VR is statistically effective for the treatment of public speaking anxiety

studies) and LSAS (four studies). Hence, two separate analyses were conducted using studies that measured public speaking anxiety using FNE and LSAS. Only studies that provided post-test means, post-test standard deviations of public speaking anxiety measured using FNE and LSAS, and sample sizes of VR and other treatment methods groups were used to run the meta-analysis (see Table 3 and Table 4).

We examined the homogeneity of the studies (the I^2 indexes) and publication bias (Kendall's tau and Egger's regression values) and estimated the grand effect size for all the studies in the analysis. The data for both analyses using FNE and LSAS were estimated to be homogenous. This is because the I^2 of the homogeneity statistics for studies that measured public speaking anxiety using FNE (Tau = 0; $Tau^2 = 0$; $H^2 = 1$; df = 7; Q = 3.593; $p = 0.825$) and LSAS (Tau = 0; $Tau^2 = 0$; $H^2 = 1$; df = 3; Q = 0.658; $p = 0.883$) were both 0%.

Funnel plots (Figure 4), Kendall's tau and Egger's regression values were used to detect publication biases. The symmetrical distribution of effect sizes in both the FNE and the LSAS funnel plots indicate no publication biases. The

Table 3 Descriptive Statistics of VR and Control Groups of Studies Measuring Public Speaking Anxiety using FNE

ID of the study	Control group	Post-test mean for VR group	Post-test SD for VR group	Post-test mean for other treatment method	Post-test SD for other treatment method	Effect sizes (Cohen's d)	Sample size for VR group	Sample size for other treatment method
Anderson et al. (2013)	Exposure group therapy	39.47	10.70	38.68	9.31	0.08	25	25
Anderson et al. (2017)	Exposure group therapy	38.77	8.54	35.93	7.24	0.35	13	15
Güleç et al. (2019)	Psychoeducation	36.57	7.55	38.57	5.26	-0.29	7	7
Bar-Zvi (2011)	Cognitive restructuring	18.90	5.02	19.50	4.48	-0.12	10	10
Bar-Zvi (2011)	Cognitive behavioral therapy	18.90	5.02	16.36	7.86	0.34	10	28
Robillard et al. (2010)	Cognitive behavioral therapy	18.00	8.21	18.50	7.66	-0.06	14	16
Safir et al. (2012)	Cognitive behavioral therapy	17.30	8.30	19.09	8.25	-0.21	28	30
Wallach et al. (2009)	Cognitive behavioral therapy	20.07	6.89	21.67	5.80	-0.25	28	30

Table 4 Descriptive Statistics of VR and Control Groups of Studies Measuring Public Speaking Anxiety using LSAS

ID of the study	Control group	Post-test mean for VR group	Post-test SD for VR group	Post-test mean for other treatment method	Post-test SD for other treatment method	Effect sizes (Cohen's d)	Sample size for VR group	Sample size for other treatment method
Güleç et al. (2019)	Psychoeducation	51.43	9.88	52.00	4.40	-0.07	7	7
Klinger et al. (2005)	Cognitive behavioral therapy	47.60	20.40	43.50	24.60	0.18	18	18
Klinger et al. (2004)	Cognitive behavioral therapy	43.50	24.60	47.60	20.40	-0.18	18	18
Robillard et al. (2010)	Cognitive behavioral therapy	47.50	17.83	50.38	23.87	-0.13	14	16

insignificant p-values of the Kendall's tau ($p = 0.72$ for FNE and 0.718 for LSAS) and the Egger's regression tests ($p = 0.622$ for FNE and 0.906 for LSAS) for both analyses also suggested no publication biases.

Consistent with the analyses of the individual studies, the forest plots for studies that measured public speaking anxiety using FNE and LSAS revealed that there were no statistically significant differences between the effectiveness of VR and other treatment methods for the treatment of public speaking anxiety (Figure 5). The other treatment groups that VR was compared to are indicated in the leftmost column of the forest plot. If VR is statistically significantly more effective than other treatment groups for the treatment of public speaking anxiety, the entire diamond will lie on the left of the "line of null effect". In contrast, if other treatment groups are statistically significantly more effective than VR for the treatment of public speaking anxiety, the entire diamond will lie on the right of the "line of null effect". The analyses using studies that measured public speaking anxiety using FNE and LSAS imply that VR is statistically as effective

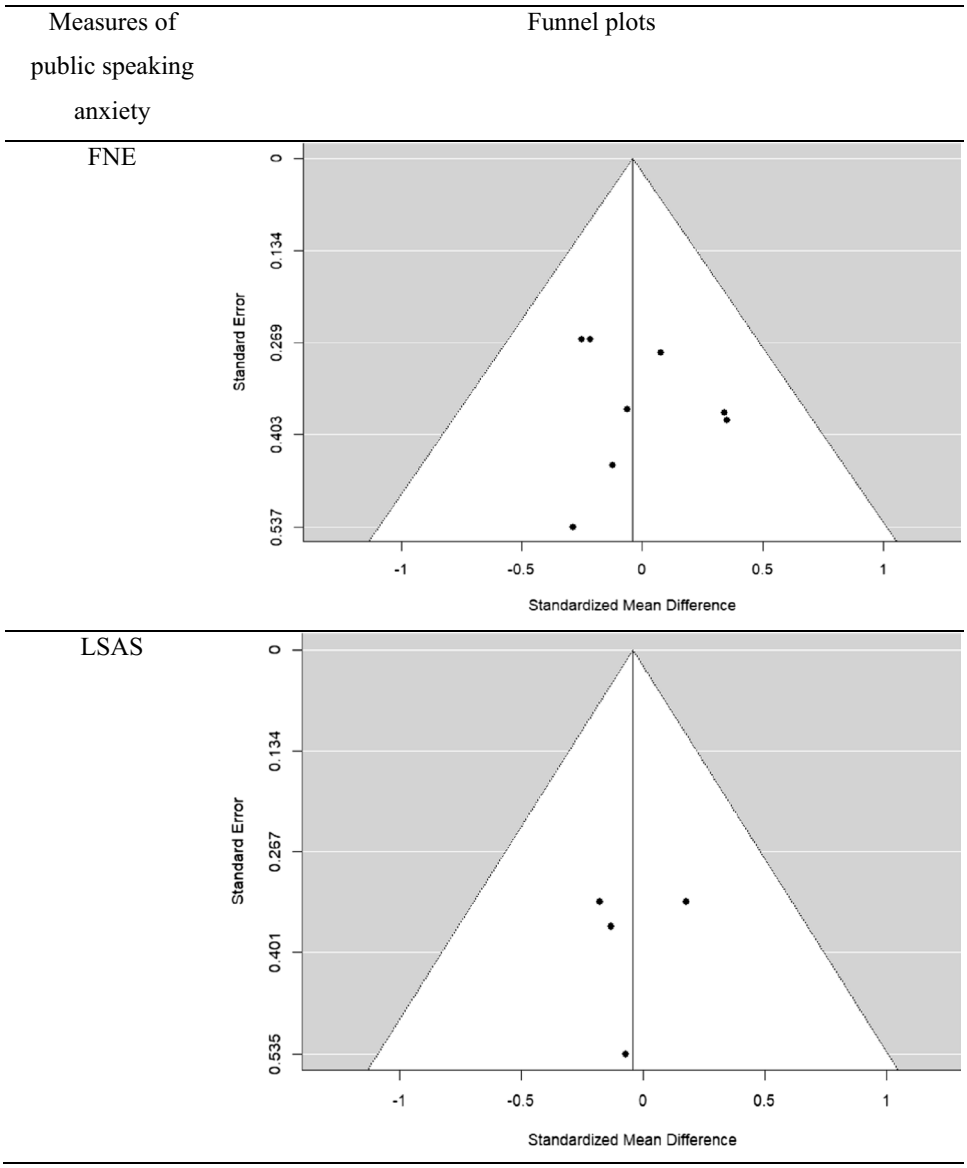

Fig. 4 Funnel Plots of Studies. *Note*. Both funnel plots indicate no publication biases

as other treatment methods for the treatment of public speaking anxiety because both diamonds cut the "line of null effect".

Summary of Findings

Overall, the descriptive statistics showed that past studies on the role of VR for the treatment of public speaking anxiety used a variety of research designs. These designs include review, experimental, quantitative non-experimental, qualitative and descriptive methods. Additionally, for non-review papers, the studies were conducted in many different countries so the findings can be generalized to people from different countries. However, many non-review studies recruited fewer than 50 research participants. The small sample size may have increased the likelihood of false positives and false negatives (Oakes, 2017). The descriptive statistics also showed that a range of the number and the length of VR sessions, virtual locations, the number of virtual audiences and the behaviors of virtual audiences were used in the non-review studies.

Discussion

This study sets out to investigate the effect of using VR in treating public speaking anxiety. This meta-analysis included 92 studies, which is significantly larger than previous review publications. The research questions of this study are discussed next.

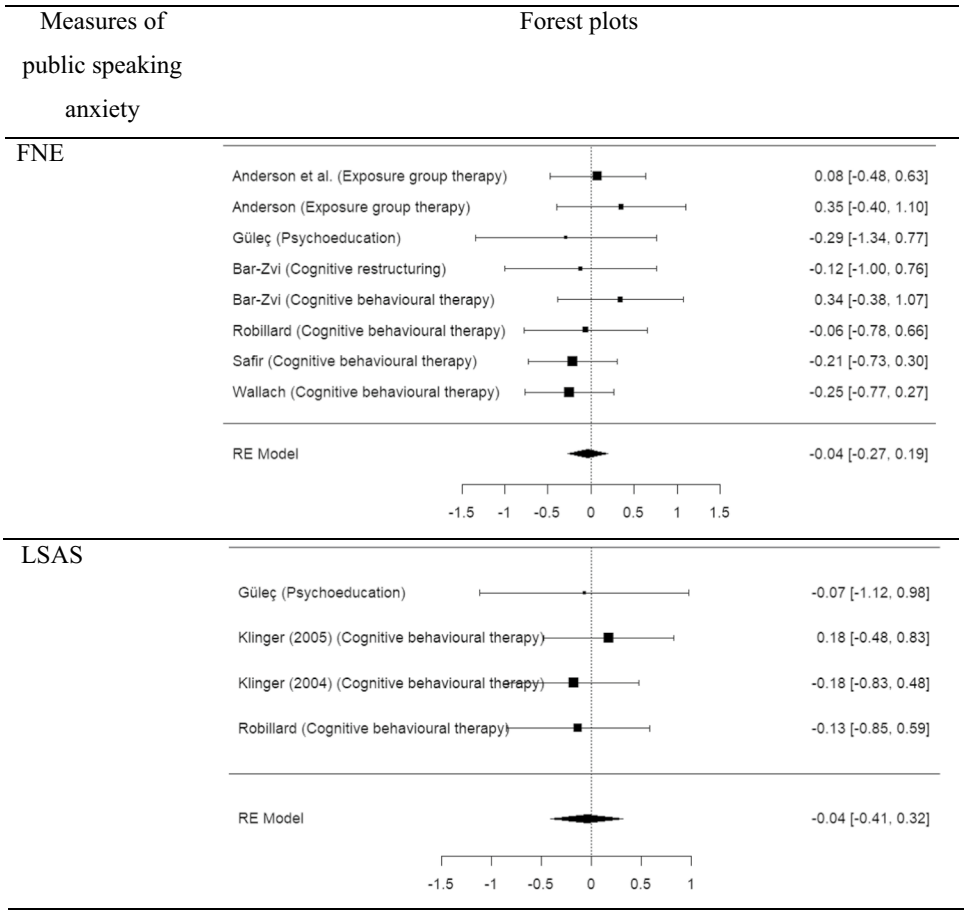

Fig. 5 Forest Plots of Studies that Measured Public Speaking Anxiety using FNE and LSAS. Both forest plots show that VR is statistically as effective as other treatment methods for the treatment of public speaking anxiety

Research Question 1

Is VR Effective for the Treatment of Public Speaking Anxiety?

This meta-analysis found that VR is a useful and promising therapeutic tool for the treatment of public speaking anxiety. There are 27 studies that examined the effectiveness of VR for the treatment of public speaking anxiety. Out of these 27 studies, 26 of the studies found that VR is effective by comparing participants' levels of public speaking anxiety during pre-test with their levels of public speaking anxiety during post-test. Furthermore, the forest plots showed that VR is effective for the treatment of public speaking anxiety. This result is consistent with the findings of Gregg and Tarrier's meta-analysis (2007). Although they did not focus specifically on public speaking anxiety, they reviewed 17 publications and found that VR is beneficial for the treatment of mental health disorders.

Notably, Slater et al. (2006, p. 627) claimed that the VR environments must be able to engender an increase in the participants' public speaking anxiety during VR sessions for it to be effective in its treatment. This is because VR therapy for the treatment of public speaking anxiety relies on anxiety habituation. The prolonged exposures to anxiety-provoking stimuli in public speaking scenarios in VR will result in systematic desensitization (Zacarin et al., 2019). Kothgassner et al.'s experiment (2016, p. 129) and Vanni et al.'s review (2013) supported the claim that public speaking anxiety in VR is comparable to public speaking anxiety in actual public speaking. Relatedly, Kothgassner et al. (2016, p. 129) found no statistically significant differences in self-reported public speaking anxiety levels of participants who presented to real audiences and those who presented to virtual audiences. Additionally, the self-reported public speaking anxiety levels of these two groups were significantly higher than the control group who presented to an empty lecture hall. Therefore, VR provides participants with prolonged exposures to anxiety-provoking stimuli in public speaking scenarios, which allows for systematic desensitization and makes it effective for the treatment of public speaking anxiety.

Anxiety habituation and systematic desensitization of anxiety-provoking stimuli in public speaking scenarios in VR is enhanced by the high similarity between the environments and the behaviors of virtual audiences in VR and actual public speaking. This will allow users to apply anxiety-coping behaviors they have learned during simulated public speaking in VR to actual public speaking in the real world (Parsons,

2016). Similar to actual public speaking environments, the VR environments that participants see change according to their head movements (Wallach et al., 2009, p. 318). VR also simulates typical public speaking locations (Vanni et al., 2013) such as classrooms or lecture rooms, auditoriums, conference rooms, offices, meeting rooms, streets, elevators, shops, bars and therapy rooms. Expressive VR characters with highly realistic appearances and a fine-grained repertoire of human-like behaviors and virtual locations are often created based on careful observations (Slater et al., 2006) or recording of real audiences and places (Dubiago et al., 2017) in actual public speaking scenarios. The virtual characters are often designed to display subtle gestures and random autonomous behaviors such as nodding, yawning and coughing in order to make them more believable and naturalistic (Slater et al., 1999, p. 2). Hence, the high resemblance between the environments in VR and actual public speaking will make it easier for participants to transfer their learned public speaking skills and knowledge such as adaptive strategies to anxiety-provoking stimuli (Kothgassner et al., 2016, p. 125) from VR to the real world (Kothgassner et al., 2012). This will in turn increase the effectiveness of VR for the treatment of public speaking anxiety.

Moreover, the effectiveness of VR for the treatment of public speaking anxiety is increased by the flexibility of VR for therapeutic usage (Geiszt et al., 2006). The therapists can easily manipulate the stimuli and elements in the VR environments such as the virtual locations, the number of virtual audiences and the behaviors of the virtual audiences to provide customized treatments for each patient in a well-controlled environment. This allows the therapists to set specific challenges and targets for each patient in order to tailor to each patient's specific treatment needs and the severity of their public speaking anxiety (Flobak et al., 2019).

Research Question 2

What Is the Average Number and Length of VR Sessions for Studies that Found VR to Be Effective for the Treatment of Public Speaking Anxiety?

Boetje and Van Ginkel (2020) argued that the optimum number of VR sessions for VR to be effective for presentation training such as the reduction of public speaking anxiety is unclear. However, they found that a third VR session is useful for the development of presentation skills. Therefore, it is important to determine the average number and length of VR sessions for studies that found that VR is effective for the treatment of public speaking anxiety. In this study, it was found that the average number and length of VR sessions for studies that found VR to be effective for the treatment of public speaking anxiety were 6.33 VR sessions and 37 minutes respectively. Despite that, a specific number and length of VR sessions cannot be recommended because the characteristics of VR treatments such as VR environments used were different for each study. The result was also based on a small number of studies that found VR to be effective for the treatment of public speaking anxiety. Nonetheless, the average number and length of VR sessions can serve as a guide for effective treatment. However, it should be adjusted according to the severity of the patients' public speaking anxiety and therapy needs. It could also help future researchers who are interested in conducting experiments in order to examine how the number and length of VR sessions affect the effectiveness of VR for the treatment of public speaking anxiety to choose the appropriate number and length of VR sessions for their treatments and control groups.

Research Question 3

Is VR more Effective than Other Treatment Methods for the Treatment of Public Speaking Anxiety?

Additionally, VR is as effective as other treatment methods for public speaking anxiety as the meta-analysis found no significant differences between the effectiveness of VR and other treatment groups for the treatment of public speaking anxiety. This result is consistent with the results of Gregg and Tarrier's meta-analysis (2007) which reviewed 17 publications and found that VR is as effective as other treatment methods for the treatment of mental health disorders. This result is also similar to the findings of Vanni et al.'s narrative review (2013) which found that VR is potentially as effective as in-vivo exposure and more effective than imaginary exposure for the treatment of public speaking anxiety.

These findings may be explained by the disadvantages of VR. For instance, while public speaking environments in VR can highly resemble actual public speaking environments, they can never be exact representations of actual public speaking environments. Virtual characters may not be able to perform complex actions accurately (Klinger et al., 2005, p. 86). For example, a participant in Pertaub et al.'s experiment (2001) commented that some members of the positive virtual audiences congratulated him or her at inappropriate moments. In most cases, their actions are also pre-programmed and may not always realistically change according to the participants' behaviors (Slater et al., 2006). Moreover, they may be unable to engage in spontaneous verbal interactions with participants. Additionally, some cognitive processes of participants in VR seemed to suggest that they may not have taken public speaking in VR as seriously as if it had been a real-life public speaking situation. For instance, some participants in Pertaub et al.'s experiment (2001) thought that it was amusing when the virtual audiences reacted to their presentations in VR. This suggests that these participants were not behaving the same way in VR as they would in actual public speaking. This will make it more

difficult for them to transfer their learned public speaking skills and knowledge such as adaptive strategies to anxiety-provoking stimuli (Kothgassner et al., 2016, p. 125) from public speaking in VR to actual public speaking (Kothgassner et al., 2012). This may lower the effectiveness of VR for the treatment of public speaking anxiety. Due to these limitations, there is still room for improvement for VR to be more effective for the treatment of public speaking anxiety.

Furthermore, other treatment methods may also have some advantages over just relying on exposure to anxiety-provoking public speaking situations in VR for the treatment of public speaking anxiety. For example, cognitive behavioral therapy can be used to correct participants' faulty and distressing thoughts and beliefs about public speaking (Glassman et al., 2016, p. 750). This is especially useful for the treatment of public speaking anxiety since people with public speaking anxiety tend to be overly self-conscious about how the audiences would perceive them during public speaking. They are likely to catastrophize and selectively focus on the threat of negative consequences that may arise during public speaking such as potential public scrutiny and criticism (Wallach et al., 2009, p. 315).

Therefore, rather than a complete replacement of existing treatment methods, VR should be seen as a complement (Lister et al., 2010, p. 379) to make up for some drawbacks of other treatment methods. For example, it can be used together with in-vivo exposure in order to expose patients to public speaking situations that they cannot experience in in-vivo exposure (Gregg & Tarrier, 2007, p. 344). Other than complementing in-vivo exposure, VR can be used as an alternative for imaginary exposure therapy for patients who have problems imagining feared public speaking situations (Kothgassner et al., 2016, p. 125). This also helps to overcome the lack of control over the public speaking environments that patients visualize in imaginary exposure therapy as the therapists can easily control the stimuli in VR (Gregg & Tarrier, 2007, p. 344). Furthermore, numerous studies have shown that using VR together with cognitive behavioral therapy is effective for the treatment of public speaking anxiety (Anderson et al., 2005; Wallach et al., 2009). Some phobic patients are also too anxious to undergo in-vivo exposure and that may lead to high rates of treatment refusal and drop-out (Meyerbröker & Emmelkamp, 2010, p. 939). Therefore, VR may be used as an intermediate treatment step to persuade these patients to first engage in mock public speaking in VR. When they gain more confidence through the VR experience, they may proceed to actual public speaking situations in the real world (Owens & Beidel, 2015).

Limitation

There is a limitation to this meta-analysis. In this study, VR is found to be effective for the treatment of public speaking anxiety by comparing participants' levels of post-test public speaking anxiety with their levels of pre-test public speaking anxiety. However, this finding may be partly influenced by outcome expectancy. This is because when participants undergo VR therapies, they tend to expect the therapies to help them overcome their public speaking anxiety (Anderson et al., 2013, p. 757). Hence, they may perceive it to be more effective than it is (Price & Anderson, 2012). This is especially problematic with self-reported measures of public speaking anxiety such as self-reported questionnaires that were used in the studies reviewed in this meta-analysis. Therefore, participants' public speaking anxiety should be measured objectively using behavioral and physiological measures. Behavioral measures involve recording participants' public speaking anxiety behavior such as avoidance of eye contact with the audiences. Physiological measures refer to biometrics measurements such as galvanic skin response, skin temperature, heart rate and heart rate variability (Ling et al., 2010). Despite this limitation, the findings of this study are clinically relevant and may be of interest to clinical psychologists and researchers looking to examine the role of VR in the treatment of public speaking anxiety.

Conclusion

This study has conducted a meta-analysis of 92 publications on the role of VR in alleviating public speaking anxiety. It has also provided useful information on the effectiveness of VR for the treatment of public speaking anxiety, which can help clinical psychologists decide whether they want to utilize this technology in therapies.

Firstly, this review found that VR is effective for the treatment of public speaking anxiety. The high similarity between VR and actual public speaking environments and the fact that the therapists can control many elements in VR environments such as the virtual locations in order to cater to each patient's therapy needs may have contributed to the effectiveness of VR for the treatment of public speaking anxiety. Moreover, the average number and length of VR sessions for studies that found that VR is effective for the treatment of public speaking anxiety were 6.33 VR sessions and 37 minutes respectively. This can serve as a guide for effective treatment although it should be adjusted according to each patient's therapy needs. Furthermore, this information may be beneficial for researchers who are interested in conducting experiments to investigate the effect of the number and length of VR sessions on the effectiveness of VR for the treatment of public speaking anxiety. Lastly, VR is generally as effective as other treatment methods for the treatment of public speaking anxiety. This may be due to some

disadvantages of VR and the advantages of other treatment methods. Hence, rather than completely replacing other treatment methods, VR should be used to complement other treatment methods to compensate for some of their disadvantages.

Nonetheless, VR technologies are currently undergoing constant and rapid development and improvement (Gregg & Tarrier, 2007, p. 344). Researchers have been actively looking into how to develop more effective VR technologies for the treatment of public speaking anxiety (Khurpade et al., 2020; Kang et al., 2013). With the advancement in technology, VR may have the potential to deliver more efficacious treatment in the future. Hence, this review should be replicated in future studies in order to obtain the most updated knowledge regarding the effectiveness of VR in alleviating public speaking anxiety.

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Data Availability Data sharing is not applicable to this article as the datasets generated during the current study are proprietary of Scopus. Using the search code discussed in the paper, interested readers who have access to Scopus can replicate the dataset.

Declarations

Compliance with Ethical Standards The authors declare that:
- there are no potential conflicts of interest;
- the study does not include any human participants and/or animals;
- and therefore no informed consent was used in the study (as it is irrelevant).

References

Ahn, E., & Kang, H. (2018). Introduction to systematic review and meta-analysis. *Korean Journal of Anesthesiology, 71*(2), 103. https://doi.org/10.4097/kjae.2018.71.2.103

Anderson, P. L., Price, M., Edwards, S. M., Obasaju, M. A., Schmertz, S. K., Zimand, E., & Calamaras, M. R. (2013). Virtual reality exposure therapy for social anxiety disorder: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 81*(5), 751. https://doi.org/10.1037/a0033559

Anderson, P. L., Zimand, E., Hodges, L. F., & Rothbaum, B. O. (2005). Cognitive behavioral therapy for public-speaking anxiety using virtual reality for exposure. *Depression and Anxiety, 22*(3), 156–158. https://doi.org/10.1002/da.20090

Anderson, P. L., Edwards, S. M., & Goodnight, J. R. (2017). Virtual reality and exposure group therapy for social anxiety disorder: Results from a 4–6-year follow-up. *Cognitive Therapy and Research, 41*(2), 230–236. https://doi.org/10.1007/s10608-016-9820-y

Bar-Zvi, M. (2011). Virtual reality exposure versus cognitive restructuring for treatment of public speaking anxiety: A pilot study. *Israel Journal of Psychiatry and Related Sciences, 48*(2), 91.

Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics, 1088-1101*. https://doi.org/10.2307/2533446

Boetje, J., & Van Ginkel, S. (2020). The added benefit of an extra practice session in virtual reality on the development of presentation skills: A randomized control trial. *Journal of Computer Assisted Learning*. https://doi.org/10.1111/jcal.12484

Botella, C., Banos, R., Guillén, V., Perpiñá, C., Alcaniz, M., & Pons, A. (2000). Telepsychology: Public speaking fear treatment on the internet. *CyberPsychology and Behavior, 3*(6), 959–968. https://doi.org/10.1089/109493100452228

Daniels, M. M., Palaoag, T., & Daniels, M. (2020). Efficacy of virtual reality in reducing fear of public speaking: A systematic review. *International Conference on Information Technology and Digital Applications, 803*. https://doi.org/10.1088/1757-899X/803/1/012003

Dubiago, M., Poeschl, S., & Doering, N. (2017). Influence of simulation fidelity on perceived simulation realism - an exploratory study on a virtual public speaking training application. *Annual Review of Cybertherapy and Telemedicine, 15*, 154–159.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. Increase in studies of publication bias coincided with increasing use of meta-analysis. *British Medical Journal, 316*, 629–634.

El-Yamri, M., Romero-Hernandez, A., Gonzalez-Riojo, M., & Manero, B. (2019). Emotions-responsive audiences for VR public speaking simulators based on the speakers' voice. *2019 IEEE 19th international conference on advanced learning technologies (ICALT), 2161*, 349-353. IEEE. https://doi.org/10.1109/ICALT.2019.00108

Emmelkamp, P. M., Bruynzeel, M., Drost, L., & Van Der Mast, C. A. G. (2001). Virtual reality treatment in acrophobia: A comparison with exposure in vivo. *CyberPsychology and Behavior, 4*(3), 335–339. https://doi.org/10.1089/109493101300210222

Flobak, E., Wake, J. D., Vindenes, J., Kahlon, S., Nordgreen, T., & Guribye, F. (2019) Participatory design of VR scenarios for exposure therapy. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1-12. https://doi.org/10.1145/3290605.3300799

Gage, N. A., Cook, B. G., & Reichow, B. (2017). Publication bias in special education meta-analyses. *Exceptional Children, 83*(4), 428–445. https://doi.org/10.1177/0014402917691016

Geiszt, Z., Kamson, M. E., Lányi, C. S., & Stark, J. A. (2006). Do we need high-scale flexibility in virtual therapies? *Proceedings of the 6th International Conference on Disability, Virtual Reality and Associated Technologies*, 97-104. https://doi.org/10.1515/ijdhd.2006.5.3.251

Glassman, L. H., Forman, E. M., Herbert, J. D., Bradley, L. E., Foster, E. E., Izzetoglu, M., & Ruocco, A. C. (2016). The effects of a brief acceptance-based behavioral treatment versus traditional cognitive-behavioral treatment for public speaking anxiety: An exploratory trial examining differential effects on performance and neurophysiology. *Behavior Modification, 40*(5), 748–776. https://doi.org/10.1177/0145445516629939

Gregg, L., & Tarrier, N. (2007). Virtual reality in mental health. *Social Psychiatry and Psychiatric Epidemiology, 42*(5), 343–354. https://doi.org/10.1007/s00127-007-0173-4

Güleç, U., Nazlıgül, M. D., Yılmaz, M., Yılmaz, A. E., İşler, V., O'Connor, R. V., ... & Clarke, P. (2019). Interactive three-dimensional virtual environment to reduce the public speaking anxiety levels of novice software engineers. *Association*

for Computing Machinery. https://doi.org/10.1145/3202710.3203162

Gupta, A., Makhiboroda, Y., & Story, B. H. (2019). *U.S. Patent No. 10,446,055*. Washington, DC: U.S. Patent and Trademark Office.

Harris, S. R., Kemmerling, R. L., & North, M. M. (2002). Brief virtual reality therapy for public speaking anxiety. *Cyberpsychology and Behavior, 5*(6), 543–550. https://doi.org/10.1089/109493102321018187

Hauck, M., & Hurd, S. (2005). Exploring the link between language anxiety and learner self-management in open language learning contexts. *European Journal of Open, Distance and E-learning, 2005*(2), 1–23.

Hinojo-Lucena, F. J., Aznar-Díaz, I., Cáceres-Reche, M. P., Trujillo-Torres, J. M., & Romero-Rodríguez, J. M. (2020). Virtual reality treatment for public speaking anxiety in students. Advancements and results in personalized medicine. *Journal of Personalized Medicine, 10*(1), 14. https://doi.org/10.3390/jpm10010014

Hu, F., Deng, Y., Saad, W., Bennis, M., & Aghvami, A. H. (2020). Cellular-connected wireless virtual reality: Requirements, challenges, and solutions. *IEEE Communications Magazine, 58*(5), 105–111. https://doi.org/10.1109/mcom.001.1900511

Ibrahim, O., & Devesh, S. (2019). Implication of public speaking anxiety on the employability of Omani graduates. *Journal of Teaching and Learning for Graduate Employability, 10*(2), 122–135. https://doi.org/10.21153/jtlge2019vol10no2art861

IntHout, J., Ioannidis, J. P., Borm, G. F., & Goeman, J. J. (2015). Small studies are more heterogeneous than large ones: A meta-meta-analysis. *Journal of Clinical Epidemiology, 68*(8), 860–869. https://doi.org/10.1016/j.jclinepi.2015.03.017

Kang, N., Brinkman, W. P., Van Riemsdijk, M. B., & Neerincx, M. A. (2013). An expressive virtual audience with flexible behavioral styles. *IEEE Transactions on Affective Computing, 4*(4), 326–340. https://doi.org/10.1109/TAFFC.2013.2297104

Katz, L. (2000). Public speaking anxiety. *UTM Counseling and Career Services, 1*, 1–3.

Khan, F., Ismail, S., Shafique, M. S., Ghous, K., & Ali, S. A. (2015). Glossophobia among undergraduate students of government medical colleges in Karachi. *International Journal of Research (IJR), 2*(1), 36–42.

Khurpade, J. M., Gangawane, A. A., Ostwal, G. S., Lalwani, D. M., & Vidye, R. G. (2020). The effect of virtual reality and heart rate variability using deep learning for reducing stage fright - Glossophobia. *2020 international conference on industry 4.0 technology (I4Tech)*, 195-198. https://doi.org/10.1109/i4tech48345.2020.9102645

Kimani, E., & Bickmore, T. (2019) Addressing public speaking anxiety in real-time using a virtual public speaking coach and physiological sensors. *Proceedings of the 19th ACM International Conference on Intelligent Virtual Agents*, 260-263. https://doi.org/10.1145/3308532.3329409

Klinger, E., Bouchard, S., Légeron, P., Roy, S., Lauer, F., Chemin, I., & Nugues, P. (2005). Virtual reality therapy versus cognitive behavior therapy for social phobia: A preliminary controlled study. *CyberPsychology and Behavior, 8*(1), 76–88. https://doi.org/10.1089/cpb.2005.8.76

Kothgassner, O. D., Felnhofer, A., Beutl, L., Hlavacs, H., Lehenbauer, M., & Stetina, B. (2012). A virtual training tool for giving talks. In *International conference on entertainment computing, 7522, 53-66*. Springer, Berlin. https://doi.org/10.1007/978-3-642-33542-6_5

Kothgassner, O. D., Felnhofer, A., Hlavacs, H., Beutl, L., Palme, R., Kryspin-Exner, I., & Glenk, L. M. (2016). Salivary cortisol and cardiovascular reactivity to a public speaking task in a virtual and real-life environment. *Computers in Human Behavior, 62*, 124–135. https://doi.org/10.1016/j.chb.2016.03.081

Lan, Y. J. (2020). Immersion, interaction, and experience-oriented learning: Bringing virtual reality into FL learning. *Language Learning and Technology, 24*(1), 1-15. 10125/44704.

Lear, C. A. (2020). *The use of virtual reality to reduce L2 speaking anxiety*.

Lewis, S., & Clarke, M. (2001). Forest plots: Trying to see the wood and the trees. *British Medical Journal, 322*(7300), 1479–1480. https://doi.org/10.1136/bmj.322.7300.1479

Lin, L., Chu, H., Murad, M. H., Hong, C., Qu, Z., Cole, S. R., & Chen, Y. (2018). Empirical comparison of publication bias tests in meta-analysis. *Journal of General Internal Medicine, 33*(8), 1260–1267. https://doi.org/10.1007/s11606-018-4425-7

Lindner, P., Miloff, A., Fagernäs, S., Andersen, J., Sigeman, M., Andersson, G., & Carlbring, P. (2019). Therapist-led and self-led one-session virtual reality exposure therapy for public speaking anxiety with consumer hardware and software: A randomized controlled trial. *Journal of Anxiety Disorders, 61*, 45–54. https://doi.org/10.1016/j.janxdis.2018.07.003

Lindner, P., Miloff, A., Hamilton, W., Reuterskiöld, L., Andersson, G., Powers, M. B., & Carlbring, P. (2017). Creating state of the art, next-generation virtual reality exposure therapies for anxiety disorders using consumer hardware platforms: Design considerations and future directions. *Cognitive Behavior Therapy, 46*(5), 404–420. https://doi.org/10.1080/16506073.2017.1280843

Ling, Y., Nefs, H. T., Brinkman, W. P., Heynderickx, I., & Qu, C. (2010). The role of display technology and individual differences on presence. *Proceedings of the 28th Annual European Conference on Cognitive Ergonomics*, 323–326. https://doi.org/10.1145/1962300.1962369

Lipsitz, J. D., & Marshall, R. D. (2001). Alternative psychotherapy approaches for social anxiety disorder. *Psychiatric Clinics, 24*(4), 817–829. https://doi.org/10.1016/S0193-953X(05)70265-3

Lister, H. A., Piercey, C. D., & Joordens, C. (2010). The effectiveness of 3-D video virtual reality for the treatment of fear of public speaking. *Journal of Cybertherapy and Rehabilitation, 3*(4), 375–381.

Meyerbröker, K., & Emmelkamp, P. M. (2010). Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. *Depression and Anxiety, 27*(10), 933–944. https://doi.org/10.1002/da.20734

Mostajeran, F., Balci, M. B., Steinicke, F., Kühn, S., & Gallinat, J. (2020). The effects of virtual audience size on social anxiety during public speaking. *2020 IEEE conference on virtual reality and 3D user interfaces (VR)*, 303-312. IEEE. https://doi.org/10.1109/VR46266.2020.00050

North, M. M., North, S. M., & Coble, J. R. (1997). Virtual reality therapy: An effective treatment for psychological disorders. *Virtual Reality in Neuro-Psycho-Physiology: Cognitive, Clinical and Methodological Issues in Assessment and Rehabilitation, 44*, 59. https://doi.org/10.3233/978-1-60750-888-5-71

North, M. M., North, S. M., & Coble, J. R. (2002). Virtual reality therapy: An effective treatment for psychological disorders. *Human Factors and ergonomics. Handbook of vVirtual eEnvironments: Design, iImplementation, and aApplications*, 1065-1078.

Oakes, L. M. (2017). Sample size, statistical power, and false conclusions in infant looking-time research. *Infancy, 22*(4), 436–469. https://doi.org/10.1111/infa.12186

Overholser, J. C. (2002). Cognitive-behavioral treatment of social phobia. *Journal of Contemporary Psychotherapy, 32*(2-3), 125–144. https://doi.org/10.1023/A:1020534025102

Owens, M. E., & Beidel, D. C. (2015). Can virtual reality effectively elicit distress associated with social anxiety disorder? *Journal of Psychopathology and Behavioral Assessment, 37*(2), 296–305. https://doi.org/10.1007/s10862-014-9454-x

Parsons, S. (2016). Authenticity in virtual reality for assessment and intervention in autism: A conceptual review. *Educational*

Research Review, 19, 138–157. https://doi.org/10.1016/j.edurev.2016.08.001

Pertaub, D. P., Slater, M., & Barker, C. (2001). An experiment on fear of public speaking in virtual reality. *Studies in Health Technology and Informatics, 372-378*. https://doi.org/10.1037/e705412011-025

Price, M., & Anderson, P. L. (2012). Outcome expectancy as a predictor of treatment response in cognitive behavioral therapy for public speaking fears within social anxiety disorder. *Psychotherapy, 49*(2), 173. https://doi.org/10.1037/a0024734

Pull, C. B. (2012). Current status of knowledge on public speaking anxiety. *Current Opinion in Psychiatry, 25*(1), 32–38. https://doi.org/10.1097/YCO.0b013e32834e06dc

Rahman, F. (2018). Glossophobia in training of speech. *ELS Journal on Interdisciplinary Studies. Humanities*, *1*(1), 28–36. https://doi.org/10.34050/els-jish.v1i1.4076.

Repetto, C., & Riva, G. (2011). From virtual reality to interreality in the treatment of anxiety disorders. *Neuropsychiatry, 1*(1), 31. https://doi.org/10.2217/npy.11.5

Robillard, G., Bouchard, S., Dumoulin, S., Guitard, T., & Klinger, E. (2010). Using virtual humans to alleviate social anxiety: Preliminary report from a comparative outcome study. *Studies in Health Technology and Informatics, 154*, 57–60. https://doi.org/10.3233/978-1-60750-561-7-57

Rothbaum, B. O., Anderson, P., Zimand, E., Hodges, L., Lang, D., & Wilson, J. (2006). Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. *Behavior Therapy, 37*(1), 80–90. https://doi.org/10.1016/j.beth.2005.04.004

Safir, M. P., Wallach, H. S., & Bar-Zvi, M. (2012). Virtual reality cognitive-behavior therapy for public speaking anxiety: One-year follow-up. *Behavior Modification, 36*(2), 235–246. https://doi.org/10.1177/0145445509331926

Šalkevicius, J., Damaševičius, R., Maskeliunas, R., & Laukienė, I. (2019). Anxiety level recognition for virtual reality therapy system using physiological signals. *Electronics, 8*(9), 1039. https://doi.org/10.3390/electronics8091039

Sedgwick, P. (2012). How to read a forest plot? *British Medical Journal, 345*, e8335. https://doi.org/10.1136/bmj.e8335

Seinfeld, J. (1993). The pilot [television]. In G. Shapiro, H. west, J. Seinfeld & L. David (producer), Seinfeld: NBC.

Slater, M., Pertaub, D. P., Barker, C., & Clark, D. M. (2006). An experimental study on fear of public speaking using a virtual environment. *CyberPsychology and Behavior, 9*(5), 627–633. https://doi.org/10.1089/cpb.2006.9.627

Slater, M., Pertaub, D. P., & Steed, A. (1999). Public speaking in virtual reality: Facing an audience of avatars. *IEEE Computer Graphics and Applications, 19*(2), 6–9. https://doi.org/10.1109/38.749116

Sterne, J. A., Becker, B. J., & Egger, M. (2005). *The funnel plot* (pp. 75–98). Prevention, Assessment and Adjustments: Publication Bias in Meta-Analysis.

Stovold, E., Beecher, D., Foxlee, R., & Noel-Storr, A. (2014). Study flow diagrams in Cochrane systematic review updates: An adapted PRISMA flow diagram. *Systematic Reviews, 3*(1), 54. https://doi.org/10.1186/2046-4053-3-54

The Jamovi project (2020). *Jamovi* (Version 1.2) [Computer Software]. https://www.jamovi.org

Thorlund, K., Imberger, G., Johnston, B. C., Walsh, M., Awad, T., Thabane, L., & Wetterslev, J. (2012). Evolution of heterogeneity (I 2) estimates and their 95% confidence intervals in large meta-analyses. *PLoS One, 7*(7), e39471. https://doi.org/10.1371/journal.pone.0039471

Van Enst, W. A., Ochodo, E., Scholten, R. J., Hooft, L., & Leeflang, M. M. (2014). Investigation of publication bias in meta-analyses of diagnostic test accuracy: A meta-epidemiological study. *BMC Medical Research Methodology, 14*(1), 70. https://doi.org/10.1186/1471-2288-14-70

Vanni, F., Conversano, C., Del Debbio, A., Landi, P., Carlini, M., Fanciullacci, C., & Dell'Osso, L. (2013). A survey on virtual environment applications to fear of public speaking. *European Review for Medical and Pharmacological Sciences, 17*(12), 1561–1568.

Vincenti, G. (2009). Fear of flying and virtual environments: An introductory review. *Emerging Topics and Technologies in Information Systems, 221-230*. https://doi.org/10.4018/978-1-60566-222-0.ch013

Wallach, H. S., Safir, M. P., & Bar-Zvi, M. (2009). Virtual reality cognitive behavior therapy for public speaking anxiety: A randomized clinical trial. *Behavior Modification, 33*(3), 314–338. https://doi.org/10.1177/0145445509331926

Wang, J., Yang, H., Shao, R., Abdullah, S., & Sundar, S. S. (2020, April). Alexa as coach: Leveraging smart speakers to build social agents that reduce public speaking anxiety. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1-13. https://doi.org/10.1145/3313831.3376561

Yuen, E. K., Goetter, E. M., Stasio, M. J., Ash, P., Mansour, B., McNally, E., & Watkins, J. (2019). A pilot of acceptance and commitment therapy for public speaking anxiety delivered with group videoconferencing and virtual reality exposure. *Journal of Contextual Behavioral Science, 12*, 47–54. https://doi.org/10.1016/j.jcbs.2019.01.006

Zacarin, M. R. J., Borloti, E., & Haydu, V. B. (2019). Behavioral therapy and virtual reality exposure for public speaking anxiety. *Trends in Psychology, 27*(2), 491–507. https://doi.org/10.9788/tp2019.2-14