

Attention Guidance Augmentation of Virtual Reality Exposure Therapy for Social Anxiety
Disorder: A Pilot Randomized Controlled Trial

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Abstract

Biased attention to social threat has been implicated in social anxiety disorder. Modifying visual attention during exposure therapy offers a direct test of this mechanism. We developed and tested a brief virtual reality exposure therapy (VRET) protocol using 360°-video and eye tracking. Participants ($N = 21$) were randomized to either standard VRET or VRET + attention guidance training (AGT). Multi-level Bayesian models were used to test (1) whether there was an effect of condition over time and (2) whether post-treatment changes in gaze patterns mediated the effect of condition at follow-up. There was a large overall effect of the intervention on symptoms of social anxiety, as well as an effect of the AGT augmentation on changes in visual attention to audience members. There was weak evidence against an effect of condition on fear of public speaking and weak evidence supporting a mediation effect, however these estimates were strongly influenced by model priors. Taken together, our findings suggest that attention can be modified *within and during* VRET and that modification of visual gaze avoidance may be casually linked to reductions in social anxiety. Replication with a larger sample size is needed.

Attention Guidance Augmentation of Virtual Reality Exposure Therapy for Social Anxiety Disorder: A Pilot Randomized Controlled Trial

Social anxiety disorder (SAD) is characterized by elevated fear or anxiety about one or more social situations in which the individual may encounter scrutiny by others (American Psychiatric Association, 2013). SAD a highly prevalent common psychological concern with a lifetime prevalence of 12% (Ruscio et al., 2008), and confers significant impairment in multiple spheres of functioning (Aderka et al., 2012). SAD is also associated with elevated risk of comorbid depression and substance abuse (Stein & Stein, 2008).

There is increasing emphasis on the importance of understanding mechanisms underpinning psychological disorders (Moreno-Peral et al., 2020). One structured approach to addressing this in research has been through the Research Domain Criteria (RDoC), which emphasizes the importance of investigating specific mechanisms across taxonomic levels, from genes to behaviors (Kozak & Cuthbert, 2016). Attentional processes figure prominently in most contemporary models of SAD (Clark & Wells, 1995; Wong & Rapee, 2016) and have been the focus of considerable empirical work (Bögels & Mansell, 2004). Several distinct attentional profiles have been implicated. These include attentional *hypervigilance* to social evaluative cues (Rapee & Heimberg, 1997), attentional avoidance (Cisler & Koster, 2010), self-focused attention (Clark & Wells, 1995), attentional switching between internal and external social-evaluative threat cues (Rapee & Heimberg, 1997) and attentional hyperscanning (Chen et al., 2015).

Both theoretical models of Social Anxiety Disorder (Clark & Wells, 1995; Wong & Rapee, 2016) and some prior research (Kim et al., 2018; Rubin et al., 2020) support the hypothesis that avoidance of social threat may serve as a maintaining factor of the disorder. However, directly testing this in the context of psychotherapy is challenging. For instance, it can

be difficult, if not impossible, for a clinician to accurately assess the degree to which a patient is actually looking at audience members during an *in vivo* public speaking exposure, to assess the degree of attentional avoidance. This difficulty can be addressed with virtual environments that incorporate eye tracking. This context makes it practicable to directly test whether attentional avoidance is causally implicated as a mechanism maintaining SAD.

To directly investigate attentional avoidance as a potential mechanism for SAD we developed a virtual reality environment where participants were required to deliver a speech to a real (that is, not digital avatars) audience who had been pre-recorded in a 360°-video. Participants were randomized to receive this public speaking exposure with or without visual attention guidance training. The attention guidance training involved instructing participants to look directly at the audience members during repeated presentations of the speech to the virtual audience. Visual gaze data were obtained for both groups using an Oculus Rift headset capable of displaying 360°-video conference room environment (See Figure 1). The integrated eye tracker in the Oculus Rift Headset allowed the clinician to validate attention allocation during each speech and provide feedback to participants. There is substantial evidence that virtual reality exposure therapy (VRET) for SAD is a highly effective intervention modality (Carl et al., 2019; Chesham et al., 2018). 360°-video is more realistic than digital computer-generated avatars and while most VRET studies have used digital avatars, considering the focus on attention in the current research, the use of more realistic stimuli was important.

In line with the primary aims of the study, we asked whether individuals who received VRET augmented with attention guidance would show greater reduction in symptoms of social anxiety following the intervention compared to VRET alone. Second, we asked if the effects of the attention guidance augmentation were mediated by changes in gaze following the

intervention. Specifically, we expected that individuals who received attention guidance would look more at uninterested (socially threatening) audience members posttreatment, and that this would at least partially account for the effects of the intervention on symptoms of social anxiety at the one-week follow-up. Thus, we tested not only whether the augmentation enhanced VRET, but also whether increased visual attention to audience members was a mechanism underpinning changes in symptoms. The current pilot RCT aimed to establish whether a larger study is warranted to test the efficacy of attentional guidance as a component for VRET.

Methods

Participants

Individuals ($N=21$) from the Austin community and from a large subject pool at the University of Texas who were diagnosed with SAD and displayed marked fear of public speaking were enrolled in the study (see Table 1 for the demographic summary). The Institutional Review Board at the University of Texas at Austin approved all study procedures. Inclusion Criteria for the study were: (1) Age 18-65; (2) Fluent in English; (3) Personal Report of Public Speaking Anxiety > 98 ; (4) Leibowitz Social Anxiety Scale > 30 ; (5) Peak fear ≥ 50 on the behavioral approach task during the baseline public speaking challenge; (6) Meets DSM-5 Criteria for Social Anxiety Disorder. Exclusion Criteria for the study were: (1) Currently receiving CBT for Social Anxiety Disorder; (2) Significant visual impairment precluding the use of virtual reality equipment; (3) Unstable dose of psychotropic medications within 3 weeks prior to baseline assessment; (4) Current alcohol or substance use disorders; (5) Current, or history of bipolar disorder; current, or history of psychosis; (6) Serious suicidal risk, as determined by clinical interview.

Study Design

The study investigated an attention augmentation strategy in a 2-arm randomized controlled trial. Adults with SAD were enrolled in a 2-week (3 visit) VRET protocol. Participants were randomly assigned to one of two conditions: (a) Virtual reality exposure therapy plus attention guidance training (VRET + AGT, $n = 11$) or (b) Standard virtual reality exposure therapy (VRET, $n = 10$). Symptoms of social anxiety were assessed at baseline, posttreatment and one-week posttreatment. Enrollment began 03/13/2019 and data collection ended 03/11/2020. The trial was registered as “Efficacy of an Attention Guidance VR Intervention for Social Anxiety Disorder”, trial number: NCT03683823 and can be accessed through clinicaltrials.gov. See Figure 2 for the flow diagram.

Screening procedures

Potential participants first completed an online pre-screen consisting of demographics information, treatment history, the Leibowitz Social Anxiety Scale (LSAS) and the Personal Report of Public Speaking Anxiety (PRPSA). Participants that endorsed clinically elevated symptoms of social anxiety (LSAS score of 30 or greater) and endorsed moderate levels of public speaking anxiety (PRPSA score of 98 or greater) were invited to the in-person assessment. When participants arrived at the lab a trained staff member reviewed the informed consent process, treatment procedures, and potential risks and benefits of participation. Participants then completed self-report questionnaires, followed by a diagnostic assessment conducted by a doctoral student in clinical psychology. After the symptom assessment, participants were invited to the VR-lab to complete a public speaking challenge. The public speaking challenge involved an orientation to the virtual reality environment, 5-minutes to prepare a 3-minute speech on a topic they selected (from a list), then giving the 3-minute speech. Participants reported subjective units of distress before and after the speech. Following the public speaking challenge, eligible

participants were randomized (using a balanced, block-randomization procedure conducted in R using the *blockrand* package (Snow & Snow, 2013) implemented by M.R.; block size was 4) to one of the two arms and started treatment immediately. The clinician that conducted the assessment also allocated the participant (they were not blind to the condition prior to allocation) and conducted the intervention. Neither the clinician nor participant were blind to the condition of the intervention following allocation.

Intervention

Virtual Reality Exposure Therapy (VRET). Participants received a brief standardized VRET protocol for social anxiety, which consisted of two 45-minute sessions delivered over a one-week period by a graduate student clinician supervised by MJT. Treatment consisted of (1) psychoeducation and (2) public speaking exposures. Threat appraisals were collected prior to and following each exposure to assess anticipated fear, peak fear, and post fear. During the first session of the treatment participants received brief psychoeducation regarding SAD and a treatment rationale emphasizing that confrontation of feared and/or avoided situations is critical. Each exposure session consisted of completing six 3-minute speeches. Participants were able to select one of several prompts at the beginning of each session. Participants had 5-minutes to prepare a speech based on the prompt and gave all six speeches during a given day on the same prompt. Between speeches participants had a 1-minute break. Following the six exposures, participants briefly processed the session with the clinician.

Virtual Reality Exposure Therapy + Attention Guidance Training (VRET + AGT).

Participants completed the same protocol as the standard VRET condition with three differences. (1) The treatment rationale included information about the importance of engaging in actions that directly counteract the naturalistic behavioral tendencies associated with anxiety and specifically

the importance of looking directly at audience members. (2) Before each speech the participant was directed to address a specific audience member throughout the speech, focusing specifically on their face. For each of the six speeches, the participant focused on a different audience member's face. (3) After each speech the clinician used an automated program to assess the percentage of time the participant was directly looking at their "target" audience member. The clinician provided the specific percentage along with encouragement to focus on the "target" audience member during each speech. Two video examples (Video 1 – standard VRET and Video 2 – VRET + AG) are provided to illustrate the difference between the two conditions in terms of gaze by study participants.

Posttreatment Assessments

Posttreatment and follow-up assessments were the same self-report measures as pre-treatment and included another public speaking challenge. Participants completed the posttreatment assessment immediately following the completion of the intervention and the follow-up assessment one-week after the posttreatment assessment.

Measures

Personal Report of Public Speaking Anxiety (PRPSA)

The PRPSA (McCroskey, 1970) is a 34-item instrument that is designed to assess public speaking anxiety. Participants rated their agreement with statements such as "I feel anxious while waiting to give a speech" on a 1-5 scale (1= strongly disagree, 5 = strongly agree), with a score ranging from 34-170.

Liebowitz Social Anxiety Scale Self Report Version (LSAS-SR)

The LSAS self-report scale (Liebowitz, 1987) is a 48-item measure of fear and avoidance concerning social interactions and performance situations (e.g. telephoning in public, talking to

people in authority). Participants rated each item on a 0-3 Likert scale for Fear or Anxiety (0 = “none”, 3= “severe”) and Avoidance (0= “never (0%) to 3 = “usually (67-100%) with a score ranging from 0-144.

Threat Appraisal Ratings. Threat appraisal ratings were administered prior to and following each exposure trial using a (0-100) visual analog scale to assess the degree of threat associated with completing the next trial (i.e. expected fear) and the greatest degree of threat experienced during the trial (i.e. peak fear).

Speech Anxiety Thoughts Inventory (SATI)

The SATI (Cho et al., 2004) is a two factor (prediction of poor performance and fear of negative evaluation by audience) instrument, measuring maladaptive cognitions associated with speech anxiety. Items (e.g., “My speech won’t impress the audience”) are rated on how strongly the statements are believed, on a 5-point scale (1 = “Not at all” to 5 = “Completely”).

Structured Clinical Interview for DSM-5 (SCID-5)

The SCID-5 (First et al., 2015) is a semi-structured clinician administered interview that is the gold-standard for determining mental health diagnoses for DSM-5. Selected portions of the SCID-5 were administered by a graduate clinician to assess for social anxiety disorder, alcohol and substance use disorders, psychosis, and bipolar disorder.

Columbia Suicidality Severity Rating Scale (C-SSRS)

The C-SSRS (Posner et al., 2011) is a semi-structured clinician-administered measure to assess suicidality. The C-SSRS was administered by a graduate clinician.

Concurrent treatment. Psychotropic medication and current utilization of psychotherapy was assessed on the online prescreen.

Demographics. Participants were asked to provide demographic information including sex, age, race/ethnicity, visual impairment, language history and use, etc. on the internet prescreen.

Materials

360°-video virtual reality environments. The 360°-video virtual reality (VR) environments consist of an audience of six individuals sitting in chairs around a conference table or in a lecture hall (Figure 1). The pre-treatment public speaking challenge and treatment context were the conference room. The post-treatment and follow-up public speaking challenge context were the auditorium. There are two groups of audience members – public speaking challenge audience members and treatment audience members. All videos featured the six audience members acting as if they are listening to a speech with varying levels of interest. Audience members were coached to behave interested (nodding, smiling), neutral (no facial expressions), or uninterested (looking away, looking at phone). Audience members played different roles in each video. The actors in the video were researchers (undergraduate, post-bac, and graduate) in psychology at the University of Texas at Austin. The video was filmed with a Samsung Gear 360 camera, mounted on a tripod (Video 3).

There were only two videos filmed for each of the treatment days. Due to logistical constraints the same video was used for all six exposures on a given day. However, no participant observed that the same 360°-video was used multiple times.

Virtual Reality Headset and Eye Tracker. Participants wore the Oculus Rift DKII virtual reality headset with built-in position tracking. The Oculus was upgraded with an SMI eyetracker to provide high-resolution eye tracking at a sampling rate of 75 Hz. A HiBall motion-tracking system (3rdTech) was used to track head movements. However, because the video was filmed from a fixed viewpoint, only the rotations (and not the translations) were used to update the

image in the HMD. Participants completed a brief calibration procedure prior to beginning the speech. Videos of the eye tracking and the video-display (i.e., what the participants saw) were recorded at each video-frame and saved as a .MOV file. These .MOV files were used to later verify the automated eye-gaze analyses.

Gaze Processing

Eye movement data were collected pre-treatment, at each exposure trial, at the posttreatment assessment and at the 1-week follow-up assessment. The methods used for processing gaze data were the same as those previously used (Rubin et al., 2020). Vizard 4 (WorldViz) was used to display the 360°-video and collect the eye tracking data. OpenPose (Cao et al., 2021) was used to detect audience members within the 360°-video and dynamic regions of interest (ROIs) that encompassed each audience member were generated using custom MATLAB code (because the audience members moved, the ROIs could not be static). ROIs encompassed the face, hand, and torsos of each audience member with a small ($\sim 3^\circ$ to $\sim 6^\circ$) buffer to encompass fixations very close to audience members. Each fixation was assigned an ROI (i.e., audience member) based on the closest OpenPose keypoint – however, if the fixation was not on an ROI it was assigned as a background fixation. Fixations were detected using a well-established in-house algorithm (Kit et al., 2014; Li et al., 2016; Tong et al., 2017). A fixation was identified if the eye was relatively stable (less than $50^\circ/\text{s}$ and longer than 85 milliseconds). Fixations that were close together (within 1° and less than 80ms apart) were combined. If there was missing gaze data (i.e., track loss) a single fixation on an ROI was still counted as long as the fixations were close together (as above).

Data Analysis Plan

The primary aims of this study were to 1) examine whether an attention guidance augmentation enhanced VRET compared to VRET alone and 2) test whether changes in gaze behavior following the intervention mediated the effects VRET. To test our primary hypotheses regarding the influence of the intervention on fear of public speaking (PRPSA), we conducted Bayesian multilevel models using the *brms* package version 2.15 (Bürkner, 2018). For aim 1 we examined the interaction between assessment and group predicting the outcome post-treatment and at 1-week-followup. For aim 2, we examined the indirect (i.e., mediating) effect of proportion of fixations to uninterested (socially threatening audience members) at the post-treatment assessment, on the relationship between intervention group and the post-treatment assessment of PRPSA at the 1-week-followup (see Figure 3). To facilitate interpretation of the mediation analysis, we partially standardized the model coefficients after completing the analyses using unstandardized variables following recommendations in the literature regarding indirect effect sizes when X is dichotomous (Hayes & Rockwood, 2017; Preacher & Kelley, 2011). In all models, we included average proportion of fixations to audience members during intervention sessions as a covariate to control for variation in treatment adherence. We completed the same analyses to evaluate our secondary outcome of general social anxiety symptoms measured with the LSAS. As integrity checks on the efficacy of the attention augmentation condition we tested whether there were group differences for average number of fixations on audience members during the intervention trials, as well as whether there were differences in proportion of fixations to uninterested audience members post-intervention and at 1-week follow-up.

We computed Bayes Factors (BFs) using the Savage-Dickey Density ratio (Wagenmakers et al., 2010) for all models where we set priors using the *hypothesis* function in *brms*. The

Savage-Dickey Density ratio was calculated in the current context by dividing the posterior density by the prior density at zero (a null effect). Given that priors exert a large influence on the posterior estimates with small samples sizes, we used BFs to provide a sense of the influence of the priors on the study data rather than using them to provide a measure of confidence in the posterior estimates themselves as they are sometimes used (in *brms* if the *hypothesis* function is directional, it provides the latter estimate rather than the Savage-Dickey Density ratio). A BF equal to one means there is equal support for the null and alternative hypotheses while smaller BFs reflect greater support for the null and larger BFs reflect greater support for the alternative, with commonly accepted guidelines for the magnitude of the support (e.g., 1-3 is anecdotal evidence in favor of the alternative; 1/3-1 is anecdotal evidence in favor of the null).

For each result we report the beta estimates, 95% highest posterior density interval (HDI), and BFs of the model estimated with our original prior. We also provide the range of BFs as well as the sensitivity of the beta estimates based on our sensitivity analyses (see below).

Prior Estimates. We set informative priors based on expected effects that were based on a literature review of brief exposure-based intervention for social anxiety, as well as based on expert review. On a theoretical level, use of priors aligns with the idea that all available data should be used to draw inferences – including data from previous findings (Kruschke & Liddell, 2018). On a more practical level, there is substantial evidence to support to the use of informative priors to address the ‘winner’s curse’ – which is where significant effects in an initial study are not subsequently replicated (Altoè et al., 2020). Moreover, Lemoine (2019) conducted simulation analyses showing that weakly informative priors can regularize results in small samples ($n < 50$), providing a more conservative estimate.

We largely followed the WAMBS (When to worry and how to Avoid the Misuse of Bayesian Statistics) checklist (Depaoli & van de Schoot, 2017). This checklist provides a step-by-step approach to ensuring that a model estimation procedure is acceptable and that the influence of the priors is well delineated. We tested the sensitivity of the priors by using less informative (smaller effects) parameter estimates as well as uninformative default (flat) priors centered on zero to determine the influence of different priors on the posterior estimates.

Priors for the effect of the intervention on fear of public speaking (PRPSA) were primarily based on a relatively recent study which also used a two-session public speaking exposure model (testing affect labeling as a potential mechanism; Niles et al., 2015). In terms of the efficacy of the augmentation for which there is no previous research, we used a prior that reflected a moderate effect ($\Delta 10$ on PRPSA score). It was impossible to predict whether there would be a greater gain at post-treatment followed by a ‘rebound’ (i.e., regression towards the mean) or whether the gains would continue and we tested the sensitivity of our priors by varying the magnitude of the effects as well as their direction (to a certain degree). We also tested a model with uninformative priors, centered on zero. Similarly, for the LSAS we used previous research to determine the priors. One challenge was that most studies addressing fear of public speaking did not have a clinical sample of socially anxious individuals – we predicted greater severity of social anxiety symptoms in the current study – and so drew from other studies as well (Lazarov et al., 2018). We primarily based our estimates of the efficacy of the intervention using a recently published single-session feasibility VRET study (Lindner et al., 2021). The estimate of the effect of the intervention provided a good starting place to inform our priors – based on the likelihood that 2 sessions would be more potent, we also used estimates from other longer intervention studies.

Priors on the effects of the intervention on proportions of fixations to audience members were not based on previously collected data because there is no literature that clearly delineates expected changes in gaze during public speaking challenges. We chose priors that reflected modest but meaningful effects, indicating changes in gaze behavior substantial enough to have potential implications for treatment outcomes as a causal mechanism. As with the other analyses, we tested several priors reflecting smaller effects as well as an uninformative prior centered on zero.

Power analysis. We did not conduct a power analysis that reflected the sample size for the current pilot study. We had initially conducted a power analysis through a simulation study prior to COVID-19, which indicated a sample size of 60 would be sufficient to detect a meaningful effect for both aims 1 and 2. However, due to COVID-19 enrollment ended before we could meet our recruitment goals. Given that research was necessarily stopped, we decided to rely on the strengths of the Bayesian approach highlighted above to investigate whether it would be worthwhile to conduct a more extensive RCT with a larger sample.

Data and syntax are available at <https://osf.io/un92m/>.

Results

Intervention Integrity Checks

Table 2 summarizes the mean proportion of fixation to Uninterested, Interested, and Neutral audience members by group across time points. We primarily evaluated the role of proportion of fixations to uninterested (socially threatening) audience members, but also explored proportion of fixations to interested and neutral audience members. There were meaningful differences in the proportion of gaze allocated to audience members during treatment in the standard-exposure compared to attention-guidance conditions $b = 0.27$, 95% highest

posterior density interval (HDI) [0.11, 0.41], Bayes Factor (BF) = 70.14, with greater gaze allocated to audience members in the attention-guidance condition during the intervention trials. There were no meaningful differences in the overall change in proportion of fixations to uninterested (socially threatening) audience members at post-treatment $b = 0.14$, 95% HDI [-0.16, 0.44], BF = 1.02 or at one-week follow-up $b = 0.23$, 95% HDI [-0.08, 0.53], BF = 2.00. Bias was large for the effect of time at post-treatment and follow-up, but BFs were similar ($\text{range}_{\text{bias}}$: 31-610%; range_{BF} : 0.93-0.94) and follow-up ($\text{range}_{\text{bias}}$: 19 – 324%; range_{BF} : 1.11-1.59). There was also no main effect of group $b = 0.09$, 95% HDI [-0.30, 0.48], BF = 1.02. Sensitivity analyses indicated a large degree of bias, but similar range of BFs ($\text{range}_{\text{bias}}$: 97-12,000%, range_{BF} : 0.99-1.00). Evidence suggests that no conclusion can be reached for the main effect of group on proportion of fixations to uninterested audience members.

There was a meaningful group (VRET vs. VRET + attention guidance) x assessment interaction at post-treatment $b = 0.16$, 95% HDI [0.07, 0.26], BF = 2.52, and at one-week follow-up $b = 0.30$, 95% HDI [0.20, 0.39], BF = 0.91. There was a large degree of bias, although BF's remained similar at post-treatment ($\text{range}_{\text{bias}}$: 84-991%, range_{BF} : 1.10-1.59) and at one-week follow-up ($\text{range}_{\text{bias}}$: 97-6,000%, range_{BF} : 1.00-1.14). Evidence suggests that the attention guidance augmentation may have led to a greater proportion of fixations to uninterested audience members at post-treatment, but that that difference may have been attenuated by the follow-up.

Multivariate exploratory analysis suggested that there was also a meaningful difference at post-treatment for Neutral audience members $b = 0.17$, 95% HDI [0.07, 0.27], BF = 3.39, where the attention guidance augmentation also led to greater proportion of fixations to the Neutral audience member at post-treatment, although this was also attenuated by follow-up $b = 0.30$, 95% HDI [0.20, 0.40], BF = 0.63.

Effects of Virtual Reality Exposure Therapy

Means and standard deviations for the primary and secondary outcomes are presented in Table 3, below. Figure 4 illustrates the primary findings for the intervention outcomes across assessments, relating to aim 1. There was a main effect of time on fear of public speaking, with a meaningful reduction in fear of public speaking post-treatment $b = -17.37$, 95% highest posterior density interval (HDI) $[-21.64, -9.63]$, Bayes Factor (BF) = 510.80 and at 1-week follow-up $b = -13.16$, 95% HDI $[-21.28, -9.01]$, BF = 26.14. The sensitivity analyses indicated a very small degree of bias based on the priors and BFs were similar in magnitude for post-treatment ($\text{range}_{\text{bias}}: 0.49\text{--}2.12\%$; $\text{range}_{\text{BF}}: 313.04\text{--}556.61$) and the one-week follow-up ($\text{range}_{\text{bias}}: 2.18\text{--}2.67\%$; $\text{range}_{\text{BF}}: 29.88\text{--}37.83$). Evidence across priors supported the presence of an effect, with somewhat stronger evidence in favor of an effect at post-treatment than at one-week follow-up.

We found weak evidence against a main effect of group (standard exposure vs. attention augmentation) on fear of public speaking $b = -5.55$, 95% HDI $[-13.88, 2.53]$, BF = 0.28. Despite extreme bias of the beta estimate ($\text{range}: 141\text{--}416\%$), BFs were only anecdotally in favor of the null for the weaker priors ($\text{range}: 0.34\text{--}0.59$). Moreover, we did not find an effect of group at post-treatment $b = 6.14$, 95% HDI $[-1.57, 13.95]$, BF = 0.38, with sensitivity analysis indicating extremely strong bias for the beta estimates ($46\text{--}372\%$) and BFs anecdotally in favor of the null (BF range: 0.34–0.59) or at one-week follow-up $b = 3.19$, 95% HDI $[-10.16, 16.57]$, BF = 0.37. Sensitivity analyses indicated *extremely* biased estimates of the posterior distribution ($\text{range}: 70\text{--}1,149\%$) with BFs anecdotally in favor of the null ($\text{range}: 0.51\text{--}0.79\%$). With substantial bias of the estimate based on the priors and consistent anecdotal evidence for the null, there was weak

evidence in support of the null – that the intervention augmentation had no effect on fear of public speaking over and above standard exposure.

We found a main effect of time for general symptoms of social anxiety at post-intervention $b = -11.72$, 95% HDI $[-18.61, -4.58]$, Bayes Factor (BF) = 6.45 and at 1-week follow-up $b = -21.99$, 95% HDI $[-29.08, -14.70]$, BF = 615.78. The sensitivity analyses indicated a very small degree of bias in the beta estimates post-treatment (range: -1.57-0.60%), and BFs remained in favor of the alternative (range: 3.55-13.32). Similarly for the follow-up there was little bias (range: -1.18-0.38%), BFs were strongly in favor of the alternative (range: 224.44 – 372.91).

We did not find a main effect of group on general social anxiety symptoms $b = -4.86$, 95% HDI $[-17.08, 11.48]$, BF = 0.84 and both the model BF as well as the alternative prior BFs were all anecdotally in favor of the null (range: 0.68-0.99). There was also large bias for the beta estimate (range: 30-277%). Similarly, we found no effect of group at post-treatment $b = -2.05$, 95% HDI $[-13.48, 18.18]$, BF = 0.24 and one-week follow-up $b = -3.20$, 95% HDI $[-15.27, 22.15]$, BF = 0.44 and evidence from those model BFs were in favor of the null. There was also substantial bias post-treatment (range: 38-608%) and for one-week follow-up (range: 69-281%) and the BFs also anecdotally favored the null post-treatment (range: 0.61-0.74) and at one-week follow-up (range: 0.53-0.83).

Mediating Effects of Gaze Behavior on Intervention Outcomes

We found anecdotal evidence (based on the BFs) that greater proportion of fixations to Uninterested audience members at the post-treatment assessment, did not mediate the effect of group (standard exposure vs. attention guidance augmentation) on fear of public speaking at the one-week follow-up (partially standardized indirect effect = -0.218, 95% HDI $[-0.605, 0.026]$,

BF = 2.85. Despite extreme bias of the estimates, there was anecdotal support for the presence of an indirect effect ($\text{range}_{\text{bias}}$: 131-3,300%; range_{BF} : 1.10-1.57). However, we found weak evidence for the mediation effect on general symptoms of social anxiety (partially standardized indirect effect = -0.097, 95% HDI [-0.197, -0.024], BF = 1.58. Despite extreme bias of the estimates, there was anecdotal support for the presence of an indirect effect ($\text{range}_{\text{bias}}$: 32-870%; range_{BF} : 1.12-1.48). Taken together our results suggest that there is weak evidence supporting the role of attention change on symptoms of fear of public speaking and general social anxiety, but further research is needed with larger samples. In Figure 5 below, we highlighted the influence of priors on our estimation of the indirect effect.

Discussion

This pilot study tested attentional avoidance as a potential change mechanism for social anxiety *during* 12 repeated public speaking exposure trials across two sessions. Our first aim was to examine whether an attention guidance augmentation would enhance the efficacy of a virtual reality exposure intervention for social anxiety disorder. There was a large reduction in fear of public speaking and general symptoms of social anxiety across groups. There was anecdotal (based on the BFs) evidence in favor of the null (that there was no difference between the two intervention groups). Given the small sample size in this pilot study, the bias of the estimates based on the priors and the consistently weak support for the null across priors, further research with larger samples may be warranted. However, preliminary evidence does not support the presence of an effect of the attention guidance augmentation on fear of public speaking or general symptoms of social anxiety.

Our second aim was to test whether the influence of intervention group on fear of public speaking and general social anxiety symptoms was mediated by changes in gaze behavior

following the intervention. There was strong evidence that our intervention engaged the target mechanism - the exposure augmentation led to a meaningful change in attention allocation, with a substantially greater proportion of gaze toward uninterested (socially threatening) audience members compared to the standard exposure group following the intervention. However, evidence regarding decreased avoidance as a potential mechanism maintaining social anxiety was slight. It is important to acknowledge that the sample size of the current study may have limited the possibility of detecting this indirect effect. In particular, if the effect of reducing gaze avoidance on symptoms of social anxiety is smaller than anticipated, then conducting a study with a larger sample is especially important.

There are other considerations beyond sample size that may have influenced the effect of the attention augmentation. We conducted a brief 2-session protocol, because the reduced efficacy compared with a full-length (e.g., 8-week) protocol makes it more feasible to test the influence of potential mechanisms (see for instance Niles et al., 2015). Given that the two-session VRET intervention was highly effective, it is possible that the influence of the intervention augmentation was masked. Longer follow-ups may have been useful in determining whether the augmentation provided additional benefits in social anxiety symptom reduction. It is also possible that the intervention and assessment periods were too few and/or too close together to detect the effect of changes in gaze behavior on social anxiety symptoms. Since gaze and attention are tightly linked to learning, it is possible that individuals with social anxiety who typically avoid social information needed more time to adjust their priors about appraisals of social information before symptom change could emerge. With only a one-week follow-up, there may not have been sufficient opportunities to acquire evidence in the real-world that greater gaze towards others in social situations is acceptable. Also, although the way we measured and

targeted attention was straightforward and based on previous work (Kim et al., 2018; Rubin et al., 2020), attention is a dynamic and complex process, and it is possible that alternative ways to evaluate gaze behavior may yield further insights as to their role in social anxiety treatment. Finally, we screened participants based on their self-reported fear following the pre-treatment public speaking challenge. This was to ensure responsivity to the 360°-video stimuli during VRET. However, this may also have facilitated some of the treatment efficacy observed across groups as individuals that found the public speaking more challenging were more likely to benefit from the intervention. It may be worthwhile to consider including anyone meeting criteria for SAD (or even sub-clinical levels of social anxiety) in future research.

Our findings highlight the utility of a Bayesian approach as we were able to conduct a meaningful analysis despite a small sample size and interpret our ambiguous findings in a way that serves to inform future research. It can be useful to identify support for the null at early stages in testing potential treatment mechanisms (Else et al., 2020), since even with small samples strong support for the null can curtail avenues of research that are unlikely to yield meaningful results. That we found no strong support in either direction, can be taken as evidence that future research with larger sample sizes is warranted to clarify the role of attention as an augmentation strategy for VRET.

Taken together our findings offer further validation that VRET for social anxiety disorder is a highly effective treatment. Additionally, we showed that attentional processes can be directly altered *during* exposure therapy. Despite ambiguous findings regarding the causal influence of attentional change on social anxiety symptoms, this study represents a useful first step towards the integration of attention modification directly into therapy.

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Table 1. Participant Demographics

	Standard Exposure (n = 10)	Exposure Augmentation (n = 11)
	M (SD)	M (SD)
Age	19.20 (1.23)	25.90 (15.42)
PRPSA	139.40 (14.30)	140.27 (16.85)
LSAS	79.70 (25.64)	75.27 (22.32)
SATI	83.40 (18.19)	86.55 (17.04)
	N (%)	N (%)
Female	5 (50)	8 (73%)
Hispanic/Latinx	5 (50)	6 (55)
Race		
American Indian or Alaska Native	1 (10)	0
Asian	3 (30)	1 (9)
Black or African American	0	1 (9)
White	6 (60)	8 (73)
Current Tx	0 (0)	2 (18)

Note. One participant in the exposure augmentation group declined to provide demographic information. PRPSA = Personal Report of Public Speaking Apprehension; LSAS = Leibowitz Social Anxiety Scale; SATI = Speech anxiety Thoughts Inventory; Current Tx = currently receiving psychotherapy (excluding CBT for social anxiety disorder).

Table 2. Proportion of Fixations on Audience Member Types Across Assessments

		Standard Exposure		Exposure Augmentation	
Audience Members		M	SD	M	SD
Uninterested	Baseline	10.42	6.74	11.69	7.91
	Post-Treatment	6.69	6.53	22.42	9.59
	Follow-up	15.38	11.65	18.35	10.69
Neutral	Baseline	11.73	7.35	10.96	5.42
	Post-Treatment	14.49	6.80	26.74	11.44
	Follow-up	5.70	5.22	19.68	12.83
Interested	Baseline	8.31	5.70	8.40	6.07
	Post-Treatment	3.29	3.49	10.17	6.43
	Follow-up	12.23	8.39	20.89	9.69

Table 3. Symptoms of Social Anxiety Across Intervention Group and Assessment

		Standard Exposure		Exposure Augmentation	
Audience Members		M	SD	M	SD
PRPSA	Baseline	139.40	14.30	140.27	16.85
	Post-Treatment	119.63	19.54	123.50	21.21
	Follow-up	123.71	17.01	123.56	18.98
LSAS	Baseline	79.70	25.64	75.27	22.32
	Post-Treatment	65.88	27.27	64.8	21.29
	Follow-up	55.57	15.08	51.89	28.18
SATI	Baseline	83.40	18.19	86.55	17.04
	Post-Treatment	70.12	19.69	73.8	22.11
	Follow-up	60.43	18.30	64.22	20.45

Note. PRPSA = Personal Report of Public Speaking Apprehension; LSAS = Leibowitz Social Anxiety Scale; SATI = Speech Anxiety Thoughts Inventory

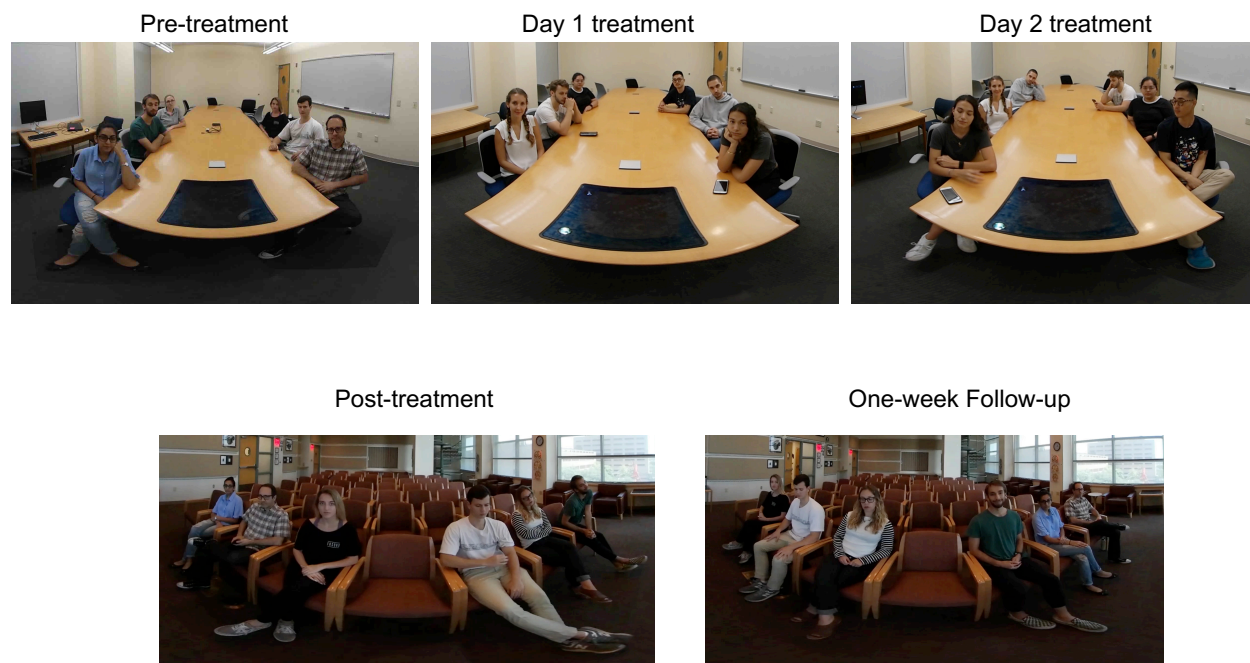


Figure 1. Stills of 360°-video stimuli used for each part of the study. All stills are cropped. Audience members in Pre-treatment, Post-treatment, and One-week Follow-up are the same; audience members in Day 1 and Day 2 are the same.

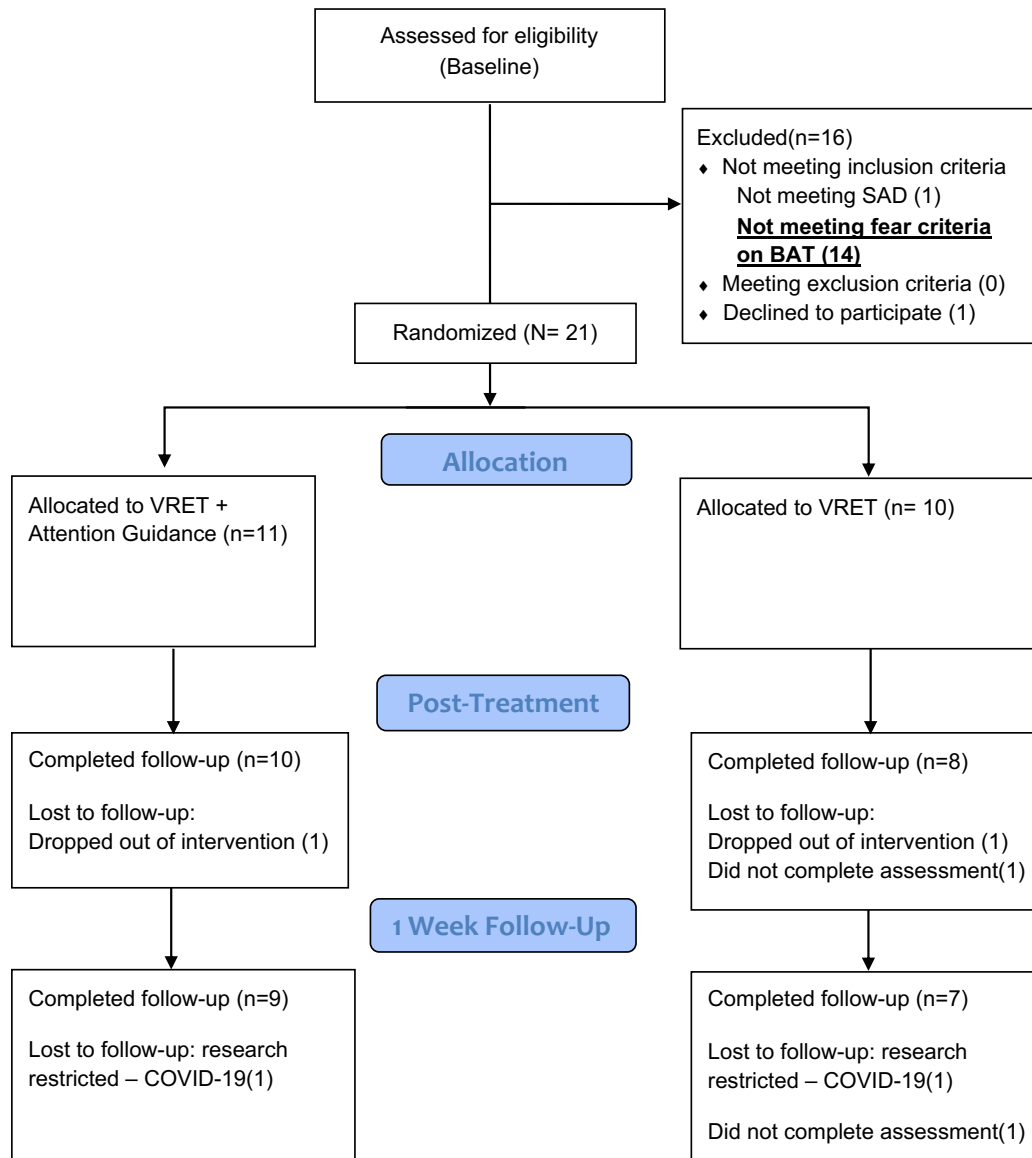


Figure 2. Flow diagram of participant enrollment.

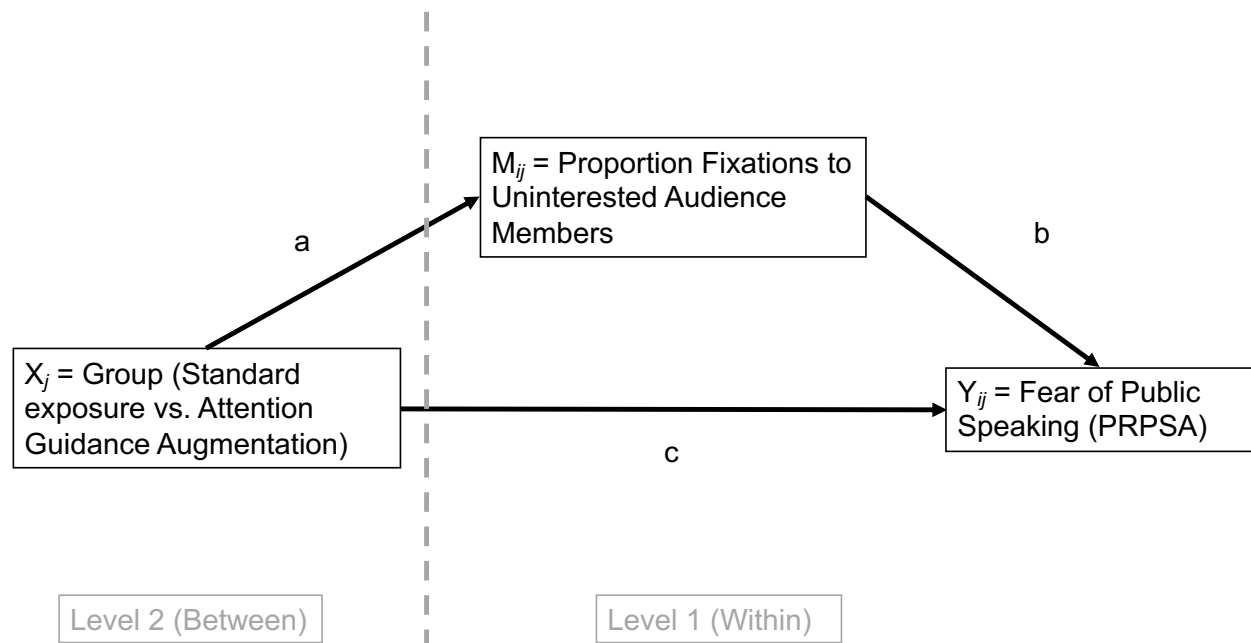


Figure 3. 2-1-1 Multi-level mediation model used in the current study to test our second hypothesis. Intervention group was a between group variable, while the mediator and dependent variables were estimated within each individual at each timepoint (baseline, posttreatment assessment and one-week follow-up assessment). The posterior estimates reported reflected proportion of fixations at post-treatment and the outcome variable at one-week follow-up.

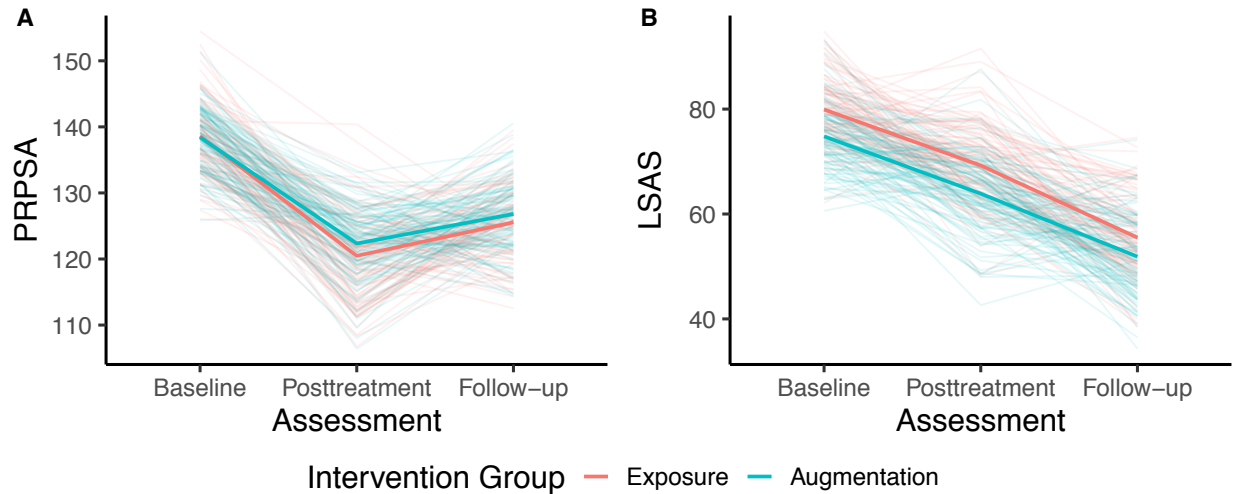


Figure 4. This figure depicts the effects of the intervention on (A) the primary outcome (fear of public speaking) and (B) the secondary outcome (general social anxiety symptoms). Solid lines reflect the median effect for each intervention group. We included 100 draws of the posterior distribution for each group, which are lightly shaded. There anecdotal evidence to support no differences (the null hypothesis) at posttreatment and follow-up.

Note. PRPSA = Personal Report of Public Speaking Apprehension; LSAS = Leibowitz Social Anxiety Scale.

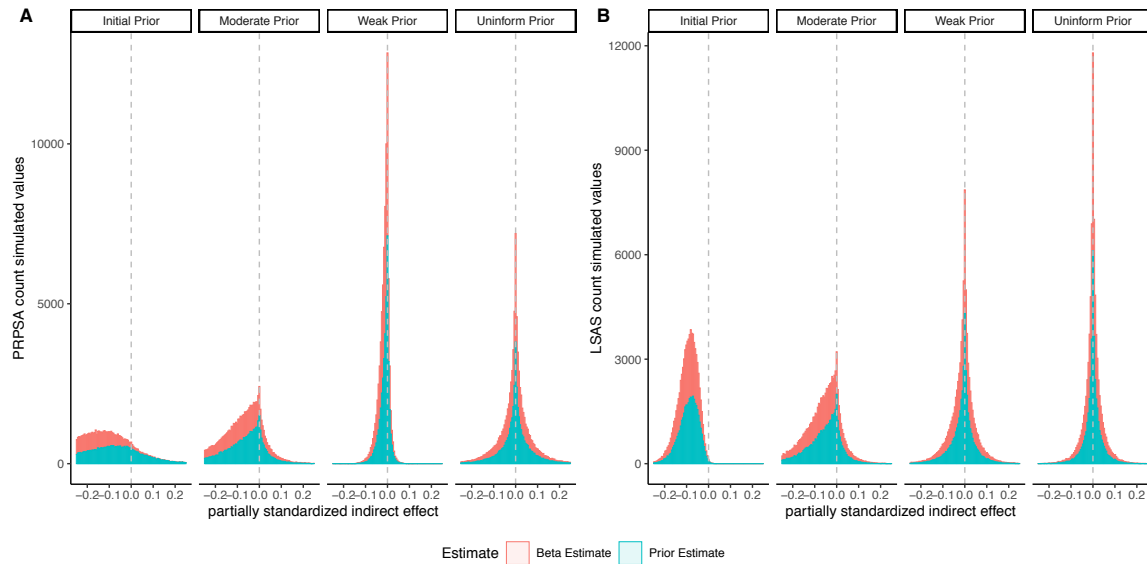


Figure 5. This figure depicts the distribution of the posterior draws for the indirect effect of the (A) primary and (B) secondary clinical outcomes. As is depicted in the above panels, our findings of the indirect effect were strongly biased by our priors. With the initial prior there is stronger support for a moderately sized indirect effect. The posterior estimates are clearly influenced by the priors – as the prior distribution approaches zero so does the posterior. Yet, the location of the posterior is consistently left of the prior, suggesting that there is likely to be an effect, although it is unclear what the magnitude of the effect is likely to be with a larger sample. *Note.* Grey dotted line reflects an indirect effect equal to zero.