Journal of Anxiety Disorders 82 (2021) 102442

Contents lists available at ScienceDirect

Journal of Anxiety Disorders

journal homepage: www.elsevier.com/locate/janxdis

Effectiveness of a smartphone-based, augmented reality exposure app to reduce fear of spiders in real-life: A randomized controlled trial

Anja Zimmer [a,e], Nan Wang [a,e], Merle K. Ibach [a,e], Bernhard Fehlmann [a,e], Nathalie S. Schicktanz [a,e], Dorothée Bentz [a,e], Tanja Michael [f], Andreas Papassotiropoulos [b,c,d,e], Dominique J.F. de Quervain [a,d,e,*]

[a] Division of Cognitive Neuroscience, Faculty of Psychology, University of Basel, CH, Switzerland
[b] Division of Molecular Neuroscience, Faculty of Psychology, University of Basel, CH, Switzerland
[c] Life Sciences Training Facility, Department Biozentrum, University of Basel, CH, Switzerland
[d] University Psychiatric Clinics Basel, CH, Switzerland
[e] Transfaculty Research Platform, University of Basel, CH, Switzerland
[f] Division of Clinical Psychology and Psychotherapy, Department of Psychology, Saarland University, D, Germany

ARTICLE INFO

Keywords:
Fear of spiders
Specific phobia
Smartphone-based AR exposure app
Stand-alone
Behavioural approach test

ABSTRACT

Although in vivo exposure therapy is highly effective in the treatment of specific phobias, only a minority of patients seeks therapy. Exposure to virtual objects has been shown to be better tolerated, equally efficacious, but the technology has not been made widely accessible yet.

We developed an augmented reality (AR) application (app) to reduce fear of spiders and performed a randomized controlled trial comparing the effects of our app (six 30-min sessions at home over a two-week period) with no intervention. Primary outcome was subjective fear, measured by a Subjective Units of Distress Scale (SUDS) in a Behavioural Approach Test (BAT) in a real-life spider situation at six weeks follow-up.

Between Oct 7, 2019, and Dec 6, 2019, 66 individuals were enrolled and randomized. The intervention led to significantly lower subjective fear in the BAT compared to the control group (intervention group, baseline: 7.12 [SD 2.03] follow-up: 5.03 [SD 2.19] vs. control group, baseline: 7.06 [SD 2.34], follow-up 6.24 [SD 2.21]; adjusted group difference -1.24, 95 % CI -2.17 to -0.31; Cohen's d = 0.57, p = 0.010).

The repeated use of the AR app reduces subjective fear in a real-life spider situation, providing a low-threshold and low-cost treatment for fear of spiders.

1. Introduction

Specific phobias are among the most common anxiety disorders, with an estimated lifetime prevalence ranging from 3% to 15 % (Eaton, Bienvenu, & Miloyan, 2018), with fears of animals such as spiders representing one of the most common form (Oosterink, De Jongh, & Hoogstraten, 2009). For those affected, exposure to spiders induces immediate emotional and physiological reactions such as intense fear, panic or disgust, and accelerated heart rate, often resulting in avoidance of the feared stimulus (American Psychiatric Association, 2013; Davey, 2011). These reactions can impede people doing a variety of daily-life activities, resulting in functional impairment for the sufferers, a negative impact on interpersonal interactions and quality of life in general (Bandelow & Michaelis, 2015). Many studies have demonstrated that exposure-based treatments are among the most effective treatments for specific phobias including fear of spiders. The current gold-standard is in vivo exposure therapy, during which therapists expose patients to the feared stimuli in real-life (Choy, Fyer, & Lipsitz, 2007; Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008).

However, many patients with specific phobias do not seek professional help, because they adapted their daily lives to their fear by trying to avoid any contact with the feared stimulus, e.g. a spider (Bandelow & Michaelis, 2015). Among the main reasons for the underuse of in vivo therapy ranks the fear of being exposed to a real phobic stimulus (Chambless & Ollendick, 2001). Further, there is a high drop-out rate of in vivo exposure treatment due to low acceptance (Choy et al., 2007). In vivo exposure therapy can be also challenging for psychotherapists. The intensity and level of perceived threat for the patient can never be fully

* Corresponding author at: Birmannsgasse 8, Basel, 4055, Switzerland.
E-mail address: dominique.dequervain@unibas.ch (D.J.F. de Quervain).

https://doi.org/10.1016/j.janxdis.2021.102442
Received 9 September 2020; Received in revised form 25 May 2021; Accepted 29 June 2021
Available online 2 July 2021
0887-6185/© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

controlled by the therapists, which might lead to concerns that exposure might be too stressful for their patients (Cook, Biyanova, Elhai, Schnurr, & Coyne, 2010; Öst, 1989). Additionally, for logistic reasons, in vivo exposure treatment can be challenging and time consuming. Consequently, there is a need for novel exposure-based treatment approaches that circumvent the raised limitations of conventional in vivo treatment.

The increasing success of using virtual reality (VR) in therapeutic settings has been documented in several studies. Virtual reality exposure therapy (VRET) has been demonstrated to be an effective and empirically validated alternative to in vivo exposure for several specific phobias (Carl, Stein, & Levihn-Coon, 2018; Wechsler, Kümpers, & Mühlberger, 2019). Furthermore, it has been reported that patients prefer exposure in VR over exposure in vivo (Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007). Despite its good efficacy including transfer to real-life situations (Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015) and high acceptability for both patients and therapists, exposure in VR is still quite restricted to laboratories and experimental studies (Botella, Fernández-Álvarez, Guillén, García-Palacios, & Baños, 2017), and only a minority of clinicians offers VR treatment (Segal, Bhatia, & Drapeau, 2011). Reasons might be the fear of potential technical difficulties, possible side effects of motion sickness, and the continuous monetary expenses for the latest equipment and software.

A variant of VR is augmented reality (AR), which augments the real world with virtual elements in real time (Azuma, 1997). In the treatment context, AR presents the same advantages as VR (e.g. control over the way the exposure is conducted, easier access to the threatening stimuli, no risk of real danger for the patient, a reduction in preparation time, exposure in the comfort of the therapy room or home), and its development only requires a few virtual elements to be designed, which reduces both costs and time of programming. Furthermore, a big advantage is that in AR the patient is able to see his or her own body while interacting with the virtual elements, which can enhance the patient's engagement in the treatment (Baus & Bouchard, 2014).

The use of AR in the treatment of mental disorders is still in its infancy. A few studies have shown that desktop computer-based AR can be successfully used to reduce fear in small animal phobia (cockroaches and spiders) (Botella et al., 2016; Chicchi Giglioli, Pallavicini, Pedroli, Serino, & Riva, 2015). In a preliminary comparison to VRET and in vivo exposure, treatment with exposure through AR has been shown to be equally efficacious to reduce fear in small animal phobia (Suso-Ribera, Fernández-Álvarez, & García-Palacios, 2019).

However, these treatments implementing AR were carried out under laboratory conditions and with continuous surveillance and guidance by an experimenter or clinician, limiting the translation into real-life practice. Additionally, these settings still needed markers in order to detect and specify the area in which the small animal should appear. A recent study showed the success of inducing fear of multiple animal species including spiders with a first markerless AR app (De Witte et al., 2020), paving the way to use mobile AR apps also for the treatment of specific phobias in exposure-based interventions.

In the present study, we developed a stand-alone, smartphone-based AR exposure app – *Phobys* – to reduce the fear of spiders. We also implemented game elements since it has been suggested that, with the appropriate design and use, digital games have the potential to be effective psychotherapeutic tools (Stetina, Felnhofer, Kothgassner, & Lehenbauer, 2012). The AR app was used as a home training with six 30-min sessions over a two-week period. This set-up allowed treatment under real-life and not laboratory conditions. We tested its effectiveness in a randomized controlled trial in subjects with clinical and subclinical fear of spiders. The main outcome measure, i.e. subjective fear in a Behavioural Approach Test (BAT) with a real spider, as well as the secondary outcome measures, such as the performance and subjective disgust in the BAT and the questionnaires to assess fear of spiders, were assessed at baseline and at six weeks follow-up.

2. Material and methods

2.1. Study design and participants

We performed a single-blind, parallel-group, randomized controlled trial to investigate real-life effectiveness of our stand-alone, smartphone-based gamified AR exposure app. We recruited physically healthy participants with fear of spiders from the German speaking general population of Switzerland by online advertisements. We included individuals with subclinical and clinical fear of spiders (DSM-5 (American Psychiatric Association, 2013)), aged 18–40 years. We excluded individuals if they currently received psycho- or pharmacotherapy, had ever been in treatment for fear of spiders or participated simultaneously in another study, showed signs of depression (Beck Depression Inventory II, BDI-II (Beck, Steer, Ball, & Ranieri, 1996) total score ≥ 20) or suicidal ideation (BDI-II item $9 > 0$), had a physical illness or chronic medication intake (except intake of oral contraceptives), were pregnant or had a BAT score over 8 at baseline. Participants were instructed to abstain from alcohol and medication intake for 12 h and from psychoactive substances (including benzodiazepines) for five days before days of testing.

The study protocol (including the definition of primary and secondary outcome measures and the statistical analysis plan) and all procedures were approved by the Ethics Committee of North-West and Central Switzerland (EKNZ) before the start of the study. All participants gave written informed consent for trial participation. Participants received a compensation of CHF 125.- for their participation. The study took place at the Division of Cognitive Neuroscience at the University of Basel, Switzerland. A clinical trial monitor oversaw data collection and entry according to a written monitoring plan approved by the EKNZ before trial conduction. This trial was registered at ClinicalTrials.gov with the identifier: NCT04162509.

2.2. Randomisation and masking

After study inclusion, participants were randomly (matched for the presence of a clinical diagnosis of fear of spiders and sex) allocated to the two groups (intervention group: gamified AR spider exposure app vs. control group: no intervention (all participants gained access to the app after trial participation)). We used two randomization lists for subjects with subclinical fear of spiders (male/female) and two for clinical fear of spiders (male/female). The groups were block-randomized within these randomization lists (in each block of six, three participants were randomly allocated to the intervention group and to the control group, respectively). The experimenter who collected the primary outcome measure in the real-life spider situation was unaware of the group assignment of the participants (single-blind).

2.3. Procedures

After a potential participant contacted the study team, more detailed information about the study was sent by email along with the main inclusion and exclusion criteria. Eligible participants were scheduled for the study. Before study enrolment, we checked all inclusion and exclusion criteria and collected basic demographic data. Fear of spiders was assessed by the section for specific phobia of the diagnostic interview for mental disorders of the DSM-5 (American Psychiatric Association, 2013). Depressive symptomatology and suicidal ideation were assessed by the Beck Depression Inventory (BDI-II (Beck et al., 1996), exclusion criteria BDI-II item $9 > 0$, BDI-II total score ≥ 20). Alcohol consumption and intake of prescribed or illicit drugs were inquired about. Participants filled out questionnaires to collect baseline measures for their fear of and beliefs about spiders (Fear of Spiders Questionnaire (FSQ) (Szymanski & O'Donohue, 1995), German version (Rinck et al., 2002), Spider Phobia Beliefs Questionnaire (SBQ) (Arntz, Lavy, Van den Berg, & Van Rijsoort, 1993), German version (Pössel & Hautzinger, 2003)) and general self-efficacy (General Self-Efficacy Scale (GSE) (Schwarzer

& Jerusalem, 1995), German version (Schwarzer & Jerusalem, 1999)). Finally, we conducted the baseline Behavioural Approach Test (BAT) in real-life that included the assessment of our primary outcome, the Subjective Units of Distress Scale (SUDS) of fear.

The BAT in vivo procedure was similar to the one used by Lass-Hennemann and Michael (2014). Participants were placed in front of a closed room and were asked to open the door and approach a living house spider measuring about 5 cm, which was placed in a sealed transparent plastic container on a table at the far end of the room. Participants were requested to approach the spider and interact with it as far as possible. In detail, the BAT comprised 13 steps: 0 = refuses to enter the test room, 1 = stops 5 m from the container, 2 = stops 4 m from the container, 3 = stops 3 m from the container, 4 = stops 2 m from the container, 5 = stops 1 m from the container, 6 = stops close to the windowsill with the container, 7 = touches the container, 8 = removes the lid, 9 = puts a hand in the container, 10 = touches the spider with one forefinger, 11 = holds the spider less than 20 s, and 12 = holds the spider for at least 20 s. Theses scores ranging from 0 to 12 were given when the BAT was completed (max. 3 min) or the participant indicated not be able to proceed any further during the BAT. To counteract a possible ceiling effect, we excluded participants who were already able to insert their hand into the box (step 9 of the 13 steps) during the baseline BAT.

Subsequently, participants of the intervention group received a short description of the mechanisms underlying exposure therapy and on how to use the AR app during their home training on the smartphones they were given. They further filled out a scale on credibility/expectancy for improvement (Borkovec & Nau, 1972). At the end of the first study day, all participants were assessed for adverse events and sent home if no safety concerns were present.

At follow-up six weeks later, we first asked about intake of alcohol or medications. Afterwards, we conducted the BAT, re-assessed the fear of spiders by the section for specific phobia of the diagnostic interview for mental disorders for DSM-5 (American Psychiatric Association, 2013) and participants again filled out the FSQ, SBQ and GSE and additionally one item each for self-reported reduction of fear and disgust in real-life. The intervention group additionally filled out a usability scale and a questionnaire concerning their feeling of immersion (Georgiou & Kyza, 2017).

2.4. Intervention

The AR app *Phobys* (Fig. 1) consists of eight levels with a pre-defined length of 2 min and a ninth level, which only lasts 30 s. Once the user opens the AR app, all the information on how to use it is given in written form. Task instructions (e.g. looking at the spider, approaching it, putting the hand underneath it) are given via small text pop-up windows. Each level starts with a surface scan of either a table, wall or the floor with a distance of approx. 1 m to the surface, followed by a tap on the display, which places the virtual spider in the scanned area and starts the timer of 2 min for level one to eight and 30 s for level nine, respectively.

The levels comprise different tasks of exposure and interaction with a realistic 3D AR spider model as follows: In level one, after the initial tap on the display to place the virtual spider, the user is instructed to stay at the distance of approx. 1 m to the table and watch the spider, which is not moving, from all sides. In level two, the user is instructed to move the smartphone closer to the spider until a sound indicates the distance to stop and watch the spider, which is not moving, from all sides. In level three, which is otherwise similar to level two, a certain distance (without sound) triggers the spider model to lift its front legs. In level four, the user is again instructed to approach the spider with the

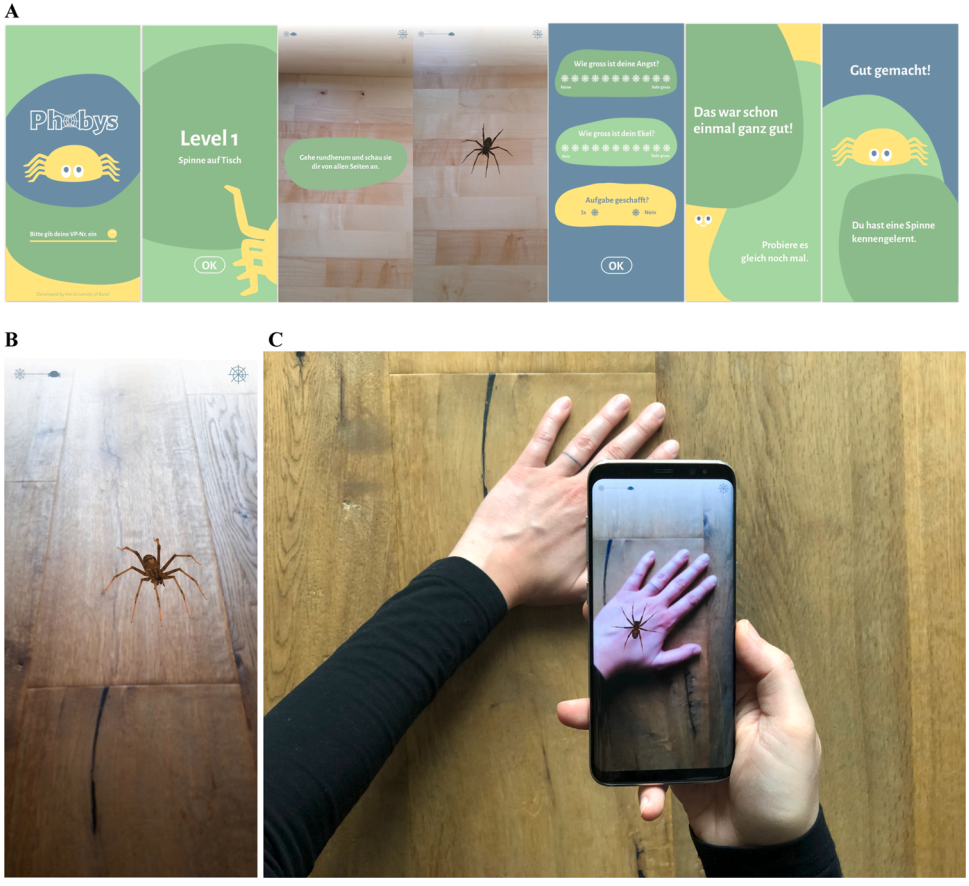

Fig. 1. Phobys. A) User interface, B) 3D AR spider model, and C) third person view of the app of level 5.

smartphone, whereby a certain distance (without sound) triggers the spider to walk away. Moving the smartphone back towards the user's body leads the spider to be walking towards the user, after which the task is repeated. In level five, the user is instructed to put the hand underneath the spider model. A net-icon should be tapped additionally to let the spider walk around in circles. In level six, the initial tap on the display places two spiders in the scene. Again, a net-icon should be tapped to allow the spiders to walk in circles and the user is asked to put the hand underneath them. For level seven, the smartphone is required to face a wall. Tapping on the display places ten spiders in the scene. The task is to collect the spiders by approaching them with the smartphone. Each spider disappears at a certain distance, accompanied by a sound effect. The spiders reappear after 10 s and should be continuously collected until the end of the level. For level eight, the smartphone is required to face the floor. Tapping on the display places many spiders in the scene with a path between them. The task is to follow the path and walk through the group of spiders, if possible several times. Level nine starts exactly as level one, with the smartphone facing the table and the placement of one spider in the scene through tapping on the display. However, this time a timer of only 30 s is started. The user is instructed to move the smartphone closer to the spider. A close distance triggers a kiss sound and hearts floating across the screen.

After each level a rating of fear and disgust on a continuous Subjective Units of Distress Scale (SUDS) from 0 to 10 is given as well as an indication, whether the tasks have been completed. From the first level the user proceeds to further levels according to a pre-defined exposure scheme. The users will repeat each level until their SUDS ratings of fear are 4 or below and have successfully completed the task.

The ratings are then followed by either a unique image (GIF) of an entertaining cartoon spider and rewarding sound effects if the level is completed (e.g. a spider clapping with a sound of cheering voices) or a standard screen informing the user that the current level will be repeated. This stepwise exposure is similar to the procedure developed by Öst for an in vivo intensive one-session exposure treatment for spider phobia (Chambless & Ollendick, 2001; Öst, 2012).

The AR app *Phobys* was developed at the University of Basel, Switzerland using Unity3D (version 2018.3.11f1 [64-bit] Unity Technologies, San Francisco, CA, USA) under MacOS Mojave (version 10.14.6) and compiled into a standard Android Package (.apk) file. The visual material of the user interface (UI) was created with Illustrator CC (version 2019), the GIF-files with a duration per frame of 0.1 s were animated in Photoshop CC (version 2019). The UI itself was designed in Sketch (version 56). The audio material (such as the sound effects) was produced using Ableton Live 10 Suite (version 10.0.1) under MacOS Mojave (version 10.14.6). The 3D spider model has been created by Computer Graphic (CG) designer, M. Gabriel Casamasso (artstation.com/gabrielcasamasso). Blender (version 2.79b) was used to create the spider geometry CG model. Inverse Kinematics (IK) was applied to the articulated spider body to enable the animations (walking, idle and attack animations were manually created in 1 s time slots that contain 30 movement frames). The Blender material was saved as texture and compiled into Filmbox (.fbx) files to make them usable in Unity3D. For the study, the AR app was installed on Samsung smartphones (Galaxy S8, Exynos 8895, 6.20″, 64 GB, resolution: 2960 × 1440 px, memory: 4 GB) running Android 8.0. With the installation of the app also ARCore (version 1.10) was installed to run the augmented reality elements, access to the camera was allowed and the volume for the sound effects was set. After that, no further setting changes or internet connection were necessary to use the app and all data was stored locally.

Participants in the current study were requested to train 6 × 30 min (always starting from the first level, irrespective of achieved level) over a two-weeks span on any chosen day with the single restriction to train only once a day. For each training, date, time and ratings were logged automatically and locally on the smartphones and assigned to the participant number.

2.5. Outcomes

The primary outcome measure, as defined in the protocol, was subjective fear (SUDS, range 0–10) in the BAT with a real-life spider. Our secondary outcomes were performance (range 0–12) as well as the subjective disgust (SUDS, range 0–10) in the BAT, the Fear of Spiders Questionnaire (FSQ Szymanski & O'Donohue, 1995, German version Rinck et al., 2002), the Spider Phobia Beliefs Questionnaire (SBQ Arntz et al., 1993, German version Pössel & Hautzinger, 2003), and one question to assess self-reported reduction of fear of spiders.

The FSQ is a self-report questionnaire and measures avoidance behaviour as well as fear of harm. It consists of 18 items on a 7-point scale (0 = not at all true to 6 = very true, α = 0.96 (Rinck et al., 2002), range 0–108) with higher scores indicating greater severity (Rinck et al., 2002; Szymanski & O'Donohue, 1995). The SBQ is a self-report questionnaire and specifically assesses spider-related catastrophic cognitions. It consists of 48 items (0 % = I do not believe that at all to 100 % = I am absolutely convinced, α = 0.98 (Pössel & Hautzinger, 2003)), separated into spider-related and self-related beliefs, with higher scores indicating greater severity (Arntz et al., 1993; Pössel & Hautzinger, 2003). In the *self-reported reduction of fear* item, participants were asked to self-rate their subjective reduction in fear of spiders in daily-life on a single scale in a range of 0 to 10 (0 = not at all and 10 = a lot).

Other outcomes of interest were *self-reported reduction of disgust* of spiders, the General Self-Efficacy Scale (GSE, German version (Schwarzer & Jerusalem, 1995, 1999)), a credibility/expectancy for improvement scale (Borkovec & Nau, 1972), a scale for usability of the app, and the Augmented Reality Immersion Questionnaire (ARI (Georgiou & Kyza, 2017)).

In the *self-reported reduction of disgust* item, participants were asked to self-rate their subjective reduction in disgust of spiders in daily-life on a single scale in a range of 0 to 10 (0 = not at all and 10 = a lot).

The GSE (Schwarzer & Jerusalem, 1995, 1999) consists of 10 items on a 4-point scale (1 = not at all to 4 = very much, α = 0.76 Schwarzer & Jerusalem, 1999), range 10–40) assessing the general self-efficacy within unknown, difficult situations.

The credibility/expectancy for improvement scale (Borkovec & Nau, 1972) consists of five items on the expectations for treatment improvement on an 11-point scale (0 = not at all to 10 = very much, α = 0.81 (Borkovec & Nau, 1972), range 0–50) and was translated into German and adapted to our app.

The scale for usability was specifically created for the purpose of this study and the app and consisted of eight items on a 11-point scale (0 = not at all to 10 = very much, range 0–80) regarding e.g. its functionality and design, and four open format questions for general feedback (see supplementary materials).

The ARI (Georgiou & Kyza, 2017) is a self-report questionnaire consisting of 21 items on a 7-point scale (0 = not at all to 6 = very much, α = 0.90 (Georgiou & Kyza, 2017), range 0–126) regarding the participants' immersive experience with the AR app, which we translated into German and adapted to our app.

2.6. Statistical analyses

We used linear models in combination with ANOVA (SS II). The analyses were done in R (version 3.6.2, GUI 1.70 (R Development Core Team, 2012)). Dependent variables were our pre-defined primary, secondary and other outcome measures, each investigated in a separate model. The independent variable was the between-subject factor group (intervention or control). As per protocol, the corresponding measures from the baseline were separately included as covariates to account for potential baseline differences. Further covariates were sex, age, and diagnosis (clinical/subclinical). In case of significant interactions of covariates with the factor group, post-hoc tests were applied to describe the interaction. In case of no significant interactions of covariates with

the factor group, the two-fold interactions were removed from the statistical models. Other outcomes of interest were each analysed in an explorative manner and only nominal p values are reported if applicable.

We present results as means (SDs) for the intervention and control group with associated two-sided p values, as well as adjusted group mean differences with 95 % CIs. $P < 0.05$ was considered significant for the primary outcome. For our five secondary outcomes, we set the significance threshold to $p < 0.01$ (Bonferroni correction for five independent tests). Outcomes of further interest were analysed in an explorative way (see appendix).

Usually the steps in the BAT are considered and analysed as a continuous variable (Botella et al., 2016; Lass-Hennemann & Michael, 2014). However, since the continuity of this test is arguable, we additionally performed a Kruskal Wallis test.

We estimated Cohen's *d* as effect size measurement. The estimate of *d* was based on the t value of the linear models. Therefore, *d* is corrected for the effects of all confounding variables included in the linear model. By convention, $d = 0.2$ is considered to be a small, $d = 0.5$ a medium and $d = 0.8$ a large effect (Cohen, 1992).

According to previous AR exposure studies to treat fear of small animals including spiders (Botella et al., 2016), we expected large effect sizes. Based on a power analysis using ANOVA with repeated measurements ($r = 0.5$) and between factors assuming to detect a large effect size ($f = 0.4$) with a power of 95 % and $\alpha = 0.05$ (software: G*Power 3.1) 32 participants in each of the 2 groups are needed resulting in 64 participants.

3. Results

Between October 7, 2019 and December 6, 2019, 71 individuals were screened for trial participation, of whom 5 were excluded after screening. Consequently, 66 individuals were enrolled, of whom 33 were randomly allocated to use the AR app (intervention group) and 33 were allocated to the control group. 66 participants (35 fulfilling DSM-5 criteria for spider phobia) completed the study as planned and were analysed (Fig. 2). Participants' baseline characteristics were balanced across groups (Table 1). Final data was collected on December 6, 2019. No dropouts or adverse events occurred.

Concurrent validity between baseline variables SUDS of fear in BAT, performance in BAT, SUDS disgust in BAT, FSQ, and SBQ were assessed using Spearman's rank correlation coefficient (r_s), which was found to be moderate with a range of $r_s \geq |0.34|$ and $r_s \leq |0.52|$ (all $p < 0.006$; all $n = 66$).

Test-retest reliability was determined by calculating intra-class correlation coefficients (ICCs) separately between Visit 1 and Visit 2 for all outcome measures (SUDS of fear in BAT, performance in BAT, SUDS of disgust in BAT, FSQ, SBQ) within the control group. ICC estimates were calculated using the psych-package (Revelle, 2021) in R based on single-rating, consistency, 2-way mixed models.

Because an exposure in a baseline measurement may affect the scores of the outcomes in a systematic way, we additionally calculated ICC estimated based on single-rating, consistency, 2-way random effect models. Here, we found a good degree of reliability between Visit 1 and Visit 2 SUDS of disgust in BAT (ICC = 0.75, $F(32,32) = 9.1$, $p < 0.0001$), moderate degree of reliability between Visit 1 and Visit 2 in BAT ratings (ICC = 0.72, $F(32,32) = 13.2$, $p < 0.0001$) and SBQ ratings (ICC = 0.51, $F(32,32) = 4.9$, $p < 0.0001$), and poor reliability between Visit 1 and Visit 2 SUDS of fear in BAT (ICC = 0.35, $F(32,32) = 3.2$, $p = 0.0008$), and FSQ (ICC = 0.28, $F(32,32) = 3.7$, $p = 0.0002$).

Uptake of the AR app: 28 (85 %) of 33 participants completed at least one session (30 min), 23 (70 %) at least 1 h, and 11 participants (33 %) at least 2 h of AR exposure. Five (15 %) had an exposure time under 30 min. The mean total time of app use was 91.12 min (SD 44.23).

Since all randomized participants completed the trial and no protocol violations were observed, the per protocol analysis was identical to an intention to treat (ITT) analysis. The analysis revealed that the repeated administration of the AR app led to significantly lower subjective fear in the BAT compared to the control group (intervention group, baseline: 7.12 [SD 2.03], follow-up: 5.03 [SD 2.19] vs. control group, baseline: 7.06 [SD 2.34], follow-up 6.24 [SD 2.21]; adjusted group difference -1.24, 95 % CI -2.17 to -0.31; Cohen's d = 0.57, p = 0.010). Further, the steps reached in the real-life BAT were significantly higher in the intervention group compared to the control group (intervention group, baseline: 5.27 [SD 2.32], follow-up: 6.76 [SD 2.40] vs. control group, baseline: 4.97 [SD 2.52], follow-up: 5.42 [SD 2.67]; adjusted group difference 1.05, 95 % CI 0.46 to 1.64; Cohen's d = 0.41, p = 0.00068). Similar results were found for the subjective ratings of disgust, the questionnaires and participants' perceived reduction of fear. There was a significant reduction in subjective disgust in the BAT of the

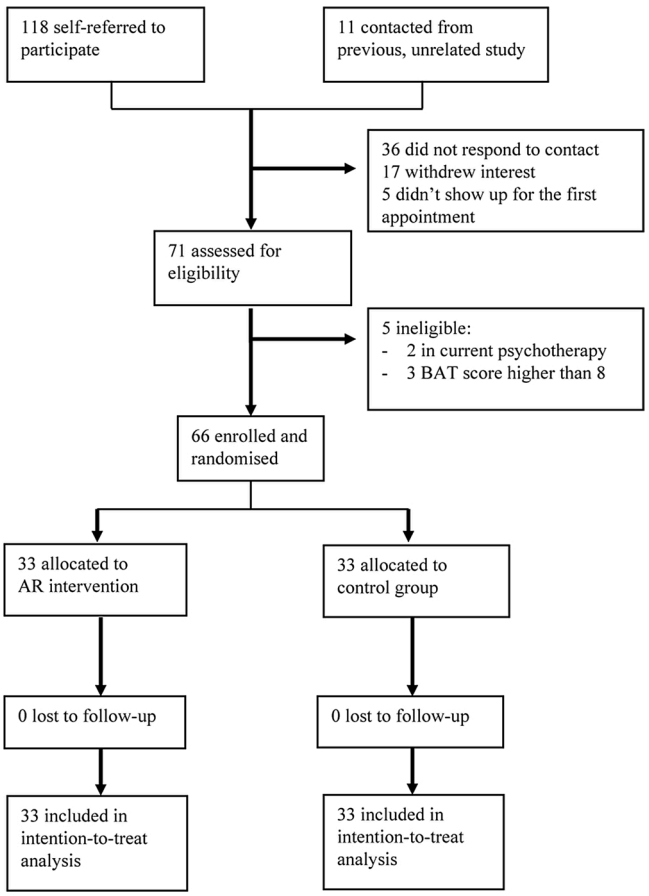

Fig. 2. Trial profile. BAT = Behavioural Approach Test.

Table 1
Baseline characteristics.

	Intervention (n = 33)	Control (n = 33)
Sex		
Male	7 (21 %)	7 (21 %)
Female	26 (79 %)	26 (79 %)
Age (years)	24 (18–39)	24.5 (18–39)
Ethnic origin		
Caucasian	28 (85 %)	29 (88 %)
Asian	3 (9%)	1 (3%)
Other	2 (6%)	3 (9%)
Diagnosis of arachnophobia	18	17
Education		
Highschool/vocational education	7 (21 %)	4 (12 %)
College/university	26 (79 %)	28 (85 %)
Other	0	1 (3%)

intervention group compared to the control group (intervention group, baseline: 7.18 [SD 2.80], follow-up: 6.09 [SD 2.60] vs. control group, baseline: 7.06 [SD 2.76], follow-up 7.03 [SD 2.50]; adjusted group difference -1.03, 95 % CI -1.80 to -0.26; Cohen's d = 0.41, p = 0.0098). The reductions of fear and disgust in in the BAT were significantly correlated in the intervention group ($r_s = 0.53$, $p < 0.0001$, spearman correlation of deltas) but not in the control group. A reduction of fear in the intervention group compared to the control group was further shown by corresponding questionnaires (FSQ: intervention group, baseline: 70.24 [SD 19.46], follow-up: 42.18 [SD 19.75] vs. control group, baseline: 68.15 [SD 17.73], follow-up 65.12 [SD 19.15]; adjusted group difference -24.42, 95 % CI -31.60 to -17.24; Cohen's d = 1.30, $p < 0.0001$; SBQ: intervention group, baseline: 54.53 [SD 20.33], follow-up: 38.81 [SD 19.59] vs. control group, baseline: 55.16 [SD 16.94], follow-up 54.99 [SD 17.98]; adjusted group difference -15.78, 95 % CI -22 to -9.55; Cohen's d = 0.85, $p < 0.0001$) and participants' subjectively perceived reduction of fear (intervention group: 3.76 [SD 2.51] vs. control group: 1.03 [SD 2.07], adjusted group difference 2.73, 95 % CI 1.60 to 3.85; Cohen's d = 1.20, $p < 0.0001$) (Table 2).

All intervention effects were independent of the presence of a DSM-5 diagnosis ($p \geq 0.5$ for interactions between diagnosis and intervention group) for the primary and secondary outcome measures. No significant interactions were found between the factor group and the covariates age and sex for the primary outcome ($p \geq 0.7$) and all secondary outcomes ($p \geq 0.2$, corrected for multiple comparison), except for the SBQ, where we found a significant interaction with sex ($p = 0.0070$). Post-hoc analyses indicated a reduction of the SBQ score of the intervention group compared to the control group for women (intervention group, baseline: 58.18 [SD 16.21], follow-up: 38.48 [SD 17.93] vs. control group, baseline: 55.34 [SD 14.61], follow-up 56.53 [SD 15.79]; adjusted group differences -20.20, 95 % CI -27.28 to -13.11; Cohen's d = 1.24; $p < 0.0001$), but not for men ($p = 0.48$).

The analyses additionally showed a significant effect of subjectively perceived reduction of disgust between the intervention and control group (intervention group, follow-up: 2.42 [SD 2.42] vs. control group, follow-up 0.52 [SD 1.37]; adjusted group difference 1.91, 95 % CI 0.93 to 2.90; Cohen's d = 0.98, p = 0.00025). Treatment did not affect general self-efficacy, GSE ($p = 0.83$).

We looked at the credibility/expectancy for improvement, the usability and the immersion in a descriptive manner, to gain feedback from the intervention group. Analyses show an average credibility/expectancy for improvement of 35.49 (SD 5.97, range 21–46). The overall acceptability of the AR app was very good, and its usability, design and functionality were rated as very appealing with an average value of 51 (SD 16.47, range 7–80). The participants showed an average immersion value of 76.85 (SD 19.07, range 17–90).

In the literature, the BAT is widely considered and analyzed as a continuous variable. In addition to the parametric tests, we also report results from a non-parametric Kruskal Wallis test with eta^2 as effect size showing that the previously reported effects of the treatment for the performance in BAT remained significant ($H(1) = 4.56$, $p = 0.033$, $eta^2 = 0.056$).

Table 2
Outcome measures at both timepoints and differences between groups. Data are mean (SD), unless otherwise indicated. SUDS = Subjective Units of Distress Scale. BAT = Behavioural Approach Test. FSQ = Fear of Spiders Questionnaire. SBQ = Spider Beliefs Questionnaire.

	Intervention (n = 33)	Control (n = 33)	Adjusted group difference (95 % CI)	Effect size (Cohen's d)	p value
Primary outcome					
SUDS of fear in BAT					
Baseline	7.12 (SD 2.03)	7.06 (SD 2.34)	..	..	..
Follow-Up	5.03 (SD 2.19)	6.24 (SD 2.21)	−1.24 (-2.17 to -0.31)	0.57	0.010
Secondary outcomes					
Performance in BAT					
Baseline	5.27 (SD 2.32)	4.97 (SD 2.52)	..	..	..
Follow-Up	6.76 (SD 2.40)	5.42 (SD 2.67)	1.05 (0.46 to 1.64)	0.41	0.00068
SUDS of disgust in BAT					
Baseline	7.18 (SD 2.80)	7.06 (SD 2.76)	..	..	..
Follow-Up	6.09 (SD 2.60)	7.03 (SD 2.50)	−1.03 (-1.80 to -0.26)	0.41	0.0098
FSQ					
Baseline	70.24 (SD 19.46)	68.15 (SD 17.73)	..	..	..
Follow-Up	42.18 (SD 19.75)	65.12 (SD 19.15)	−24.42 (-31.60 to -17.24)	1.30	<0.0001
SBQ					
Baseline	54.53 (SD 20.33)	55.16 (SD 16.94)	..	..	..
Follow-Up	38.81 (SD 19.59)	54.99 (SD 17.98)	−15.78 (-22 to -9.55)	0.85	<0.0001
Reduction of fear					
Baseline	..	..	..	..	..
Follow-Up	3.76 (SD 2.51)	1.03 (SD 2.07)	2.73 (1.60 to 3.85)	1.20	<0.0001

4. Discussion

We report that repeated home-use of the stand-alone, smartphone-based, gamified AR exposure app was effective in the reduction of phobic fear in participants with fear of spiders. Specifically, the app use led to reductions in fear, disgust and avoidance behaviour at medium effect sizes when tested in a real-life situation, and to reductions at large effect sizes in questionnaire-based fear measures.

Studies with in vivo exposure therapy or desktop-based AR exposure treatments typically report large effect sizes. The AR exposure treatments in those studies were carried out under laboratory conditions and continuous surveillance and guidance by an experimenter or clinician (Botella et al., 2016; Chicchi Giglioli et al., 2015; Suso-Ribera et al., 2019). In our study, participants carried out the treatment by themselves in their homes. This unsupervised form of treatment resulted in individual differences in the actual exposure time. The reasons for less exposure may have been compliance issues or technical challenges. The latter were mainly due to issues of a correct surface detection by the app. Despite these challenges and based on the participants' feedbacks in the usability questionnaire, the overall acceptability of the AR app was very good, and its usability, design and functionality were rated as very appealing by the participants. It is noteworthy that even with an average exposure time of approx. 90 min instead of the suggested 180 min, the fear of spiders was reduced at clinically relevant effect sizes, although we can of course not exclude that the placebo effect contributed to the observed effects. Importantly, we showed the benefits of our intervention in a real-life spider situation on subjective fear and disgust as well as on the objectively measurable behavioural level (BAT). Finally, we

found that treatment effects were independent of the presence of a DSM-5 diagnosis of specific phobia, indicating the app to be a beneficial intervention for both subclinical and clinical fear of spiders.

Our study has several limitations. First, it was framed as a smartphone-based intervention to treat fear of spiders. This might have led to a selection bias of participants willing to use modern technologies for treatment purposes, potentially reducing the generalizability of the findings. Second, we only included participants aged 18–40, reducing the generalization of the findings to the older generation. Third, from the current data we do not know whether treatment effects outlast the six weeks we assessed. Fourth, we only tested one intervention regime of 6 × 30 min over a two-week period. We do not know, if other treatment regimes would have led to other results. Fifth, please note that the test-retest reliability was lower for SUDS fear in BAT than for SUDS disgust in BAT and BAT performance. Sixth, as we did not conduct a full diagnostic interview, we cannot make any statement on the possible influences of other comorbid specific phobias. Last, we did not include a direct comparison to other evidence-based interventions.

Even though our understanding of the underlying mechanisms of exposure has evolved and therapy protocols are constantly being improved through strategies targeting the cognitive aspects of fear (i.e. inhibitory learning, violation of expectancy, dysfunctional beliefs, self-efficacy), there is still a number of individuals experiencing a return of fear (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014; Tardif, Therrien, & Bouchard, 2019). We see a great potential in our smartphone-based, stand-alone AR exposure app to act as a complementary tool for psychotherapy and especially as a re-booster or re-fresher of the learned associations and strategies to cope with fear of spiders in real-life.

Recent literature emphasized the role of disgust in small animal phobia, especially in spider phobia (next to blood-injury-injection type and obsessive-compulsive disorder, OCD). It has been discussed, that the emotion of disgust might be much more treatment resistant than fear in the context of exposure-based intervention and might even be increased (Knowles, Jessup, & Olatunji, 2018). Our results show a similar reduction of fear and disgust for the intervention group, but interestingly not for the control group, here we see a slight decrease in fear but almost none in disgust. This observation needs to be further addressed, as well as the potential of the here developed app to target and treat disgust of spiders.

5. Conclusion

Given the current underuse of conventional in vivo exposure therapy for specific phobias, there is definitely a need for alternative evidence-based approaches. Smartphone-based interventions implementing AR technology for exposure purposes have the potential to become a game changer for the current dissemination problem of in vivo treatments. Apps are highly accessible due to the widespread use of smartphones in the general population. Furthermore, digital marketplaces are already in place to enable the dissemination of apps to practitioners or, as self-help tools, directly to patients. Smartphone-based exposure has all the benefits mentioned for stationary AR and, in addition, it can be conducted both in the treatment rooms without cost-expensive gear and as a stand-alone add-on for homework in between sessions (blended treatment). Finally, the here presented beneficial effects of the gamified AR app are likely to encourage people to face their fears in a subtle and fun, yet effective way.

Contributions

AZ and DQ designed the exposure app and the trial, and drafted the paper. NW and MKI programmed and visually designed the app. AZ collected the data. DB contributed clinical advice. AP and TM commented on the design of the exposure app and trial. AZ, BF and NSS analysed the data. All authors commented on the paper.

Funding

The study was funded by the Swiss National Science Foundation (SNSF), from which Anja Zimmer received a Doc.CH grant for the course of four years during her PhD (P0BSP1_181761 / 1), and by the Trans-faculty Research Platform of theUniversity of Basel, Switzerland. The SNSF had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data availability

The data (de-identified) that support the findings of this study are available on request from the corresponding author [DQ].

Declaration of Competing Interest

DQ and AP are co-founders of GeneGuide AG, a spin-off company of the University of Basel. DQ and AP are acquiring a license from the University of Basel to use the developed technology for commercial purposes. Neither DQ nor AP have been involved in data acquisition or data analysis. All other authors declare no conflicts of interest.

Acknowledgements

We thank Amanda Aerni for monitoring the study, Fabian Müller for designing sound effects for the app, Milena Cavegn, Johanna Weibel, Jule Schröder, Daria Bühler, Nina Waldthaler, Johanna Otte, Galya Iseli and Irena Kovacic for helping in trial conduction.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.janxdis.2021.102442.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th edn.). Washington: American Psychiatric Association.

Arntz, A., Lavy, E., Van den Berg, G., & Van Rijsoort, S. (1993). Negative beliefs of spider phobics: A psychometric evaluation of the Spider Phobia Beliefs Questionnaire. *Advances in Behaviour Research and Therapy, 15*, 257–277. https://doi.org/10.1016/0146-6402(93)90012-Q

Azuma, R. T. (1997). A survey of augmented reality. *Presence, 6*(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

Bandelow, B., & Michaelis, S. (2015). Epidemiology of anxiety disorders in the 21st century. *Dialogues in Clinical Neuroscience, 17*(3), 327.

Baus, O., & Bouchard, S. (2014). Moving from virtual reality exposure-based therapy to augmented reality exposure-based therapy: A review. *Frontiers in Human Neuroscience, 8*, 112. https://doi.org/10.3389/fnhum.2014.00112

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. (1996). Comparison of Beck Depression Inventories–IA and –II in psychiatric outpatients. *Journal of Personality Assessment, 67*, 588–597.

Borkovec, T. D., & Nau, S. D. (1972). Credibility of analogue therapy rationales. *Journal of Behaviour Therapy and Experimental Psychiatry, 3*(4), 257–260. https://doi.org/10.1016/0005-7916(72)90045-6

Botella, C., Fernández-Álvarez, J., Guillén, V., García-Palacios, A., & Baños, R. (2017). Recent progress in virtual reality exposure therapy for phobias: A systematic review. *Current Psychiatry Reports, 19*, 42. https://doi.org/10.1007/s11920-017-0788-4

Botella, C., Pérez-Ara, MÁ, Breton-Lopez, J., Quero, S., Garcia-Palacios, A., & Baños, R. M. (2016). In vivo versus augmented reality exposure in the treatment of small animal phobia: A randomized controlled trial. *PloS One, 11*(2). https://doi.org/10.1371/journal.pone.0148237. e0148237.

Carl, E., Stein, A., Levihn-Coon, A., et al. (2018). Virtual reality exposure therapy for anxiety and related disorders: A meta-analysis of randomized controlled trials. *Journal of Anxiety Disorders, 61*, 27–36. https://doi.org/10.1016/j.janxdis.2018.08.003

Chambless, D., & Ollendick, T. H. (2001). Empirically supported psychological interventions: Controversies and evidence. *Annual Review of Psychology, 52*, 685–716.

Chicchi Giglioli, I. A., Pallavicini, F., Pedroli, E., Serino, S., & Riva, G. (2015). Augmented reality: A brand new challenge for the assessment and treatment of

psychological disorders. *Computational and Mathematical Methods in Medicine*. https://doi.org/10.1155/2015/862942

Choy, Y., Fyer, A. J., & Lipsitz, J. D. (2007). Treatment of specific phobia in adults. *Clinical Psychology Review, 27*, 266–286. https://doi.org/10.1016/j.cpr.2006.10.002

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159.

Cook, J., Biyanova, T., Elhai, J., Schnurr, P., & Coyne, J. (2010). What do psychotherapists really do in practice? An Internet study of over 2,000 practitioners. *Psychotherapy Theory Research Practice Training, 47*(260). https://doi.org/10.1037/a0019788

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy, 58*, 10–23.

Davey, G. (2011). Disgust: the disease-avoidance emotion and its dysfunctions. *Philosophical Transactions Biological Sciences, 366*(1583), 3453–3465. https://doi.org/10.1098/rstb.2011.0039

De Witte, N. A., Scheveneels, S., Sels, R., Debard, G., Hermans, D., & Van Daele, T. (2020). Augmenting exposure therapy: Mobile augmented reality for specific phobia. *Frontiers in Virtual Reality, 1*(8). https://doi.org/10.3389/frvir.2020.00008

Eaton, W. W., Bienvenu, O. J., & Miloyan, B. (2018). Specific phobias. *The Lancet Psychiatry, 5*(8), 678–686. https://doi.org/10.1016/S2215-0366(18)30169-X

Garcia-Palacios, A., Botella, C., Hoffman, H., & Fabregat, S. (2007). Comparing acceptance and refusal rates of virtual reality exposure vs. In vivo exposure by patients with specific phobias. *Cyberpsychology & Behavior, 10*(5), 722–724. https://doi.org/10.1089/cpb.2007.9962

Georgiou, Y., & Kyza, E. A. (2017). The development and validation of the ARI questionnaire: An instrument for measuring immersion in location-based augmented reality settings. *International Journal of Human-Computer Studies, 98*, 24–37. https://doi.org/10.1016/j.ijhcs.2016.09.014

Knowles, K. A., Jessup, S. C., & Olatunji, B. O. (2018). Disgust in anxiety and obsessive-compulsive disorders: Recent findings and future directions. *Current Psychiatry Reports, 20*(9), 1–10.

Lass-Hennemann, J., & Michael, T. (2014). Endogenous cortisol levels influence spider phobia. *Behaviour Research and Therapy, 60*, 39–45. https://doi.org/10.1016/j.brat.2014.06.009

Morina, N., Ijntema, H., Meyerbröker, K., & Emmelkamp, P. (2015). Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. *Behaviour Research and Therapy, 74*, 18–24. https://doi.org/10.1016/j.brat.2015.08.010

Oosterink, F., De Jongh, A., & Hoogstraten, J. (2009). Prevalence of dental fear and phobia relative to other fear and phobia subtypes. *European Journal of Oral Sciences, 117*(2), 135–143. https://doi.org/10.1111/j.1600-0722.2008.00602.x

Öst, L. (1989). One-session treatment for specific phobias. *Behaviour Research and Therapy, 27*, 1–7. https://doi.org/10.1016/0005-7967(89)90113-7

Öst, L. G. (2012). One-session treatment for specific phobias in adult and children (2012). In T. E. Davis, T. H. Ollendick, & L. G. Öst (Eds.), *Intensive one-session treatment of specific phobias* (pp. 58–95). New York: Springer.

Pössel, P., & Hautzinger, M. (2003). Dysfunktionale Überzeugungen bei Spinnenangst. Eine deutsche Version des "Spider Phobia Beliefs Questionnaire". *Zeitschrift für Klinische Psychologie und Psychotherapie, 32*, 24–30. https://doi.org/10.1026/0084-5345.32.1.24

R Development Core Team. (2012). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing.

Revelle, W. (2021). *Psych: Procedures for psychological, psychometric, and personality research*. R package version 2.1.3. Evanston, Illinois: Northwestern University https://CRAN.R-project.org/package=psych.

Rinck, M., Bundschuh, S., Engler, S., Müller, A., Wissmann, J., & Ellwart, T. (2002). Reliabilität und Validität dreier Instrumente zur Messung von Angst vor Spinnen. *Diagnostica, 48*, 141–149.

Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. Measures in health psychology: A user's portfolio. *Causal and control beliefs, 1*(1), 35–37.

Schwarzer, R., & Jerusalem, M. (1999). Skalen zur Erfassung von Lehrer-und schülermerkmalen. *Dokumentation der psychometrischen Verfahren im Rahmen der Wissenschaftlichen Begleitung des Modellversuchs Selbstwirksame Schulen. Berlin, 25*, 2014.

Segal, R., Bhatia, M., & Drapeau, M. (2011). Therapists' perception of benefits and costs of using virtual reality treatments. *Cyberpsychology, Behavior and Social Networking, 14*, 29–34. https://doi.org/10.1089/cyber.2009.0398

Stetina, B. U., Felnhofer, A., Kothgassner, O. D., & Lehenbauer, M. (2012). Games for health: Have fun with virtual reality! Virtual reality in psychological. *Medical and Pedagogical Applications*, 65–80. https://doi.org/10.5772/50677

Suso-Ribera, C., Fernández-Álvarez, J., García-Palacios, A., et al. (2019). Virtual reality, augmented reality, and in vivo exposure therapy: A preliminary comparison of treatment efficacy in small animal phobia. *Cyberpsychology, Behavior and Social Networking, 22*(1), 31–38. https://doi.org/10.1089/cyber.2017.0672

Szymanski, J., & O'Donohue, W. (1995). Fear of spiders questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry, 26*, 31–34. https://doi.org/10.1016/0005-7916(94)00072-T

Tardif, N., Therrien, C. E., & Bouchard, S. (2019). Re-examining psychological mechanisms underlying virtual reality-based exposure for spider phobia. *Cyberpsychology, Behavior and Social Networking, 22*(1), 39–45.

Wechsler, T. F., Kümpers, F., & Mühlberger, A. (2019). Inferiority or even superiority of virtual reality exposure therapy in phobias?—A systematic review and quantitative meta-analysis on randomized controlled trials specifically comparing the efficacy of virtual reality exposure to gold standard in vivo exposure in agoraphobia, specific phobia, and social phobia. *Frontiers in Psychology, 10*, 1758.

Wolitzky-Taylor, K., Horowitz, J., Powers, M., & Telch, M. (2008). Psychological approaches in the treatment of specific phobias: A meta-analysis. *Clinical Psychology Review, 28*, 1021–1037. https://doi.org/10.1016/j.cpr.2008.02.007