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Submitted to: Journal of Medical Internet Research
on: September 25, 2025

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Abstract

Background: The global gap between demand for and access to evidence-based psychological treatment is large and accelerating. Smartphone-based augmented reality may help reduce this gap by improving accessibility to exposure-based therapies and reducing cost.

Objective: This study evaluated the effectiveness and user engagement of a fully automated smartphone-based augmented reality treatment for spider phobia symptoms.

Methods: We conducted a single-blind randomized controlled trial to evaluate the effectiveness of a fully automated smartphone-based AR cognitive behavioural therapy (CBT) app for spider phobia. A total of 113 adults (ages 18-65) with spider phobia symptoms were randomized to either the 6-week AR-CBT intervention (n = 56) or a wait-list control group (n = 57). All participants completed assessments remotely at baseline, post-intervention (6 weeks), and 3- and 12-month follow-ups. The intervention guided users through graded AR-based exposure to spiders via their own smartphone without therapist involvement. The primary outcome was change in spider phobia symptoms, measured by the Fear of Spiders Questionnaire. Secondary outcomes included anxiety, depression, app engagement, and in-app fear/disgust ratings. Analyses followed the intention-to-treat principle and were preregistered.

Results: The intervention group showed significantly greater spider phobia reductions at post-test compared to controls (d = 1.25; 95% CI, 0.77–1.73; P < .001). Effects were maintained at 3-month- (d = 1.69) and 12-month follow-up (d = 1.64). Number needed to treat was 2.1. Longer session duration predicted greater improvement; practice session count did not. Overall dropout was 21%.

Conclusions: This study is the first to demonstrate that a fully automated mobile AR-CBT intervention, delivered in real-world settings without therapist involvement, can lead to strong and sustained reductions in spider phobia symptoms. By leveraging everyday smartphones and cutting-edge mobile AR technology, this intervention offers a low-threshold, widely accessible, scalable alternative for treating specific phobias. Clinical Trial: Prospectively Registered, Overview of Medical Research in the Netherlands, NL70238.029.19 (TrialNL9221) (<https://onderzoekmetmensen.nl/nl/trial/27993>).

(JMIR Preprints 25/09/2025:84727)

DOI: <https://doi.org/10.2196/preprints.84727>

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Original Manuscript

1. TITLE PAGE

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Word count: 3,643

2. ABSTRACT

Background: The global gap between demand for and access to evidence-based psychological treatment is large and accelerating. Smartphone-based augmented reality may help reduce this gap by improving accessibility to exposure-based therapies and reducing cost.

Objective: This study evaluated the effectiveness and user engagement of a fully automated smartphone-based augmented reality treatment for spider phobia symptoms.

Methods: We conducted a single-blind randomized controlled trial to evaluate the effectiveness of a fully automated smartphone-based AR cognitive behavioural therapy (CBT) app for spider phobia. A total of 113 adults (ages 18-65) with spider phobia symptoms were randomized to either the 6-week AR-CBT intervention ($n = 56$) or a wait-list control group ($n = 57$). All participants completed assessments remotely at baseline, post-intervention (6 weeks), and 3- and 12-month follow-ups. The intervention guided users through graded AR-based exposure to spiders via their own smartphone without therapist involvement. The primary outcome was change in spider phobia symptoms, measured by the Fear of Spiders Questionnaire. Secondary outcomes included anxiety, depression, app engagement, and in-app fear/disgust ratings. Analyses followed the intention-to-treat principle and were preregistered.

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Conclusions: This study is the first to demonstrate that a fully automated mobile AR-CBT intervention, delivered in real-world settings without therapist involvement, can lead to strong and sustained reductions in spider phobia symptoms. By leveraging everyday smartphones and cutting-edge mobile AR technology, this intervention offers a low-threshold, widely accessible, scalable

alternative for treating specific phobias.

Trial Registration: Prospectively Registered, Overview of Medical Research in the Netherlands, NL70238.029.19 (TrialNL9221) (<https://onderzoekmetmensen.nl/nl/trial/27993>).

Key words: Spider Phobia; Augmented Reality; Automated; Smartphone Application, Usage Data



3. TEXT

INTRODUCTION

The global need for mental healthcare is costly and growing [1]. In the U.S., one in five adults experiences mental illness each year, costing \$282 billion annually (1.7% of GDP) [2]. In Europe, over 84 million people are affected by mental disorders, with annual costs exceeding €600 billion [2–4]. In spite of these costs, between 35% and 85% of people with mental illness do not receive treatment [5]. Despite these already high numbers, the gap between demand for and availability of evidence-based treatment is increasing due to increasing prevalence and workforce shortages. This suggests an imminent need for scalable solutions at reduced costs. Digital technologies are increasingly perceived as essential to address the gap [6-8]. However, despite the proliferation of mental health apps, fewer than 5% are evidence-based [9,10]. Here, we test a fully automated, scalable, low-cost smartphone-based treatment for one of the most prevalent mental disorders worldwide, specific phobias.

Specific phobias, defined by excessive fears of particular objects or situations, affecting 7.2%–12.5% of individuals over their lifetime [11,12]. Spider phobia is one of the most common specific phobias [11,12]. While exposure therapy (ET) is the gold-standard treatment for phobias [13], traditional in vivo ET faces barriers such as cost, limited availability, and low user acceptance [14]. Augmented reality exposure therapy (ARET), which overlays virtual objects onto the real world, enabling users to confront feared objects in everyday environments, has shown efficacy for small animal phobias [15-19]. Prior interventions involve therapist support and expensive hardware, which hinder scalability [20]. However, advances in mobile technology now allow ARET to be delivered via regular smartphones, which are widely accessible —smartphone penetration exceeds 85% in both the European Union and the United States [21,22]. Initial research on smartphone-based ARET for spider phobia shows promise [23-26], but are therapist-guided or did not assess long-term

outcomes.

This study extends prior work demonstrating that low-cost, automated VR-CBT can produce durable effects for phobias [20, 26-29], while highlighting a key challenge in automated exposure: user engagement. Without therapist support, engagement is critical for adherence and outcomes. In automated VR studies for specific phobia, outcomes correlated more with time spent per session than with session count [30, 31]. Building on this work, we aimed to evaluate whether these findings generalize to a different modality—augmented reality— by testing a fully automated AR-CBT app for spider phobia used independently by participants in their own environment and in their own time, with 3 and 12 months follow-ups. We also examined how engagement, usability, and presence related to treatment outcomes. We hypothesized that participants using the app would show greater reductions in spider phobia symptoms, general anxiety, and depressive symptoms from pre- to post-treatment compared to a waitlist control group, with sustained effects at 3- and 12-month follow-ups. Additionally, we hypothesized that the app would be rated user-friendly and satisfactory, and that greater perceived realism, usability, and user intensity would predict larger reductions in spider phobia symptoms at post-test. We also predicted that longer practice time, but not number of sessions, resulted in lower spider phobia symptom post-test scores, and that higher realism scores were correlated with stronger decreases in spider anxiety ratings directly after AR exposure. Furthermore, higher spider phobia symptoms at pre-test were hypothesized to correlate positively with AR anxiety and disgust ratings, and negatively with a reduction in spider phobia symptoms at post-test, but not with AR practice time. Lastly, we predicted that post-session anxiety and disgust consistently decreased from pre- to post-session across repeated AR use.

METHOD

Participants,

Procedure,

and

Design

This two-arm, single-blind randomized controlled trial (RCT) recruited participants from the Dutch general population via online advertisements and local media. Interested individuals were directed to the study website, where they received detailed study information and completed an online response form followed by a screening questionnaire. Eligibility criteria were: age 18–64, a score of ≥ 59 on the Fear of Spiders Questionnaire (FSQ) [32, 33], access to a compatible smartphone (iOS ≥ 12 or Android 7.0+ with ARCore), and provision of informed consent. Exclusion criteria included current treatment for phobia, recent changes in psychotropic medication (< 3 months), or insufficient Dutch language proficiency. Ineligible respondents automatically received an email explaining exclusion, and up to two reminder emails (1-week intervals) were sent to non-responders.

Eligible participants were sent an informed consent form and a participant information letter (digitally, or by mail upon request). If necessary, two reminders (email and phone) were provided. After returning signed consent, participants completed a baseline questionnaire and were randomly assigned by an independent researcher to either the treatment or waitlist control condition. Participants allocated to the treatment group received email instructions and a unique unlock code to access the *ZeroPhobia* app, whereas those in the waitlist condition were informed they would gain access after six weeks. During the intervention period, weekly reminder emails encouraged continued use of the app. Data were collected online at baseline, post-treatment (6 weeks), and at 3- and 12-month follow-ups. After completing the post-treatment assessment, the waitlist group received access to the app.

Randomization and Masking

Randomization (1:1) was performed at post-baseline using Sealed Envelope™ (<https://www.sealedenvelope.com/simple-randomiser/v1/lists>) with variable block sizes (6–12), and managed by an independent researcher. The research team remained blinded until allocation.

Participants were informed of their condition, and all assessments were completed online.

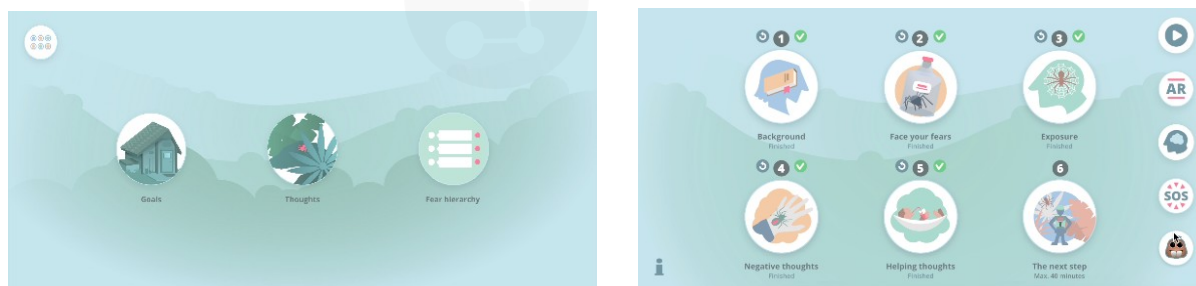
Intervention: AR-CBT app

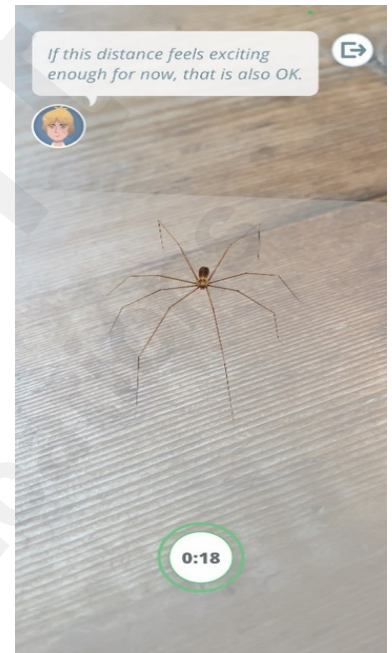
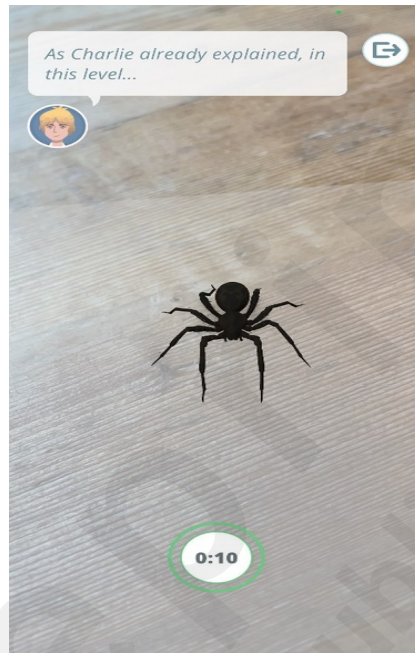
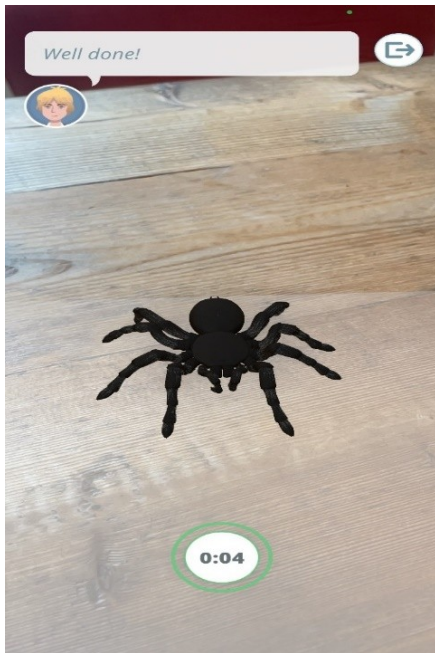
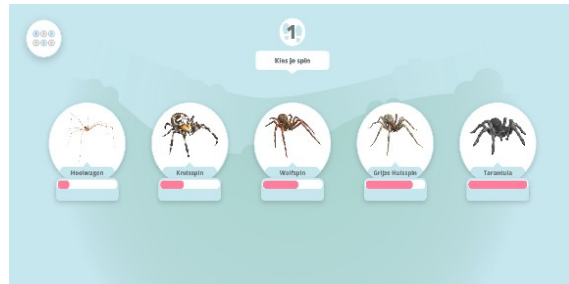
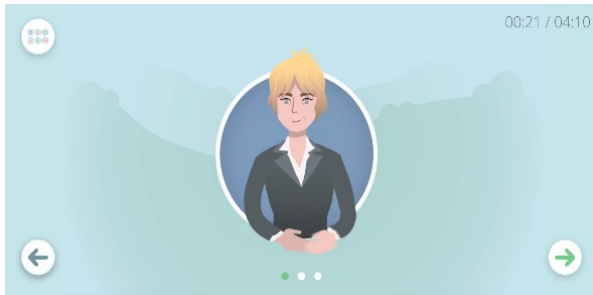
Participants downloaded the AR-CBT app, “ZeroPhobia-Fear of Spiders”, onto their own smartphone (beta version via Google Play and App Store). Access was granted through a unique URL and PIN code. Technical support was available through email.

The app featured six CBT-based animated modules with a virtual therapist (5–40 min each), five virtual spider types (e.g., Tarantula, Daddy Longlegs), and various AR exposure challenges (e.g., spiders moving across a table or on the participant’s hand; see Figure 1 for screenshots.). Scenarios also varied in number and movement of spiders. Gamification included caring for a virtual pet spider fed with flies earned through exposure; neglecting it for five days led to its "death" and restart. After one week, users could unlock items (e.g., hat, sunglasses) for their pet spider. The app was developed in Unity (v2020.1.17f1) by the first and last authors (TD, JLvG) together with a design team and 3D developer. User testing involved 15 people with spider phobia symptoms. Further details are in Toffolo et al. [34].

The app is currently available for purchase in the app stores (~\$10), compatible with ARCore-supported smartphones (Android/iOS, 2016+), with no extra hardware needed.

Figure 1. Screenshots from the AR-CBT app and AR environment





AR: Augmented Reality.
CB: Cognitive Behaviour Therapy

Outcome measures

Primary outcome

Fear of Spiders Questionnaire (FSQ)

Spider anxiety was assessed at baseline, post-test and follow-up using the 18-item FSQ [32] (score range: 18-126), a widely used measure with excellent reliability and validity [32, 33]. The Cronbach's Alpha reliability in this study was 0.96.

Secondary Outcomes

Spider Phobia Questionnaire (SPQ)

The 31-item true/false SPQ [35] (score 0-31) was administered at all time points to validate spider anxiety outcomes and has good validity [36]. The Cronbach Alpha in this study was 0.90.

Beck Anxiety Inventory (BAI)

The 21-item BAI [37] (range: 0-63) measured general anxiety at all time points. It has strong psychometric properties [38].

Patient Health Questionnaire (PHQ)

The 9-item PHQ-9 [39] (range: 0-27) assessed depressive symptoms at all time-points. Validity is good [40].

Credibility/Expectancy Questionnaire (CEQ)

The 6-item CEQ ([41] (range: 1-9) completed at baseline (intervention group only) assessed self-

reported treatment expectations and exhibits good reliability and validity [42].

Client Satisfaction Questionnaire (CSQ)

The reliable and valid 8-item CSQ-8 [43] (range: 8-32) measured treatment satisfaction at post-test (intervention group only).

System Usability Scale (SUS)

The 10-item SUS ([44] SUS (range: 0-100) assessed app usability at post-test. Scores ≥ 70 are acceptable. Reliability and validity are good [44].

Igroup Presence Questionnaire (IPQ)

Four selected items from the Dutch IPQ [45] assessed realism of the AR environment at post-test (range: -12 to 12) (intervention group only). The four items used are: “How real did the virtual environment seem to you?”, “To what extent did your experience of the virtual world compare to your experience in the real world?”, “How real did the virtual world seem to you?”, “The virtual world seemed more real than the real world”. A higher score indicates a more realistic experience. The total IPQ demonstrated good reliability [45].

Interpersonal Reactivity Index (IRI)

The 7-item sub-section Fantasy scale of from the IRI [46] (score range: 0-28) assessed imaginative capacity at baseline. This questionnaire has demonstrated good reliability and validity [47].

Professional Treatment and Medication

Treatment and medication use and visual impairment were assessed at all time point as control variables.

All self-report measures were administered online in participants' natural environment and outside researchers' presence using Survalyzer software (<http://www.survalyzer.com>). Full details are in Toffolo et al. [34].

Usage Data

Usage data included time spent per AR level, total practice time, number of sessions practiced, and post-session spider anxiety/disgust ratings (1–10 scale). Participants were advised to move on to the next level when fear ratings dropped below 4, repeat levels if between 4–7, and continue practicing if 8–10.

Usage Data Retrieval

Usage data were securely stored on an encrypted server. Data entry required a participant-specific key to prevent unauthorized access. Pseudonymized data were linked to participant IDs and included timestamps, time per level, and post-exposure anxiety/disgust levels.

Statistical Analyses

A pre-specified statistical analysis plan was developed [34], with power calculations (using G-Power 3.1.9.7) based on the FSQ as the primary outcome. Drawing from prior effect sizes for VR ($d = 1.11–1.12$) [48,49] and AR exposure therapy ($d = 0.57–0.80$) [26,50], a conservative estimate of Cohen's $d = 0.60$ was used considering the self-guided nature and basic equipment requirements of our AR-CBT app. To detect this effect with 80% power at $\alpha = .05$ (two-tailed), a sample of 112 participants (56 per group) was required, accounting for a 20% dropout rate [28,29].

Baseline characteristics were summarized and group differences between groups tested using chi-square or ANOVA. A balancing table assessed dropout bias by comparing complete cases

(participants who completed post-test) and dropout cases (participants who discontinued treatment after commencing). Missing post-test values were imputed using multiple imputation (MI) based on pre-scores and background characteristics (gender, age, severity of symptoms, and a dummy variable for whether a participant had missing values on one or more of the background characteristics). Standardized mean differences (Cohen's d) were calculated. Robustness analyses included nonparametric treatment effect bounds (Random Forest Lee Bounds [RFLB; 51] and MI using an iterative Markov chain Monte Carlo method [52]. Potential heterogeneity and treatment mechanisms were explored by estimating variation in treatment effects across pre-scores, general anxiety, user-friendliness, treatment expectation/credibility and satisfaction, and realism. Regression analysis examined whether baseline fear of spiders predicted outcome improvements. Sensitivity analysis compared ITT and complete-case results. Clinically significant change (CSC) on the FSQ were assessed for the ITT sample using Evans' "method (C) [53] with an FSQ score of $M = 39.9$ ($SD: 25.4$) [54]. The reliable change criterion was determined based on the standard deviation of the FSQ pre-test scores and the pre-test Cronbach's alpha of the FSQ ($\alpha = .96$) (ITT sample), yielding a standard error of change of 3.23 and, in turn, a reliable change criterion of 8.94 (3.23×1.96) points on the FSQ [55,56]. Number-needed-to-treat (NNT) was calculated based on the effects on the FSQ, using the formula by Furukawa and Leucht [57] for both the ITT sample and the complete-case sample. Usage data were summarized for (means, SDs, ranges for participants who have engaged in at least one AR session. Statistical significance was set at $p < .05$ (two-sided). Stata SE (v17; StataCorp) was employed for all analyses.

Ethical Considerations

The study was ethically approved (VU Medical Center, 2019-321) (Supplement 1), pre-registered [34], followed Consolidated Standards of Reporting Trials [58], and adhered to the principles of the Declaration of Helsinki. Participants provided written informed consent after receiving a complete description of the study. The study was registered with the Overview of Medical Research in the

Netherlands (OMON) under registration number NL70238.029.19 (TrialNL9221) (<https://onderzoekmetmensen.nl/nl/trial/27993>). We deviated on one issue from the ethics protocol (Supplement 1) before trial commencement. No protocol changes were made after trial start, and data were analyzed after study completion. Participants were informed that their privacy and confidentiality would be carefully safeguarded. All data were de-identified and stored on secure, password-protected servers, with access restricted to authorized members of the research team. Any personally identifying details were removed before analysis. Participants were reminded that they could withdraw from the study at any point, without consequences and without having to give a reason. Although no monetary compensation was offered, participants were granted full access to the intervention.

RESULTS

Treatment adherence and attrition

Between September 2021 and December 2022, 113 eligible participants were randomized to AR-CBT (n=56) or waitlist (n=57); the final follow-up ended on Jan 5, 2024. Data was completed in May 2025. In the AR-CBT group, 72% completed the post-test, 57% the 3-month, and 29% the 12-month follow-up. In the waitlist group, 84% completed the post-test. Overall dropout was 21%, and unrelated to most baseline variables, though higher BAI ($P=.015$) and PHQ scores ($P<.001$) predicted post-test dropout (see eTable 1, Supplement 2). See Figure 2 for the participant flowchart.

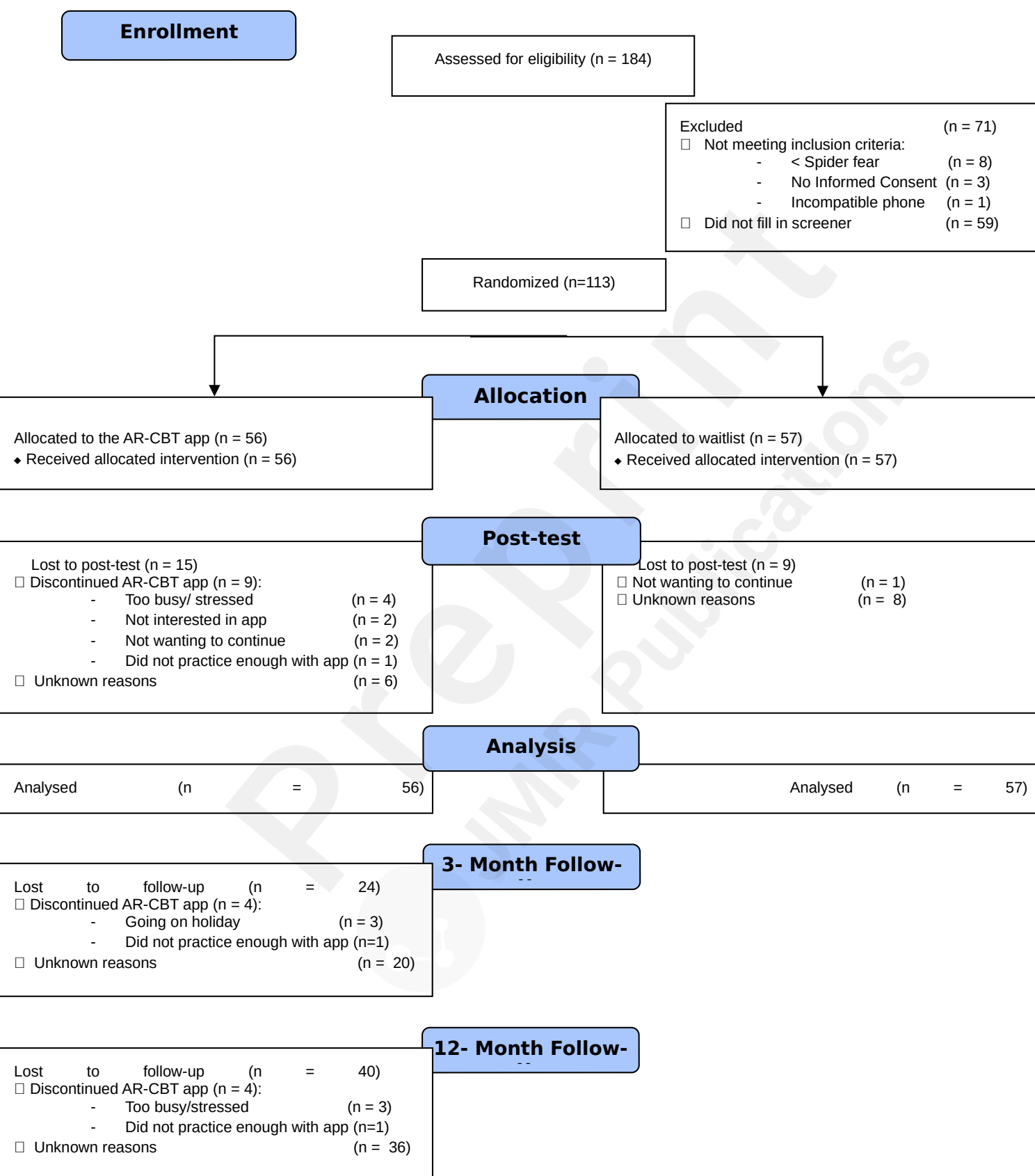


FIGURE 2. CONSORT Diagram of Participant Flow Through the Trial.

Abbreviations: FSQ, Fear of Spider Questionnaire; AR, Augmented Reality; CBT, Cognitive Behaviour Therapy

Participant characteristics

Participants (M age = 39, SD = 11.58) were mostly female (79%) and highly educated (83%), 95% had >5 years of spider phobia symptoms. The mean baseline FSQ score was 95.65 (SD = 16.13). Groups were balanced at baseline (Table 1).

Table 1. Demographic and Baseline Characteristics^a

Measure	AR treatment group (n = 56)	Wait-list control group (n = 57)
Age, mean (SD), y	39 (10.72)	39 (12.45)
Female, No. (%)	46 (80.70)	43 (76.79)
Education, No. (%)^a		
Primary	1 (1.80)	2 (3.60)
Secondary	8 (14.30)	8 (14.30)
Postsecondary	47 (83.90)	46 (82.10)
Employment status, No. (%)^a		
Employed	47 (83.90)	48 (85.70)
Unemployed	9 (16.10)	8 (14.30)
Outcome Measures, mean (SD)		
FSQ	97.73 (16.92)	93.61 (15.18)
SPQ	24.34 (3.41)	23.18 (3.33)
BAI	12.27 (0.82)	10.84 (9.02)
PHQ	4.55 (3.87)	4.38 (4.11)
Prescribed Medication (> 3 mo), No. (%)	1 (0.6)	0 (0.00)
Duration of spider phobia symptoms, No. (%)[*]		
< 6 months	1 (1.79)	0 (0.00)
6–12 months	0 (0.00)	0 (0.00)
1–5 years	1 (1.79)	3 (0.00)
> 5 years	54 (96.43)	53 (92.98)
Professional treatment and medication use during the study	0 (0.00)	0 (0.00)
Smartphone type, No. (%)		
iPhone	22 (39.29)	30 (52.63)
Android	34 (60.71)	27 (47.37)

^a n = 1 missing in the control group
AR: Augmented Reality. Mo: months.

Effectiveness (Intention-to-Treat Analysis)

The AR-CBT app significantly reduced FSQ spider phobia symptoms compared to the control group at post-test ($b = -32.09$ [95% CI, -41.07 to -23.10], $P < .001$; $d = 1.25$ [95% CI = 0.77, 1.73]; NNT: 2.1). Significant group differences also emerged on the SPQ at post-test ($b = -4.82$ [95% CI, -6.75 to -2.89], $P < .001$; $d = 0.97$ [95% CI, 0.51 to 1.43]) and general anxiety (BAI) ($b = -4.02$ [95% CI, -7.52 to -.52], $P = .025$; $d = 0.39$ [95% CI, -.04 to 0.82]). A trend was observed for depressive symptoms (PHQ-9) at post-test ($b = -1.48$ [95% CI, -3.61 to .20], $P = .08$; $d = 0.28$ [95% CI, -0.14 to 0.70]). Full ITT results are presented in Tables 2 and 3.

Table 2. Outcome measure scores, Intention to Treat ($n = 113$)^a

Outcomes	AR treatment group ($n = 56$)	Wait-list control group ($n = 57$)
Primary outcome, Mean (SD)		
FSQ		
baseline	97.73 (16.92)	93.61 (15.18)
post-test	60.38 (42.50)	88.67 (26.02)
Secondary outcome		
SPQ		
baseline	24.34 (3.41)	23.18 (3.33)
post-test	19.93 (8.58)	24.29 (5.50)
BAI		
baseline	12.27 (10.83)	10.84 (9.02)
post-test	6.80 (12.16)	10.30 (15.14)
PHQ		
baseline	4.55 (3.87)	4.38 (4.11)
post-test	3.91 (7.49)	5.28 (7.37)

^a Inferential statistics of treatment outcome measures, multiple imputation (100).
 AR: Augmented Reality.
 FSQ: Fear of Spiders Questionnaire.
 SPQ: Spider Phobia Questionnaire.
 BAI: Beck Anxiety Inventory.
 PHQ: Patient Health Questionnaire.

Robustness and Sensitivity Analyses

Given the differential dropout rates between conditions, Random Forest Lee Bounds (RFLB) estimates were calculated (see [51]) which confirmed a statistically significant treatment effect on the FSQ (see Table 3, Model 2). The regression coefficient estimated in Model 1 ($b = -32.09$,

Table 3. Estimated Effects of AR-CBT app on spider phobia symptoms, general anxiety, and depression

Post-test ^a						
	Model 1 ($n = 113$) ^b			Model 2 ($n = 89$) ^b		
Measure	b MI (SE)	P value ^c	Effect size (95% CI)	b Lower bound (SE)	b Upper bound (SE)	P value ^c
Primary outcome						
FSQ	-32.09 (4.50)	<.0001	1.25 (0.77–1.73)	-32.63 (5.28)	-24.25 (5.11)	<.0001
Secondary outcomes						
SPQ	-4.82 (0.97)	<.0001	0.97 (0.51–1.43)	-5.30 (1.02)	-3.49 (1.04)	<.0001
BAI	-4.02 (1.75)	<0.05	0.39 (-.04–0.82)	-4.61 (2.22)	-0.44 (2.27)	<0.05
PHQ	-1.48 (0.84)	<.10	0.25 (-0.14–0.70)	-2.18 (1.20)	0.40 (1.10)	<.10

^a For ethical reasons, we do not have follow-up data for the wait-list control group participants: they were given access to the AR treatment after the post-test. Hence, we could not analyze the follow-up results for the intent-to-treat sample.

^b Effect sizes reported in Model 1 are all Cohen's d for unadjusted group means based on the pre-measure–post-measure difference. Treatment effects reported in Model 2 are Lee Bounds estimates. Two-sided.

^c Treatment effects in Model 1 are derived through multiple (100) imputations, assuming MAR (missing at random), applying multivariate normal regression with imputation by experimental group, and accommodating arbitrary missing outcome value patterns using an iterative Markov chain Monte Carlo (MCMC) method. Pre-score and background controls are included for improved precision of the regression point estimates reported in Models 1. Background control variables are gender, age, and a dummy variable for whether a participant had missing values on one or more background characteristics.

AR: Augmented Reality.
 ITT: Intent-to-treat.
 FSQ: Fear of Spiders Questionnaire.
 SPQ: Spider Phobia Questionnaire.
 BAI: Beck Anxiety Inventory.
 PHQ: Patient Health Questionnaire.
 MI: Multiple Imputation
 SE: standard error.

Heterogeneous Treatment Effects and Mechanisms

Primary outcome measure (FSQ – Fear of Spiders)

FSQ reductions were not significantly related to baseline fear-of-spiders symptoms ($b = .29$ [95% CI, $-.25$ to $.83$], $SE = .27$, $P = .29$), treatment expectancy/credibility (CEQ) ($b = -.52$ [95% CI, -1.44 to $.39$], $SE = .46$, $P = .26$), visual impairment ($b = .87$ [95% CI, -8.76 to 10.49], $SE = 4.83$, $P = .86$), imaginative capacity (IRI) ($b = .37$ [95% CI, -1.10 to 1.84], $SE = .74$, $P = .61$), usability (SUS) ($r = -0.02$, $P = .86$), or presence (IPQ) ($r = -0.28$, $P = .08$). However, greater satisfaction (CSQ) with the AR-CBT app was significantly correlated with larger FSQ reductions ($r = -0.43$, $P = .01$).

Secondary outcome measures (SPQ – Fear of Spiders, General Anxiety, Depressive symptoms)

No significant associations were found between app usability (SUS) and baseline-posttest change in secondary outcome measures, including fear-of-spiders symptoms (SPQ) ($r = 0.02$, $P = .89$), general anxiety (BAI) ($r = 0.26$, $P = .11$) or depressive symptoms (PHQ) ($r = 0.07$, $P = .70$). Presence also showed no significant relationships with changes in SPQ ($r = -0.30$, $P = .07$), BAI ($r = 0.00$, $P = .97$) or PHQ ($r = -0.09$, $P = .60$). Likewise, satisfaction with the AR-CBT app (CSQ) was not significantly correlated with changes in general anxiety (BAI) ($r = -0.14$, $P = .38$) or depressive symptoms (PHQ) ($r = -0.15$, $P = .36$). However, a significant association was found between reductions in SPQ scores and satisfaction with the AR-CBT app (CSQ) ($r = -0.39$, $P = .01$).

Complete Cases

Among post-test completers, the between-group FSQ effect size was large ($d = 1.29$ [95% CI, 0.82 to 1.74; NNT = 2.1]). Of the 56 participants in the intervention group, 41 (73.2%) showed reliable change. Additionally, 28 of 41 post-test completers (68%) demonstrated clinically significant improvement, reaching the CSC FSQ threshold of 74.6. Within-group FSQ effect sizes remained large at 3-month ($d = 1.69$ [95% CI, 1.11 to 2.28]) and 12-month ($d = 1.64$ [95% CI, 0.78 to 2.51]) follow-up. SPQ also showed strong effects at post-test (between-group $d = 1.00$ [95% CI, 0.55 to 1.44]), 3-month follow-up (within-group $d = 0.88$ [95% CI, 0.47 to 1.28]), and 12-month follow-up ($d = 0.74$ [95% CI, 0.19 to 1.30]). For general anxiety, no short-term effects were observed, but significant improvements emerged at 3-month follow-up ($d = 0.85$ [95% CI, 0.44 to 1.26]; and at 12-month follow-up ($d = 0.64$ [95% CI, 0.10 to 1.18]). Depressive symptoms followed a similar pattern, with small-to-moderate improvements at both follow-ups (3-month follow-up: $d = 0.41$ [95% CI, 0.04 to .77; 12-months follow-up: $d = 0.57$ [95% CI, 0.04 to 1.10) (see eTable 2 in

Supplement 2). Mean post-test IPQ score for the intervention group was -2.48 ($SD = 5.68$).

User-Friendliness and Treatment Satisfaction

The AR-CBT app was rated as moderately easy to use (SUS: Median = 70, $M = 67.6$, $SD = 6.98$). Expectancy/Credibility (CEQ) averaged $M = 33.58$ ($SD = 10.77$) and treatment satisfaction (CSQ) was high ($M = 22.95$, $SD = 3.49$). No negative effects were reported.

User engagement

Of the 56 participants in the AR-CBT group, 40 engaged with the AR component. Their total practice time averaged 109 minutes (range: <2 to >2000 minutes), with a mean of 14 practice sessions. Each session lasted on average 6.39 minutes ($SD = 9.16$). Anxiety and disgust ratings (1 [very low]-10 [very high] scale) were generally higher in earlier levels than in later ones (eTable 3, Supplement 2). On average, each level ended with a reduction of 0.78 points in anxiety ($SD = 3.13$) and 0.24 points in disgust ($SD = 3.06$). Mean anxiety declined from 4.32 ($SD = 2.58$) during the first exposure to 3.76 ($SD = 3.02$) at final attempt. Some levels (e.g., Level 1) were repeated up to 30 times (eTable 4, Supplement 2). As shown in eFigure 1 (Supplementary Files), more practice time was associated with greater FSQ improvement (FSQ: $b = -0.016$ [95% CI, $-.022$ to $-.009$], $SE = 0.003$, $P < .001$; SPQ: $b = -0.007$ [95% CI, $-.009$ to $-.006$], $SE = 0.001$, $P < .01$), whereas the number of sessions did not ($P = .87$). Presence (IPQ) was unrelated to AR post-session anxiety ($P = .82$). Baseline FSQ scores did not predict AR usage time ($P = .58$) or disgust ($P = .77$), but were linked to higher anxiety during the first AR session ($b = 3.686$ [95% CI, $.66$ to 6.71], $SE = 1.50$, $P = .018$). AR usage time was not significantly correlated with usability (SUS: $P = .31$), satisfaction (CSQ: $P = .30$), or imaginative involvement (IRI: $P = .27$). However, greater reductions in disgust during AR were associated with higher satisfaction (CSQ: $b = -0.26$ [95% CI, $-.37$ to $-.16$], $SE = 0.051$, $P < .001$).

DISCUSSION

Principal Results

This single-blind RCT demonstrated that a fully automated AR-CBT app can significantly reduce spider phobia symptoms. Large effects were observed for spider phobia symptoms with smaller effects on general anxiety and depression. These results suggest that AR-CBT primarily targets specific fears, but may have spillover benefits on broader emotional well-being. Importantly, effect sizes equal those of therapist-guided in vivo and high-end VR/AR exposure [59, 60]. The app's effectiveness therefore rivals that of therapist-led exposure therapy, but with the added convenience of standalone use, higher accessibility, and lower cost.

Complete-case analysis showed strong adherence: approximately 80% completed the app, with around 70% achieving clinically significant improvement. Effects increased further at 3- and 12-month follow-ups. General anxiety and depressive symptoms also continued to improve, suggesting delayed benefits. SPQ scores followed a similar pattern. As hypothesized, greater exposure time—but not session count—was associated with stronger reductions in spider anxiety. Treatment effectiveness was not significantly related to usability, presence, or treatment expectancy. Participants reported high overall satisfaction despite moderate usability ratings. Usability scores were slightly lower than those reported for standalone VR apps [28,29], possibly due to challenges specific to AR such as lighting and tracking issues not present in fully immersive VR. Dropout rates were consistent with those found in therapist-supported VR and AR studies [61].

Strengths

A key strength of this study was its high ecological validity: participants used the app independently, on their own smartphones, in their own environment, allowing effects to be attributed solely to the intervention. Additional strengths include broad device compatibility and long-term follow-up. Differential dropout was accounted for using RFLB calculations, supporting the robustness of the

findings. Notably, this is the first study to demonstrate long-term effectiveness of fully automated AR-CBT in a real-world setting.

Limitations

Limitations include self-selection bias, modest follow-up samples, and reliance on self-report, although previous research shows strong alignment between self-report and behavioral outcomes [62]. Future research should compare AR-CBT with treatment-as-usual (TAU) in diverse samples to further examine relative efficacy and generalizability.

Conclusions

Building on earlier work [20, 23-29], these findings represent an important step forward: effective, durable treatment for specific phobias is now achievable without ever seeing a therapist. This study provides compelling evidence that a fully automated, smartphone-based AR-CBT intervention can produce substantial and enduring reductions in spider phobia symptoms. As the global need for mental health care continues to outstrip available resources, there is a growing demand for scalable, accessible solutions. By harnessing widely accessible smartphone technology, AR-CBT offers an effective, low-cost, self-guided alternative to traditional exposure therapy —paving the way for broader adoption of automated interventions in mental health care empowering individuals to manage their fears independently.

Acknowledgements

We would like to thank Doruk Eker, MSc, and Gianluca Di Vincenzo, MSc, (Orb Amsterdam), for programming ZeroPhobia, Bruno de Vos, BA, (Studio Barbaar), for designing ZeroPhobia, Rufus

van Baardwijk, MSc, for sound design, and Luc Versleijen for designing the virtual spiders. Studio Barbaar, Orb Amsterdam, Rufus van Baardwijk and Luc Verslijen received financial compensation. Additionally, we would like to thank Imane Mir and Justin Pieternella for assistance with recruitment and participant management. Finally, we sincerely thank all of the participants who participated in the study.

Funding Statement

The study was funded by the Dutch Research Council (NWO) Aspasia grant (ref 015.014.072), the Dutch Research Council (NWO) TKI CLICK NL for the Creative Industrie grant (ref KI.18.039) and an MIT R&D grant from Province of North Holland, the Netherlands. The funders had no role in the study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the paper for publication.

Conflicts of Interest

TD and JLvG (InSession) developed the AR-CBT app that was used in the this study. The AR-CBT app is intended for commercial release. Hence, TD and JLvG were not involved in data analysis or with any decisions related to the publication of findings. The other authors declare that they have no competing interests.

Data availability

De-identified row-level data are available via data use agreement with the Vrije Universiteit Amsterdam per institutional requirement; contact corresponding author to initiate the contracting process. Analyses were conducted using StataSE. The script for manuscript analyses is available upon reasonable request to the corresponding author.

Author**contributions**

IC and CvK had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. The study was conceived and designed by T.D. Data were acquired, analysed, and interpreted by IC, CvK, TD, RNK and JLvG. TD drafted the manuscript. All authors— IC, CvK, RNK, JRF, AvS, MBT, and JLvG critically revised the manuscript for important intellectual content. Statistical analysis was conducted by IC and CvK. Funding was obtained by TD and JLvG. Administrative, technical, and material support was provided by JRF, MBT. TD supervised the study.

ABBREVIATIONS

AR: augmented reality

ARET: augmented reality exposure therapy

BAI: Beck Anxiety Inventory

CBT: Cognitive Behavioural Therapy

CEQ: Credibility/Expectancy Questionnaire

CSC: clinically significant change

CSQ: Client Satisfaction Questionnaire

ET: exposure therapy

FSQ: Fear of Spiders Questionnaire

GDP: gross domestic product

IPQ: Igroup Presence Questionnaire

IRI: Interpersonal Reactivity Index

ITT: intent to treat

MI: multiple imputation

NNT: number needed to treat

PHQ: Patient Health Questionnaire

RCT: randomized controlled trial

RFLB: Random Forest Lee Bounds

SPQ: Spider Phobia Questionnaire

SUS: System Usability Scale

TAU: treatment as usual

VR: virtual reality



4. REFERENCES

1. World Health Organization. Mental health atlas 2017 [Internet]. Geneva: World Health Organization; 2018 [cited 2025 Sep 18]. Available from: <https://www.who.int/publications/i/item/9789241514019>
2. Columbia Business School. Economic impact of mental illness [Internet]. 2025 [cited 2025 Sep 18]. Available from: <https://business.columbia.edu/research-brief/economic-impact-mental-illness>
3. European Commission. Mental health [Internet]. 2025 [cited 2025 Sep 18]. Available from: https://health.ec.europa.eu/non-communicable-diseases/mental-health_en
4. Zeilstra A, den Ouden A, Vermeulen W. Middellangetermijnverkenning zorg 2022–2025 [Internet]. The Hague: CPB Netherlands Bureau for Economic Policy Analysis; 2019 [cited 2025 Sep 18]. Available from: <https://www.cpb.nl/sites/default/files/omnidownload/CPB-Middellangetermijnverkenning-zorg-2022-2025-nov2019.pdf>
5. World Health Organization. World mental health report: Transforming mental health for all [Internet]. Geneva: World Health Organization; 2022 [cited 2025 Sep 18]. Available from: <https://www.who.int/publications/i/item/9789240049338>
6. Torous J, Wykes T. Opportunities from the COVID-19 pandemic for transforming psychiatric care with telehealth. *JAMA Psychiatry*. 2020;77(12):1205-1206.
7. Mohr DC, Schueller SM, Montague E, Burns MN, Rashidi P. The Behavioral Intervention Technology Model: An integrated conceptual and technological framework for eHealth and mHealth interventions. *J Med Internet Res*. 2017;19(5):e146. doi:10.2196/jmir.7101

8. Hollis C, Morriss R, Martin J, Amani S, Cotton R, Denis M, Lewis S. Technological innovations in mental healthcare: harnessing the digital revolution. *Br J Psychiatry*. 2015;206(4):263-265. doi:10.1192/bjp.bp.113.142612
9. Larsen ME, Huckvale K, Nicholas J, Torous J et al.. Using science to sell apps: Evaluation of mental health app store quality claims. *NPJ Digit Med*. 2019;2:18. doi:10.1038/s41746-019-0093-1
10. Lagan S, D'Mello R, Vaidyam A, Bilden R, Torous J. Assessing mental health apps marketplaces with objective metrics from 29,190 data points from 278 apps. *Acta Psychiatrica Scand*. 2021 Aug;144(2):201-210. doi: 10.1111/acps.13306. Epub 2021 Apr 29. PMID: 33835483.
11. Eaton WW, Bienvenu OJ, Miloyan B. Specific phobias. *Lancet Psychiatry*. 2018;5(8):678-686. doi:10.1016/S2215-0366(18)30169-X
12. McCabe RE, Stetin MB. Specific phobia in adults: epidemiology, clinical manifestations, course, and diagnosis [Internet]. UpToDate; 2022 [cited 2025 Sep 18]. Available from: <https://www.uptodate.com/contents/specific-phobia-in-adults-epidemiology-clinical-manifestations-course-and-diagnosis>
13. Nathan PE, Gorman JM, editors. A guide to treatments that work. 4th ed. New York: Oxford University Press; 2007.
14. Olatunji BO, Deacon BJ, Abramowitz JS. The cruellest cure? Ethical issues in the implementation of exposure-based treatments. *Cogn Behav Pract*. 2009;16(2):172-180. doi:10.1016/j.cbpra.2008.12.004
15. Suso-Ribera C, García-Palacios A, Baños RM, Botella C. Virtual reality, augmented reality,

- and in vivo exposure therapy: a preliminary comparison of treatment efficacy in small animal phobia. *Cyberpsychol Behav Soc Netw*. 2019;22(1):31-38. doi:10.1089/cyber.2018.0176
16. Hasan S, Alhaj H, Hassoulas A. The efficacy and therapeutic alliance of augmented reality exposure therapy in treating adults with phobic disorders: systematic review. *JMIR Ment Health*. 2023;10:e51318. doi:10.2196/51318
17. Juan MC, Raya MA, Monserrat C, Botella C. Using augmented reality to treat phobias. *IEEE Comput Graph Appl*. 2005;25(6):31-37. doi:10.1109/MCG.2005.143
18. Botella C, Breton-Lopez J, Quero S, Banos R, García-Palacios A,. Treating cockroach phobia with augmented reality. *Behav Ther*. 2010;41(4):401-413. doi:10.1016/j.beth.2009.07.002
19. Botella C, Breton-Lopez J, Quero S, Banos, R. Treating cockroach phobia using a serious game on a mobile phone and augmented reality exposure: a single case study. *Comput Hum Behav*. 2011;27(1):217-227. doi:10.1016/j.chb.2010.08.016
20. Miloff A, Lindner P, Dafgård P, Deak S, Garke M et al. Automated virtual reality exposure therapy for spider phobia vs in-vivo one-session treatment: a randomized non-inferiority trial. *Behav Res Ther*. 2019;118:130-140. doi:10.1016/j.brat.2019.04.004
21. Statista. Smartphone penetration rate in the EU 2011–2024. Statista. 2025. Available from: <https://www.statista.com/statistics/203722/smartphone-penetration-per-capita-in-europe-since-2000>
22. Pew Research Center. Mobile fact sheet: Smartphone ownership in the U.S. Pew Research Center. 2025. Available from: <https://www.pewresearch.org/internet/fact-sheet/mobile>
23. Jurcik T, Zaremba-Pike S, Kosonogov V, Mohammed A-R et al. The efficacy of augmented

reality exposure therapy in the treatment of spider phobia—a randomized controlled trial.

Front Psychol. 2024;15:1214125. doi:10.3389/fpsyg.2024.1214125

24. Javanbakht A, Madaboosi S, Grasser LR. Real-life contextualization of exposure therapy using augmented reality: a pilot clinical trial of a novel treatment method. *Ann Clin Psychiatry.* 2021;33(4):220-231. doi:10.12788/acp.0042
25. De Witte NAJ, Scheveneels S, Sels R, Debard G, et al. Augmenting exposure therapy: mobile augmented reality for specific phobia. *Front Virtual Real.* 2020;1:8. doi:10.3389/frvir.2020.00008
26. Zimmer A, Wang N, Ibach MK, Fehlmann B et al. Effectiveness of a smartphone-based, augmented reality exposure app to reduce fear of spiders in real life: a randomized controlled trial. *J Anxiety Disord.* 2021;82:102442. doi:10.1016/j.janxdis.2021.102442
27. Bentz D, Wang N, Ibach MK, Schicktanx NS, et al. Effectiveness of a stand-alone, smartphone-based virtual reality exposure app to reduce fear of heights in real life: a randomized trial. *NPJ Digit Med.* 2021;4:16. doi:10.1038/s41746-021-00387-7
28. Donker T, Cornelisz I, van Klaveren C, et al. Effectiveness of self-guided app-based virtual reality cognitive behavior therapy for acrophobia: a randomized clinical trial. *JAMA Psychiatry.* 2019;76(7):682-690. doi:10.1001/jamapsychiatry.2019.0219
29. Donker T, Cornelisz I, van Klaveren C, et al. Automated mobile virtual reality cognitive behavior therapy for aviophobia in a natural setting: a randomized controlled trial. *Psychol Med.* 2023;53(33):6232-6241. doi:10.1017/S0033291722003531
30. Donker T, Cornelisz I, van Klaveren C, et al. Analysis of usage data from a self-guided app-based virtual reality cognitive behavior therapy for acrophobia: a randomized controlled trial.

J Clin Med. 2020;9(6):1614. doi:10.3390/jcm9061614

31. Hong YJ, Lee HJ, Kim H, et al. Usefulness of the mobile virtual reality self-training for overcoming a fear of heights. *Cyberpsychol Behav Soc Netw.* 2017;20(11):753-761. doi:10.1089/cyber.2017.0263
32. Szymanski J, O'Donohue W. Fear of spiders questionnaire. *J Behav Ther Exp Psychiatry.* 1995;26(1):31-34. doi:10.1016/0005-7916(94)00072-T
33. Muris P, Merckelbach H. A comparison of two spider fear questionnaires. *J Behav Ther Exp Psychiatry.* 1996;27(3):241-244. doi:10.1016/S0005-7916(96)00020-8
34. Toffolo MBJ, Fehribach, JR, van Klaveren, CPBJ, Cornelisz C, et al., et al. Automated app-based augmented reality cognitive behavioral therapy for spider phobia: study protocol for a randomized controlled trial. *PLoS One.* 2022;17(2):e0271175. doi:10.1371/journal.pone.0271175
35. Klorman R, Weerts TC, Hastings JE, Melamed BG, Lang PJ. Psychometric description of some specific-fear questionnaires. *Behav Ther.* 1974;5(3):401-409. doi:10.1016/S0005-7894(74)80005-6
36. Johnsen BH, Hugdahl K. Fear questionnaires for simple phobias: Psychometric evaluations for a Norwegian sample. *Scand J Psychol.* 1990;31(1):42-48. doi:10.1111/j.1467-9450.1990.tb00800.x
37. Beck AT, Epstein N, Brown G, Steer RA. An inventory for measuring clinical anxiety: psychometric properties. *J Consult Clin Psychol.* 1988;56(6):893-897. doi:10.1037//0022-006X.56.6.893
38. Fydrich T, Dowdall D, Chambless DL. Reliability and validity of the Beck Anxiety Inventory. *J Anxiety Disord.* 1992;6(1):55-61. doi:10.1016/0887-6185(92)90026-4

39. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* 2001;16(9):606-613. doi:10.1046/j.1525-1497.2001.016009606.x
40. Wittkamp KA, van Ravesteijn H, van Weert HC, et al. Diagnostic accuracy of the mood module of the Patient Health Questionnaire: a systematic review. *Gen Hosp Psychiatry.* 2007;29(4):388-395. doi:10.1016/j.genhosppsych.2007.06.004
41. Devilly GJ, Borkovec TD. Psychometric properties of the credibility/expectancy questionnaire. *J Behav Ther Exp Psychiatry.* 2000;31(2):73-86. doi:10.1016/S0005-7916(00)00012-4
42. Mertens VC, Moser A, Verbunt J, Smeets R et al. Content validity of the credibility and expectancy questionnaire in a pain rehabilitation setting. *Pain Pract.* 2017;17(6):902-913. doi:10.1111/papr.12543
43. Attkisson CC, Greenfield TK. The UCSF Client Satisfaction Scales: I. The Client Satisfaction Questionnaire-8. *Eval Program Plann.* 2004;27(3):263-271. doi:10.1016/j.evalprogplan.2004.04.001
44. Bangor A, Kortum PT, Miller JT. An empirical evaluation of the system usability scale. *Int J Hum Comput Interact.* 2008;24(6):574-594. doi:10.1080/10447310802205776
45. Schubert T, Friedmann F, Regenbrecht H. The experience of presence: factor analytic insights. *Presence Teleoperators Virtual Environ.* 2001;10(3):266-281. doi:10.1162/105474601300343603
46. Davis MH. A multidimensional approach to individual differences in empathy. *Cat Sel Doc Psychol.* 1980;10:85.
47. De Corte K, Buysse A, Verhofstadt LL, Roeyers H, Ponnet K. Measuring empathic tendencies: Reliability and validity of the Dutch version of the Interpersonal Reactivity Index. *Psychol Belg.* 2007;47(4):235-260. doi:10.5334/pb-47-4-235

48. Powers MB, Emmelkamp PM. Virtual Reality Exposure Therapy for Anxiety Disorders: A Meta-analysis. *J Anxiety Disord.* 2008;22(3):561-569. doi:10.1016/j.janxdis.2007.04.006
49. Oprîş D, Pinteă S, García-Palacios A, Botella C, Szamosközi Ş, David D. Virtual reality exposure therapy in anxiety disorders: a quantitative meta-analysis. *Depress Anxiety.* 2012;29(2):85-93. doi:10.1002/da.20910
50. Botella C, Angeles Perez-Ara M, Breton-Lopez J, Quero S et al. In Vivo versus Augmented Reality Exposure in the Treatment of Small Animal Phobia: A Randomized Controlled Trial. *PLoS One.* 2016;11(2):e0148237. doi:10.1371/journal.pone.0148237
51. Lee DS. Training, wages, and sample selection: Estimating sharp bounds on treatment effects. *Rev Econ Stud.* 2009;76(3):1071-1102. doi:10.1111/j.1467-937X.2009.00536.x
52. Hamra G, MacLehose R, Richardson D. Markov chain Monte Carlo: an introduction for epidemiologists. *Int J Epidemiol.* 2013;42(3):627-634. doi:10.1093/ije/dyt043
53. Evans C. Reliable and clinically significant change. 2022. Available from: <http://www.psychtc.org/stats/rcsc.htm>
54. Muris P, Merckelbach H. A comparison of two spider fear questionnaires. *J Behav Ther Exp Psychiatry.* 1996;27(3):241-244. doi:10.1016/S0005-7916(96)00022-5
55. Jacobson NS, Truax P. Clinical significance: a statistical approach to defining meaningful change in psychotherapy research. *J Consult Clin Psychol.* 1991;59(1):12-19. doi:10.1037/0022-006X.59.1.12
56. Christensen L, Mendoza JL. A method of assessing change in a single subject: An alteration of the RC index. *Behav Ther.* 1986;17(3):305-308. doi:10.1016/S0005-7894(86)80022-0
57. Furukawa TA, Leucht S. How to obtain NNT from Cohen's d: comparison of two methods.

PLoS One. 2011;6(4):e19070. doi:10.1371/journal.pone.0019070

58. Eysenbach G; CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res*. 2011;13(4):e126. doi:10.2196/jmir.1923
59. Wolitzky-Taylor KB, Horowitz JD, Powers MB, Telch MJ. Psychological approaches in the treatment of specific phobias: a meta-analysis. *Clin Psychol Rev*. 2008;28(6):1021-1037. doi:10.1016/j.cpr.2008.02.007
60. Carl E, Stein AT, Levihn-Coon A, et al. Virtual reality exposure therapy for anxiety and related disorders: a meta-analysis of randomized controlled trials. *J Anxiety Disord*. 2019;61:27-36. doi:10.1016/j.janxdis.2018.08.003
61. Benbow AA, Anderson PL. A meta-analytic examination of attrition in virtual reality exposure therapy for anxiety disorders. *J Anxiety Disord*. 2019;61:18-26. doi:10.1016/j.janxdis.2018.06.006
62. Fodor LA, Cotet CD, Cuijpers P, Szamoskozi S et al. The effectiveness of virtual reality based interventions for symptoms of anxiety and depression: a meta-analysis. *Sci Rep*. 2018;8:10323. doi:10.1038/s41598-018-28113-6

Supplementary Files

Multimedia Appendixes

Ethical Application.

URL: <http://asset.jmir.pub/assets/0a37222695242cf534f0499801b77826.pdf>

Supplementary files.

URL: <http://asset.jmir.pub/assets/65c423c4359bf70570f0ea7c72d47fdc.pdf>

CONSORT (or other) checklists

CONSORT eHealth checklist.

URL: <http://asset.jmir.pub/assets/873a62125be33fd3e175cc105641450d.pdf>

CONSORT checklist for RCTs.

URL: <http://asset.jmir.pub/assets/b00ac15a7af5959e9da2da952a8a6aae.pdf>