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DESIGN AND USABILITY EVALUATION OF A PORTABLE VR SERIOUS GAME FOR ADOLESCENT SOCIAL ANXIETY

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ABSTRACT

Aim/Purpose	This study aims to design and evaluate the usability and user experience of a portable Virtual Reality-based Serious Game (VRSG) informed by Cognitive Behavioral Therapy (CBT) principles to support exposure-oriented practice for adolescents with Social Anxiety Disorder (SAD).
Background	Adolescents with SAD often face barriers to accessing conventional mental health services, including stigma, limited availability of therapists, and low engagement with traditional treatment formats. While digital mental health interventions and Virtual Reality Exposure Therapy (VRET) have shown promise, many existing systems rely on non-portable hardware and provide limited integration between therapeutic structure and engagement-oriented design. There remains a need for accessible, portable, and user-centered VR solutions tailored to adolescent users.
Methodology	A VR serious game prototype, named SAVIRE, was developed using a Rapid Game Development approach and deployed on untethered VR hardware. An early-stage evaluation was conducted in two phases. First, mental health professionals (n = 3) assessed user experience and perceived therapeutic alignment using the User Experience Questionnaire (UEQ). Second, adolescents clinically diagnosed with SAD (n = 20) participated in usability testing using the System Usability Scale (SUS). Qualitative feedback was also collected to explore perceptions related to engagement, comfort, and system design features.
Contribution	This study contributes a design-focused and usability-oriented evaluation of a portable VR serious game informed by CBT principles for adolescent social anxiety. By foregrounding usability, user experience, and feasibility, the study provides foundational evidence to support further development and future efficacy-oriented research.
Findings	Results indicate high levels of usability and acceptance. Expert reviewers reported positive user experience ratings (overall UEQ mean = 2.75), with particularly strong scores for ease of understanding. Usability testing with adolescents yielded an excellent mean SUS score of 80.38, suggesting that the system is user-friendly and appropriate for repeated use. Qualitative findings further highlighted design features that supported engagement and emotional comfort during simulated social exposure.
Recommendations for Practitioners	Mental health practitioners may consider portable VR serious games as supplementary tools to support exposure-oriented activities, particularly in non-clinical or resource-limited settings, provided they are integrated into appropriate clinical frameworks.
Recommendations for Researchers	Future research should extend this work through controlled clinical studies to evaluate therapeutic outcomes and explore adaptive system features that personalize exposure scenarios.
Impact on Society	By demonstrating the feasibility of a portable, engaging VR-based system, this research highlights the potential of immersive technologies to expand access to mental health support for adolescents, especially in underserved contexts.
Future Research	Future studies may build on this work by conducting larger-scale, longitudinal investigations to examine clinical outcomes and sustain user engagement. The design framework applied in this study, integrating CBT-informed exposure

with social learning theory and Bloom's revised taxonomy, may also be adapted for the development of similar VR-based serious games in other adolescent mental health contexts.

Keywords social anxiety disorder, virtual reality, serious games, cognitive behavioral therapy, usability evaluation, adolescents

INTRODUCTION

Social Anxiety Disorder (SAD) is a prevalent mental health condition characterized by persistent fear and avoidance of social interactions in which individuals anticipate negative evaluation by others (Fachtyan et al., 2023; Laldinpuii et al., 2024). During adolescence, SAD is associated with impaired peer relationships, academic difficulties, and reduced emotional well-being, with symptoms frequently persisting into adulthood if left unaddressed (Khairina et al., 2024; Ramadhan & Noorizki, 2024). These characteristics make adolescence a critical period for early and developmentally appropriate intervention.

From a cognitive-behavioral perspective, SAD is maintained through maladaptive beliefs, heightened self-focused attention, and avoidance of anxiety-provoking situations (Gilboa-Schechtman & Azoulay, 2022). Exposure-oriented practice is therefore a central component of evidence-informed interventions, enabling individuals to confront feared situations in a structured manner and gradually reduce avoidance. However, despite the established effectiveness of Cognitive Behavioral Therapy (CBT) (Jeong et al., 2021; Savitri et al., 2023), many adolescents encounter significant barriers to accessing treatment (N. U. Dewi et al., 2021) and sustaining engagement with traditional therapeutic modalities (Ng et al., 2020).

Limited availability of trained therapists, high treatment costs, stigma associated with mental health care, and low adolescent engagement collectively constrain the reach of conventional interventions (Benton et al., 2021; Torous et al., 2021). These challenges are particularly pronounced in under-resourced regions, where access to specialized mental health services is often limited. Consequently, scalable and accessible alternatives that can support engagement beyond traditional clinical settings are increasingly needed.

Digital mental health interventions (Bond et al., 2023) have emerged as promising approaches to address these challenges by leveraging technology to enhance accessibility and user engagement. Virtual reality (VR) offers immersive and controllable environments in which exposure-oriented practice can be conducted safely and consistently (Damianova & Berrezueta-Guzman, 2025). Virtual reality exposure therapy (VRET), grounded in CBT principles, enables users to engage with simulated social situations that may be difficult to reproduce reliably in real-world contexts (Bender & Broderick, 2021).

Nevertheless, VR-based interventions alone do not guarantee sustained engagement, especially among adolescent users. Serious games that integrate goal-oriented interaction, feedback, and progression mechanics have demonstrated potential to enhance motivation and adherence in digital health contexts (Maxim & Arnedo Moreno, 2023). Despite this promise, prior research has frequently examined CBT-based digital tools, VRET systems, and serious games in isolation (Liu et al., 2022). Integrated solutions that cohesively combine CBT-informed exposure, immersive VR, and engagement-oriented game design, while remaining portable and adolescent-friendly, remain relatively limited.

In addition, many existing VR-based mental health systems rely on tethered or high-cost hardware configurations, restricting their scalability and practical deployment (Rimer et al., 2021). Such technological constraints limit adoption in schools, community settings, and low-resource environments, where accessible interventions are most needed (Fradette et al., 2025). These limitations underscore

the importance of designing portable, usability-focused VR interventions that align with both therapeutic principles and adolescent user characteristics.

To address these gaps, this study introduces SAVIRE (social anxiety–virtual reality–serious game), a portable VR-based serious game designed to support exposure-oriented practice for adolescents with SAD. SAVIRE integrates CBT-informed exposure principles with immersive VR interaction and serious game mechanics. Social learning theory and Bloom's Revised Taxonomy are employed as design heuristics to structure interaction progression and scenario complexity, rather than as outcome models to be empirically tested.

Given the early-stage nature of the intervention, the present study does not aim to evaluate clinical effectiveness. Instead, it focuses on usability, user experience, perceived acceptability, and feasibility as foundational indicators of readiness for further development. Accordingly, the study is guided by the following research questions:

- **RQ1:** How usable is the SAVIRE prototype for adolescents with social anxiety disorder, as measured through standardized usability and user experience instruments?
- **RQ2:** How do adolescents and mental health professionals perceive the acceptability and therapeutic appropriateness of SAVIRE as a VR-based serious game for exposure-oriented practice?
- **RQ3:** To what extent does usability evidence support SAVIRE's feasibility as a scalable and portable digital intervention for adolescents with social anxiety disorder?
- **RQ4:** What design features of SAVIRE are perceived as most supportive of engagement and emotional comfort during simulated social exposure?

By addressing these questions, this study contributes to the field of digital mental health by presenting a clearly scoped, usability-driven evaluation of a portable VR serious game for adolescent social anxiety. The findings provide design-relevant and methodological insights that inform iterative system development and future efficacy-focused research.

LITERATURE REVIEW

This section synthesizes prior theoretical and empirical work relevant to the design and early-stage evaluation of SAVIRE, a portable Virtual Reality Serious Game (VRSG) intended to support exposure-oriented practice for adolescents with Social Anxiety Disorder (SAD). The section establishes a clear conceptual and methodological foundation for the study's research questions (RQ1–RQ4). Specifically, the review: (1) situates the study within the broader context of digital mental health interventions for adolescents, (2) examines virtual reality exposure therapy (VRET) and serious games as complementary approaches, (3) justifies usability, acceptability, and user experience as primary evaluation outcomes in early-stage systems, and (4) clarifies the role of learning theories as design-oriented frameworks rather than outcome models. Accordingly, this review emphasizes design feasibility and usability considerations, rather than clinical outcome effectiveness.

DIGITAL MENTAL HEALTH INTERVENTIONS FOR ADOLESCENTS

The increasing prevalence of mental health challenges among adolescents has intensified the need for scalable and accessible intervention models beyond traditional face-to-face therapy (McGorry et al., 2022). Digital mental health interventions have emerged as viable approaches for extending the reach of evidence-informed treatments, particularly in contexts characterized by limited clinical resources, geographic barriers, and social stigma (Banerjee et al., 2020).

For adolescent users, digital interventions that emphasize interactivity, autonomy, and self-paced engagement align well with developmental preferences and contemporary patterns of technology use (Nisa & Handayani, 2025; Przybylski & Weinstein, 2017). Prior research indicates that such systems may reduce barriers to participation by providing privacy, flexibility, and a diminished sense of social

judgment (Raj et al., 2024; Stalmach et al., 2025). However, digital delivery alone does not guarantee meaningful engagement or sustained use. Usability, acceptance, and perceived relevance (Sawrikar & Mote, 2022) are increasingly recognized as critical determinants of whether adolescents interact with digital mental health systems as intended.

Despite rapid technological advancement, many existing digital interventions for anxiety remain limited to web- or mobile-based platforms, offering limited experiential fidelity for exposure-oriented practice. These limitations have driven growing interest in immersive technologies – particularly Virtual Reality (VR) – as alternative delivery mechanisms capable of supporting realistic yet controlled interaction scenarios. This body of work provides an important contextual foundation for RQ3, which examines the feasibility of portable VR systems as scalable mental health tools.

Virtual Reality Exposure Therapy for Social Anxiety Disorder

Virtual Reality Exposure Therapy (VRET) represents a technologically mediated extension of exposure-based Cognitive Behavioral Therapy (CBT) (van Loenen et al., 2022). Foundational studies have demonstrated that virtual environments can elicit emotional and physiological responses (Rothbaum et al., 1995) comparable to real-world social situations, supporting their use in anxiety-related exposure contexts.

Within the domain of social anxiety disorder, VRET enables repeated and structured engagement with anxiety-provoking social scenarios, such as public speaking or interpersonal interaction, under controlled and customizable conditions (Emmelkamp et al., 2020). Empirical studies and systematic reviews have reported positive clinical outcomes when VRET was implemented as part of therapist-guided CBT protocols (Carl et al., 2022). However, the majority of this literature prioritizes symptom reduction and clinical efficacy, with comparatively limited attention to system usability, user experience, and deployment feasibility (Benbow & Anderson, 2019), factors that are particularly salient for adolescent users.

Moreover, many VRET implementations rely on tethered or high-cost hardware configurations and require continuous clinician involvement (Singha & Singha, 2025), limiting their applicability in non-clinical or resource-constrained settings. These constraints raise important questions regarding whether such systems are usable, acceptable, and practical for adolescents outside specialized clinics. Such considerations directly inform RQ1 and RQ3, which focus on usability and scalability rather than therapeutic effectiveness.

Serious Games and Engagement in Adolescent Mental Health

Serious games integrate game mechanics with non-entertainment objectives to enhance motivation, engagement, and persistence (Elmunsyah et al., 2021). In adolescent mental health contexts, serious games have been associated with increased emotional involvement, intervention, and willingness to engage with intervention content, particularly among users who may be reluctant to participate in conventional therapeutic formats (Cheng et al., 2019).

Game-based environments may provide psychologically safe spaces in which adolescents can explore social interactions and coping strategies without immediate real-world consequences (Rosyid et al., 2021; Zheng et al., 2021). However, prior studies indicate that many serious games for mental health either operate independently of immersive VR environments or lack explicit integration with structured therapeutic approaches such as CBT (Sabbar et al., 2024). As a result, their capacity to support systematic exposure and skill-oriented practice remains limited.

Conversely, VR-based CBT systems often prioritize exposure realism while paying less attention to motivational and experiential design principles derived from game research (Tabbaa et al., 2020). This separation between therapeutic structure and engagement design has resulted in relatively few integrated systems that cohesively combine immersive exposure with game-based interaction. Addressing

this fragmentation underpins the rationale of the present study and informs RQ2 and RQ4, which examine user experience quality and the perceived relevance of system design features.

Usability and User Experience in VR-Based Mental Health Systems

Usability refers to the extent to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction (Magylaitė et al., 2022). In digital mental health research, usability is increasingly treated as a foundational requirement rather than a secondary technical concern (Balcombe & De Leo, 2022). Systems with poor usability may increase cognitive load, frustration, or anxiety, thereby undermining their intended supportive role (Ngabo-Woods et al., 2025).

Standardized instruments such as the System Usability Scale (SUS) and the User Experience Questionnaire (UEQ) are widely used to assess usability and experiential quality in health technologies (Hajesmaeel-Gohari et al., 2022), including VR-based applications (Bruni et al., 2025). In early-stage intervention research (Stawarz et al., 2018), usability-focused and experience-focused evaluation provides essential evidence on whether a system is suitable for iterative refinement and subsequent efficacy-oriented investigation.

In VR-based anxiety interventions, usability encompasses additional dimensions such as interaction naturalness, comfort, immersion, and perceived safety (Pardini et al., 2022). Research suggests that systems perceived as easy to use and emotionally manageable are more likely to be accepted and used repeatedly (Shahid et al., 2024). For adolescents with social anxiety characteristics, minimizing interaction complexity and technical friction is particularly important. These considerations directly justify the emphasis of RQ1 and RQ2 on usability and user experience evaluation.

Learning Theories as Design-Oriented Frameworks

Some digital mental health systems draw on learning theories to inform the structure and progression of interactions. In the present study (Amsari et al., 2024; Presti et al., 2025), social learning theory (SLT) and Bloom's revised taxonomy are explicitly applied as design-oriented frameworks rather than as theoretical models to be empirically tested. SLT emphasizes learning through observation, modelling, and reinforcement, which conceptually aligns with simulated social interaction in virtual environments. Bloom's taxonomy provides a structured approach to sequencing task complexity, supporting gradual increases in interaction demands (A. K. Dewi et al., 2024).

Importantly, social anxiety disorder is not framed here as a traditional educational learning problem. Learning theories are not operationalized as outcome constructs, nor are learning gains empirically measured. Instead, these frameworks guide scenario design and progression to ensure that exposure tasks are organized, predictable, and psychologically manageable (Pattiasina, Rosyid, Handayani, Junaedi, Trianto, & Octadianto, 2024). This design-oriented application directly supports RQ4, which explores how specific system features are perceived as supportive of engagement and emotional comfort during exposure-oriented practice.

Research Gap and Alignment with Research Questions

The synthesis of prior research reveals several interconnected gaps. First, although VRET and serious games have independently demonstrated promise for anxiety-related interventions, integrated VR serious games that cohesively combine CBT-informed exposure principles with engagement-focused design remain scarce, particularly for adolescent populations (Stasolla et al., 2025). Second, many existing systems rely on non-portable or resource-intensive hardware, limiting scalability and accessibility in non-clinical contexts (Pattiasina, Rosyid, Handayani, Junaedi, & Trianto, 2024). Third, usability, acceptability, and user experience are often underrepresented as primary evaluation outcomes in early-stage VR mental health research (Zarei et al., 2025).

To address these gaps, this study introduces SAVIRE, building upon an engineering-oriented framework that establishes the technical feasibility and modular logic required for immersive social anxiety simulations (Pattiasina et al., 2025). The study prioritizes usability, user experience, acceptability, and perceived feasibility as central evaluation outcomes, leading to the formulation of four research questions: RQ1 and RQ2 examine usability and perceived appropriateness from adolescent and professional perspectives; RQ3 addresses portability and scalability; and RQ4 explores the perceived relevance of system design features. This alignment ensures conceptual coherence among the literature, the research questions, and the study's methodological approach.

METHODOLOGY

This study employed a design-oriented, mixed-method usability evaluation to assess the feasibility, usability, and perceived acceptability of a portable virtual reality serious game (VRSG) designed to support exposure-oriented practice for adolescents with social anxiety disorder (SAD). Consistent with the early-stage nature of the intervention, the methodology prioritizes system design validation and user experience assessment, rather than clinical efficacy testing.

The methodological approach was structured into six components: study design, participants, instruments, procedure, analysis, and a separate system description section detailing the developed VR system.

STUDY DESIGN

A two-phase exploratory study was conducted to address the research questions (RQ1–RQ4). The study adopted a cross-sectional usability evaluation design, combining quantitative usability metrics with qualitative feedback.

- Phase 1 focused on expert review by mental health professionals to evaluate user experience quality and perceived therapeutic appropriateness (RQ2).
- Phase 2 involved adolescent users diagnosed with SAD to assess usability, acceptability, and perceived engagement during system use (RQ1, RQ3, RQ4).

No control group or pre-post clinical comparison was employed, as the study did not aim to evaluate treatment effectiveness. Instead, the design emphasizes feasibility and readiness for further development.

PARTICIPANTS

Two participant groups were involved in the evaluation of the SAVIRE prototype: adolescent users and expert reviewers. The inclusion of both groups was intended to capture usability, user experience, and perceived therapeutic appropriateness from complementary end-user and professional perspectives, in line with the study's usability-focused research questions (RQ1–RQ4).

Adolescent users

A total of 20 adolescents diagnosed with social anxiety disorder (n = 20) participated in the usability evaluation phase. Participants were recruited from a clinical setting using purposive sampling. They were screened against predefined inclusion and exclusion criteria to ensure both relevance to the target user group and safe interaction with virtual reality (VR) technology.

The inclusion and exclusion criteria are presented in Table 1. These criteria were explicitly defined to support early-stage usability and user experience evaluation rather than to assess clinical effectiveness or stratify symptom severity. Inclusion criteria ensured that participants experienced social anxiety symptoms aligned with the exposure scenarios implemented in the system and fell within the intended adolescent–young adult age range for autonomous interaction. Exclusion criteria were primarily safety-driven and aligned with established recommendations for VR use, including exclusion of individuals with epilepsy, severe motion sickness, or comorbid conditions that could compromise VR

tolerance. Applying these criteria minimized the risk of adverse effects during exposure sessions and ensured that participants could meaningfully engage with the system interface and interaction mechanics.

Table 1. Inclusion and exclusion criteria for participant selection

Inclusion criteria	Exclusion criteria
Aged between 17 and 24 years	History of epilepsy or photosensitive seizures
Diagnosed with moderate to severe SAD (based on LSAS and DSM-5 criteria)	Comorbid psychiatric conditions affecting VR tolerance
Willingness to participate and provide informed consent (with parental consent if minor)	Susceptibility to motion sickness

To support transparent interpretation of usability and user experience findings, the demographic characteristics of the adolescent participants are summarized in Table 2. Age range, gender, and educational level are reported to provide contextual information relevant to interaction preferences, autonomy, and familiarity with digital technologies, which may influence usability perceptions among adolescents. These demographic variables were not treated as predictors or outcome measures and were not subjected to inferential analysis; instead, they were used to contextualize the sample in this exploratory usability study.

Table 2. Demographic characteristics of adolescent participants (n = 20)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	7	35%
	Female	13	65%
Education level	High School	5	25%
	University (undergraduate)	15	75%
Age group	17–20 years	12	60%
	21–24 years	8	40%

The adolescent participants ranged in age from 17 to 24 years and represented both secondary and undergraduate education levels. This age distribution aligns with the intended target users of the SAVIRE system and reflects late-adolescent developmental characteristics relevant to self-directed engagement and autonomous use of VR-based interventions.

All procedures involving adolescent participants received formal ethical approval from the Research Ethics Committee of the State University of Malang (UM, Indonesia) (Approval No. 21.7.13/UN32.14/PB/2025). Written informed consent was obtained from all participants prior to participation. For participants aged 17–18 years, parental or guardian consent was obtained in accordance with national ethical guidelines. All collected data were anonymized at the point of collection and stored in encrypted, password-protected digital formats accessible only to the research team.

Expert participants

In addition to adolescent users, three mental health professionals (n = 3) participated as expert reviewers. All experts had professional experience in adolescent mental health and familiarity with cognitive behavioral therapy and anxiety-related interventions. Their role was to evaluate the SAVIRE prototype from a professional perspective, focusing on user experience quality, perceived therapeutic alignment, and design appropriateness for exposure-oriented practice.

Expert participation was intended to provide informed qualitative and experiential feedback appropriate for early-stage system development rather than statistical generalization. This expert review directly supports RQ2 by complementing adolescent usability data with professional judgments regarding the system's alignment with therapeutic principles and practical deployment considerations.

INSTRUMENTS

To address the study's usability-focused and design-focused research questions, a combination of standardized questionnaires and system-embedded measures was employed. The selected instruments were chosen to evaluate usability, user experience, and perceived acceptability, rather than clinical symptom change. This approach is consistent with the early-stage, formative nature of the intervention.

System Usability Scale

The System Usability Scale (SUS) was used to evaluate overall usability and user acceptance of the SAVIRE prototype from the perspective of adolescent participants. SUS is a widely adopted, technology-agnostic instrument comprising 10 items rated on a 5-point Likert scale. It provides a single composite score ranging from 0 to 100, enabling rapid comparison across interactive systems (Eva et al., 2025).

SUS was selected due to its strong psychometric properties, ease of administration, and suitability for early-stage digital health and VR applications. In the context of this study, SUS directly addresses RQ1, which examines the usability and acceptability of SAVIRE for adolescents with Social Anxiety Disorder. The instrument focuses on perceived ease of use, learnability, and confidence in system interaction, which are particularly relevant for exposure-oriented VR environments where excessive cognitive or technical load may interfere with engagement.

User Experience Questionnaire

The User Experience Questionnaire (UEQ) was administered to mental health professionals to assess the experiential and design-related qualities of the SAVIRE system. UEQ evaluates six dimensions of user experience: Attractiveness, Perspicuity (Ease of Understanding), Efficiency, Dependability, Stimulation, and Novelty, using a semantic differential scale (Darmawan et al., 2021).

UEQ was selected to capture expert perspectives on interaction quality, engagement potential, and perceived system reliability in an early-stage prototype. Its multidimensional structure allows evaluators to assess both pragmatic and hedonic aspects of the system, which are critical in serious game–based interventions. The expert-based UEQ evaluation supports RQ2 by examining how professionals perceive the user experience and therapeutic appropriateness of SAVIRE within an exposure-oriented context.

Qualitative feedback

In addition to standardized questionnaires, qualitative feedback was collected from both adolescent participants and expert reviewers. Adolescents were invited to share open-ended comments regarding comfort, perceived realism, pacing, and emotional safety during interaction with the system. Experts were asked to provide design-oriented feedback related to therapeutic alignment, scenario structure, and interaction flow.

Qualitative input was used to contextualize quantitative findings and to identify specific system features perceived as supportive or challenging during exposure-oriented interaction. This feedback contributes directly to RQ4, which explores perceived design features that support engagement and emotional comfort.

In-game self-reported distress ratings

To provide contextual insight into adolescents' emotional experience during exposure-oriented game-play, the system recorded in-game self-reported distress levels using a simplified version of the Subjective Units of Distress Scale (SUDS). Ratings ranged from 1 (no distress) to 10 (extreme distress) and were collected at predefined interaction checkpoints embedded within each scenario stage.

The SUDS scale was adapted for in-game use to support rapid, low-burden self-reflection without interrupting immersion. To facilitate comprehension and reduce cognitive demand, each numerical range was accompanied by brief descriptive labels and color-coded visual cues, as summarized in Table 3. This design supports intuitive reporting of momentary emotional states during exposure tasks.

Table 3. In-game self-reported distress rating scale (adapted SUDS)

Score Range	Description	Color
1 – 3	*Calm* – User experiences little to no distress and remains at ease within the interaction context.	**Green**
4 – 5	*Mild Anxiety* – Mild tension or nervousness that remains controllable and does not interfere with task engagement.	**Yellow**
6 – 7	*Moderate Anxiety* – User experiences heightened unease accompanied by increased restlessness and cognitive effort.	**Orange**
8 – 9	*High Anxiety* – User reports pronounced discomfort with noticeable physiological reactions during the interaction.	**Red**
10	*Extreme Anxiety* – User experiences an intense anxiety response approaching panic, indicating a need to pause or disengage from the task.	**Dark Red**

Importantly, these distress ratings were not intended as clinical outcome measures and were not used to evaluate symptom reduction, habituation effects, or therapeutic efficacy. Instead, they functioned as experiential indicators to support descriptive interpretation of emotional comfort, perceived safety, and feasibility during repeated interaction with the system.

Within the scope of this study, the distress ratings were used solely to contextualize usability findings and to assess whether the exposure scenarios remained emotionally manageable in a portable, self-directed setting. As such, they directly support RQ3, which examines the feasibility and readiness of the SAVIRE system for repeated use outside traditional clinical environments.

Procedure

The study procedure was designed to evaluate the usability, user experience, and perceived feasibility of the SAVIRE prototype in a controlled yet low-burden setting. Given the exploratory nature of the study, the procedure prioritized participant safety, clarity of interaction, and consistency of exposure across sessions. The procedure consisted of two sequential evaluation phases: an expert review phase and an adolescent usability testing phase.

Expert review phase

The expert review phase involved three licensed mental health professionals with experience in Cognitive Behavioral Therapy and adolescent mental health. Prior to system interaction, experts were provided with a brief overview of the study objectives, the intended user group, and the evaluation scope, emphasizing that the system was an early-stage prototype.

Experts interacted with the SAVIRE system independently using the standalone VR headset. They were encouraged to explore all available scenarios and interaction features relevant to exposure-oriented practice. Following system use, experts completed the User Experience Questionnaire (UEQ) and provided written qualitative feedback focusing on interaction flow, scenario pacing, clarity of objectives, and perceived therapeutic appropriateness. No time constraints were imposed to allow evaluators to interact with the system at their own pace.

Adolescent usability testing phase

Following expert evaluation and minor interface refinements, usability testing was conducted with adolescent participants diagnosed with social anxiety disorder. Prior to participation, all participants received a standardized orientation explaining the purpose of the study, system operation, and safety considerations related to VR use. Informed consent was obtained from participants, with parental consent secured where required.

Each participant engaged in an individual session using the SAVIRE system on a standalone VR device. The session included a brief familiarization period to allow users to adjust to the VR environment and interaction controls. Participants then progressed through a predefined sequence of exposure-oriented scenarios designed with increasing interaction demands.

During system interaction, participants self-reported perceived distress using a simplified numerical scale at predefined checkpoints embedded within the system. These checkpoints were intended to capture experiential responses without interrupting immersion. Participants were free to pause or discontinue the session at any time if discomfort occurred.

Upon completion of the session, participants completed the SUS. Open-ended feedback was subsequently collected to capture perceptions related to comfort, realism, pacing, and overall experience.

Ethical and safety considerations

Throughout the procedure, measures were implemented to ensure participant safety and well-being. The VR sessions were monitored by research staff, and clear withdrawal criteria were communicated prior to participation. The exposure scenarios were designed to avoid extreme or unpredictable stimuli, emphasizing gradual progression and emotional safety.

No therapeutic claims or clinical interventions were administered as part of the procedure. The study focused solely on usability and experiential evaluation to inform subsequent system refinement and future research.

Analysis

Data analysis was conducted using a descriptive, usability-oriented approach consistent with the exploratory nature of the study. Quantitative data obtained from the User Experience Questionnaire (UEQ) and the System Usability Scale (SUS) were analyzed using their respective standardized scoring procedures. Given the prototype-stage focus of the research, inferential statistical testing was not performed.

Quantitative analysis

For the UEQ, mean scores were calculated for each of the six UEQ dimensions, as well as an overall user experience score. The average score for each UEQ dimension (S_d) was computed by averaging participant response scores across all respondents:

$$S_d = \frac{\sum_{i=1}^{N} R_{i,d}}{N} \quad (1)$$

S_d = average score for UEQ aspects (d)
$R_{i,d}$ = response score of users (i) for UEQ aspects (d)
N = total number of respondents

where $R_{i,d}$ represents the response score of participant i for UEQ dimension d, and N denotes the total number of respondents.

The overall UEQ score (S_{UEQ}) was then calculated as the mean of all dimension scores:

$$S_{UEQ} = \frac{\sum_{d=1}^{N} S_d}{D} \quad (2)$$

where D represents the total number of UEQ dimensions.

For the System Usability Scale, individual item responses were converted to adjusted scores according to the standard SUS scoring protocol. For odd-numbered items, one point was subtracted from the raw response; for even-numbered items, the response was subtracted from five. The adjusted item scores were then summed and multiplied by 2.5 to yield a total SUS score ranging from 0 to 100:

$$SUS = \left(\sum_{i=1}^{10} S_i\right) \times 2.5 \quad (3)$$

where S_i = the adjusted score for each question (Q1–Q10), calculated as follows:

Higher SUS scores indicate greater perceived usability. To facilitate interpretation, SUS scores were categorized according to established usability benchmarks: scores above 80 indicate excellent usability, scores between 68 and 80 indicate good usability, scores between 50 and 67 indicate acceptable usability with room for improvement, and scores below 50 indicate poor usability (Table 4).

Table 4. SUS score interpretation

SUS score range	Usability level
Above 80	Excellent usability
68 - 80	Good usability
50 - 67	OK usability (needs improvement)
Below 50	Poor usability (significant issues)

Qualitative analysis

In addition to quantitative measures, qualitative feedback was collected from both adolescent participants and expert reviewers. Open-ended comments focused on perceived immersion, interface clarity, emotional comfort, and interaction pacing during simulated exposure scenarios. These qualitative insights were analyzed descriptively to identify recurring themes relevant to user experience, engagement, and perceived safety.

Qualitative findings were used to contextualize quantitative usability scores and to inform iterative refinements to system elements such as narrative flow, non-player character (NPC) responsiveness, and scenario difficulty progression. This mixed descriptive approach supported triangulation between numerical usability indicators and user-reported experiences.

Mapping of measures to research questions

The analysis framework was explicitly structured to ensure alignment between the selected evaluation measures and the study's research questions. The System Usability Scale (SUS) served as the primary quantitative measure addressing RQ1, capturing adolescents' perceived usability, ease of use, and acceptance of the SAVIRE system during exposure-oriented interaction.

Expert-based User Experience Questionnaire (UEQ) results informed RQ2 by providing professional judgments on experiential quality, interaction clarity, and perceived therapeutic appropriateness of the system design. These expert perspectives complemented end-user data by situating usability findings within a clinical and design-relevant context.

Descriptive trends across usability scores, in-game distress ratings, and session completion supported RQ3, which examines feasibility and readiness for repeated use in portable, non-clinical settings. Rather than indicating therapeutic change, these measures contextualized whether the system remained emotionally manageable and practically usable across exposure scenarios.

Finally, qualitative feedback from both adolescents and experts directly informed RQ4 by identifying specific design features, such as predictable NPC behavior, gradual scenario progression, and controllable pacing, that were perceived as most supportive of engagement and emotional comfort during simulated social exposure.

SYSTEM DESCRIPTION

This section describes the Social Anxiety–Virtual Reality–Serious Game (SAVIRE) system as a developed Virtual Reality Serious Game designed to support exposure-oriented practice for adolescents with Social Anxiety Disorder (SAD). The description focuses on what was built, how the system functions, and how its design supports graded exposure and user engagement. Development processes and implementation methodologies are not discussed here, as the emphasis is on system features and interaction logic relevant to the study's research questions.

WHAT WAS BUILT

SAVIRE is a portable, standalone VR serious game implemented on the Meta Quest 3S headset. The system was designed to enable adolescents to engage in simulated social situations commonly associated with social anxiety in a safe, controlled, and repeatable virtual environment. SAVIRE integrates CBT-informed exposure principles with immersive VR interaction and game-based mechanics to support autonomous, self-paced practice.

The system operates without external sensors or tethered hardware, allowing untethered use in non-clinical settings such as homes, schools, or community environments. User interaction is primarily conducted through natural head movement and handheld VR controllers, with comfort settings enabled to reduce motion sickness and cognitive overload.

CORE FEATURES

The core features of SAVIRE were designed to support usability, emotional comfort, and sustained engagement:

- **Immersive Environment:** A realistic virtual supermarket environment was constructed to represent everyday social situations that frequently trigger anxiety, such as crowd navigation, queuing, and interpersonal proximity (Figure 2). Ambient sounds and visual cues were used to enhance realism while maintaining user comfort.
- **Guided Interaction and Feedback:** Users receive clear visual guidance through directional cues and task prompts to minimize uncertainty during interaction. Immediate feedback is provided through in-game scoring, NPC reactions, and post-task summaries to reinforce reflection and self-awareness.
- **Self-Reported Anxiety Tracking:** At predefined checkpoints, users report their perceived anxiety levels using a simple in-game scale. These self-reports are used descriptively to track changes in emotional response across exposure stages rather than as clinical outcome measures.

Figure 2. Interactive supermarket environment

SCENARIO STRUCTURE

SAVIRE consists of three sequential scenarios that increase social complexity and interaction demand. These scenarios are designed to approximate graded exposure while maintaining psychological safety.

- **Stage 1: Supermarket Exploration**
  Users navigate the virtual environment by following directional markers while avoiding collisions with NPCs. This stage emphasizes orientation, basic navigation, and initial exposure to social presence with minimal interaction demand (Figure 3).

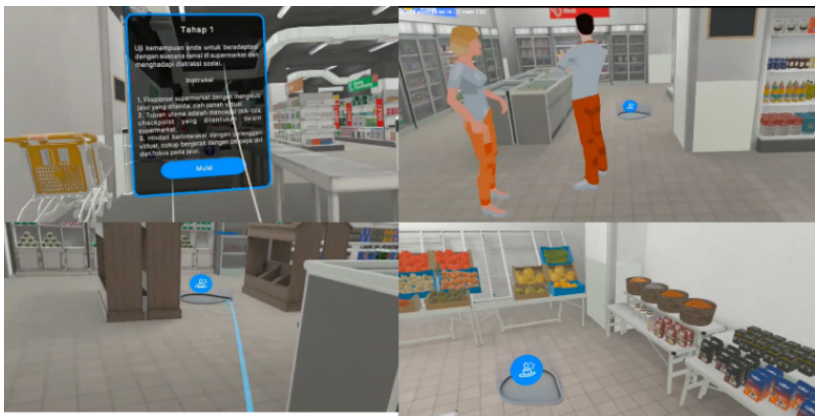

Figure 3. Exploration and navigation checkpoint

- **Stage 2: Item Search with Social Interference**
  Users are tasked with locating specific items while encountering NPC-related obstacles such as blocking, crowding, or proximity. Users may choose to wait, avoid, or proceed, allowing multiple behavioral responses without penalty. These interactions increase social pressure while preserving user control (Figure 4).
- **Stage 3: Checkout and Exit Simulation**
  The final stage introduces direct social interaction at a checkout counter, including queuing, interruptions, and turn-taking challenges. User responses are categorized as assertive, neutral, or passive, contributing to a cumulative performance summary and anxiety reflection (Figure 5).

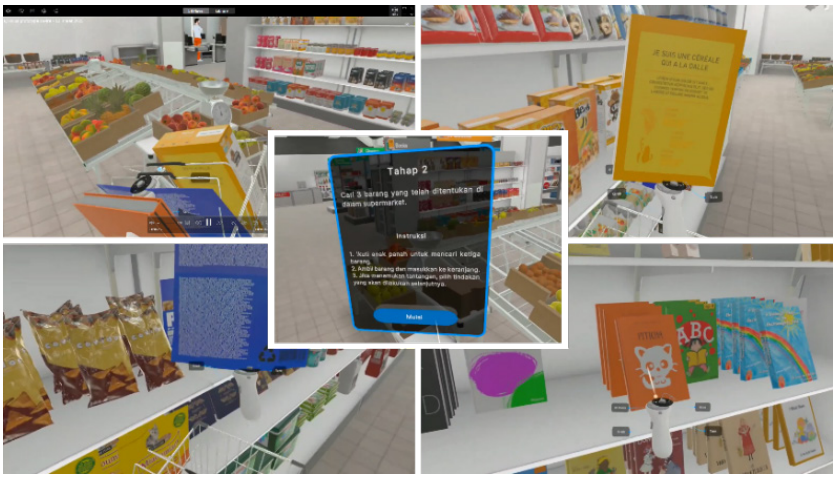

Figure 4. Item retrieval with NPC interference

Figure 5. Checkout and exit

NPC Interaction Logic

Non-player characters (NPCs) are a core component of SAVIRE's exposure-oriented interaction design. NPC behavior is implemented using **rule-based logic** rather than adaptive artificial intelligence, prioritizing predictability, emotional safety, and ease of use during early-stage evaluation.

User–NPC interactions follow a dual-choice mechanism. During social encounters, users select either Active Engagement, which initiates an interaction and triggers immediate NPC feedback, or Passive Avoidance, which allows task progression without social response. These choices are processed by a scoring algorithm that reflects interaction efficiency rather than therapeutic performance or behavioral correctness.

NPC responses are intentionally consistent and limited to simple reactions (e.g., acknowledgment or disengagement) to reduce cognitive load and prevent anxiety escalation. This design supports low-risk behavioral rehearsal and observational learning while maintaining user comfort – an important consideration for adolescents with social anxiety characteristics.

Figure 6 provides a code-level representation of this logic, illustrating the conditional branch that triggers NPC feedback and score increments based on the user's interaction state. This ensures a

transparent and predictable feedback loop, which is essential for grounding the serious game mechanics in a verifiable technical framework.

```
if (playerChoice == "engagement")
    npc.React();
    score += 10;
} else {
    score += 0;
    // Avoidance State
}
```

Figure 6. Interaction state and feedback logic script

Exposure Progression Framework

Exposure progression in SAVIRE is structured through incremental increases in task complexity, social density, and interaction demand, rather than through symptom severity or therapeutic outcome levels. This approach aligns with the study's usability and design-focused scope and supports controlled, predictable exposure experiences for adolescent users.

To organize this progression, principles from Social Learning Theory (SLT) and Bloom's Revised Taxonomy (BRT) are applied as design-oriented heuristics, consistent with their role as described in the Literature Review. These frameworks inform how interaction demands are sequenced across scenarios, rather than serving as theoretical models for outcome evaluation.

As illustrated in Figure 7, early stages emphasize attention, recognition, and basic understanding, reflected in simple navigational and observational tasks within low-density social environments. Subsequent stages introduce reproduction and application, where users actively respond to NPC interactions and make decisions during simulated social encounters. Later stages incorporate reinforcement and evaluative elements through feedback, scoring, and reflective summaries following each scenario.

Figure 7. Design-oriented exposure progression framework

This structured progression ensures that users move from low-demand interactions toward more complex social decision-making in a gradual and psychologically manageable manner. SLT principles are operationalized through observation of NPC behavior, modeling of social responses, and immediate reinforcement via system feedback. Bloom's taxonomy supports the sequencing of interaction demands, ensuring that exposure tasks increase in cognitive and behavioral complexity across scenarios.

Importantly, SLT and Bloom's Revised Taxonomy are not treated as outcome frameworks. The system does not assess learning achievement or therapeutic change directly. Instead, these frameworks guide scenario structure, interaction flow, and exposure pacing, supporting exposure-oriented practice that is developmentally appropriate, predictable, and aligned with adolescent usability needs.

RESULT AND USABILITY EVALUATION

To evaluate the usability, acceptability, and feasibility of the SAVIRE prototype, an exploratory evaluation was conducted involving adolescent users diagnosed with Social Anxiety Disorder (SAD) and mental health professionals. In line with the early-stage and design-oriented nature of this study, descriptive analyses were prioritized to examine usability, user experience, and perceived design relevance rather than clinical efficacy. The findings directly address RQ1–RQ4.

EXPERT REVIEW FINDINGS

Three mental health professionals (C, P1, P2) evaluated SAVIRE using the User Experience Questionnaire (UEQ) (Figure 8). Although the sample size was small (n = 3), expert involvement was intended to provide informed qualitative and experiential feedback appropriate for early-stage system validation rather than statistical generalization.

Figure 8. Expert evaluation using UEQ dimensions

As summarized in Table 5, mean scores across all six UEQ dimensions exceeded the positive benchmark threshold (>0.8), with average values ranging from 2.67 to 2.83 on a scale from −3 to +3. The highest scores were observed for *Ease of Understanding* and *Stimulation* (both 2.83), indicating that experts perceived the system as intuitive and engaging for adolescent users. Lower, but still positive, scores in *Dependability* and *Novelty* (2.67) highlighted areas for further technical and experiential refinement.

Importantly, expert feedback explicitly addressed therapeutic alignment. Experts noted that SAVIRE's predictable interaction flow, graded exposure structure, and NPC response consistency aligned with CBT-informed exposure principles. Specific recommendations, such as increasing reflection time between interactions and enhancing NPC expressiveness, were used to refine pacing and feedback mechanisms. These findings support RQ2 by demonstrating that professionals perceived SAVIRE as therapeutically appropriate at the design level, rather than as a clinically validated intervention.

Table 5. Average UEQ dimension scores

Evaluator	Dimension					
	A	**U**	**E**	**D**	**S**	**N**
C	2.33	2.75	2.75	2.5	2.75	2.75
P1	3	3	3	3	3	2.5
P2	2.83	2.75	2.5	2.5	2.75	2.75
AVG score	**2.72**	**2.83**	**2.75**	**2.67**	**2.83**	**2.67**

USABILITY EVALUATION BY ADOLESCENTS

Twenty adolescents with clinically diagnosed SAD completed the System Usability Scale (SUS) following hands-on interaction with SAVIRE. Individual and aggregate scores (Table 6) directly address RQ1, indicating strong usability and acceptance among adolescent users.

Table 6. Average SUS score

Participant	Age	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total score	SUS score
P1	24	4	2	5	3	4	2	5	3	4	2	30	75
P2	20	4	3	5	4	4	3	5	3	5	3	27	67.5
P3	24	4	2	4	3	4	3	5	4	4	2	27	67.5
P4	21	3	2	4	3	3	2	4	4	5	2	26	65
P5	20	3	2	4	3	4	3	4	4	5	2	26	65
P6	18	5	1	5	2	4	3	5	1	5	1	36	90
P7	22	5	2	4	2	5	1	5	3	5	2	34	85
P8	22	4	1	4	1	5	2	4	1	5	1	36	90
P9	19	5	1	5	2	5	1	4	2	5	1	37	92.5
P10	19	4	2	4	1	4	1	5	2	5	2	34	85
P11	21	3	1	3	1	4	2	5	1	3	1	32	80
P12	20	5	1	5	1	5	1	3	2	3	2	34	85
P13	18	5	3	5	1	5	1	4	2	4	3	33	82.5
P14	17	5	2	4	1	4	1	4	1	5	1	36	90
P15	17	4	1	4	2	4	3	4	1	5	2	32	80
P16	22	3	1	5	2	3	1	4	2	5	1	33	82.5
P17	21	2	3	2	3	5	2	5	2	3	2	25	62.5
P18	19	5	1	5	2	5	2	4	1	4	3	34	85
P19	18	3	1	3	1	5	1	5	1	5	1	36	90
P20	19	4	1	4	1	5	2	4	1	5	2	35	87.5
												Mean SUS score	**80.38**

Feasibility and Scalability Indicators

Beyond usability scores, feasibility was assessed through observed interaction completion, self-reported comfort, and successful deployment on a standalone VR device. Participants completed all exposure stages without technical assistance, and no adverse events related to VR discomfort were reported.

The untethered Meta Quest deployment, combined with high usability scores, supports SAVIRE's feasibility as a scalable intervention suitable for non-clinical or resource-limited contexts. These findings respond to RQ3 by demonstrating that usability evidence can meaningfully support claims of portability and scalability at the prototype stage.

Design-Relevant Qualitative Feedback

Qualitative comments from adolescents reinforced quantitative findings. Participants emphasized perceived safety, controllability, and emotional comfort:

- "I liked how I could go at my own pace; it felt safe."
- "It felt real enough to practice, but not scary."

These perceptions highlight the importance of predictable interaction logic, gradual scenario progression, and limited social pressure – key design features that participants associated with engagement and emotional regulation. This directly addresses RQ4 by identifying which system elements were perceived as most supportive during exposure-oriented interaction.

Discussion

This study examined the usability, user experience, and perceived feasibility of SAVIRE, a portable VR-based serious game designed to support exposure-oriented practice for adolescents with Social Anxiety Disorder. Consistent with the early-stage and design-driven scope of the research, the discussion focuses on how the findings contribute to design knowledge, system readiness, and methodological positioning for future digital mental health interventions, rather than clinical effectiveness.

From a usability perspective, the consistently high System Usability Scale (SUS) score indicates that adolescent users were able to interact with SAVIRE with minimal cognitive and technical friction. In anxiety-sensitive contexts, usability is not merely a matter of convenience but a prerequisite for engagement, as interaction difficulties or ambiguity may amplify avoidance tendencies (Freeman et al., 2018). The strong SUS performance, therefore, suggests that SAVIRE's interaction flow, navigation structure, and task clarity were appropriate for adolescent users and compatible with an exposure-oriented use. Importantly, this finding supports usability as a foundational design requirement for VR interventions targeting social anxiety, where emotional load must be carefully balanced with interaction demands.

The use of SUS as a primary usability measure is particularly relevant in this context. As a validated and widely adopted instrument, SUS provides a reliable indicator of perceived ease of use, learnability, and confidence in system interaction across diverse technologies (Vlachogianni & Tselios, 2021). In this study, SUS scores serve not as evidence of therapeutic benefit, but as a proxy for whether the system can be engaged with repeatedly and autonomously without introducing additional stressors. This operationalization aligns with the study's focus on feasibility and readiness rather than symptom change and supports the interpretation of usability as a meaningful design outcome in early-stage mental health systems.

Expert evaluation using the User Experience Questionnaire (UEQ) complements adolescent usability findings by situating system performance within a broader experiential and design-oriented framework. UEQ dimensions such as Perspicuity, Dependability, and Stimulation map directly onto psy-

chological constructs (Kollmorgen et al., 2025) relevant to anxiety-related interaction, including clarity of cognition, predictability of system behavior, and motivational engagement. The positive expert ratings across these dimensions suggest that SAVIRE's design supports emotional manageability and interaction coherence – key factors for exposure-based tools intended for vulnerable populations. The convergence between expert judgment and adolescent usability data strengthens the validity of the findings by demonstrating consistency across user and professional perspectives.

Beyond individual scores, the results provide broader insight into how usability intersects with emotional and social dimensions of exposure-oriented VR design. Qualitative feedback highlighted feelings of safety, controllability, and emotional comfort, which can be interpreted as indicators of reduced perceived threat and manageable cognitive load during simulated social interaction. These perceptions are closely tied to specific design choices, including predictable NPC behavior, rule-based interaction logic, and gradual scenario progression. Together, these features appear to support a balance between realism and emotional containment, enabling adolescents to engage in socially relevant practice without overwhelming distress.

These findings have implications beyond the SAVIRE system itself. They suggest that for VR-based serious games targeting social anxiety, usability should be conceptualized not only as interface efficiency but as a multidimensional construct encompassing emotional regulation, cognitive clarity, and social predictability. Designing for usability in this context involves minimizing ambiguity, supporting user control, and structuring interaction demands in a gradual and transparent manner. Such principles may enhance engagement and acceptability across diverse cultural and social settings, particularly where stigma or limited clinical access constrains traditional intervention delivery.

The study also reinforces the role of Social Learning Theory and Bloom's Revised Taxonomy as design-oriented frameworks rather than outcome models. In SAVIRE, these frameworks informed the sequencing of scenarios and interaction demands, guiding users from simple attentional engagement toward more complex social responses. The findings suggest that theory-informed structuring can contribute to predictable and psychologically manageable exposure experiences, even when learning or symptom outcomes are not directly measured. This supports the value of integrating educational and behavioral theories at the design level in early-stage digital mental health tools.

Several limitations must be acknowledged. The sample size was modest, and the study did not include clinical outcome measures or longitudinal follow-up. While usability and user experience findings provide essential design insight, they cannot be interpreted as evidence of therapeutic effectiveness. Nevertheless, these limitations are consistent with the study's formative objectives and highlight clear directions for future research. Subsequent studies should examine how usability interacts with emotional, cognitive, and social variables over time, and how exposure-oriented VR systems can be adapted to diverse user groups and cultural contexts.

In summary, this study contributes design-relevant evidence demonstrating that a portable VR serious game can achieve strong usability, perceived acceptability, and experiential coherence when usability is treated as a psychologically informed design construct rather than a purely technical metric. By operationalizing usability through validated instruments and linking findings to concrete design features, the study provides transferable insights for the development of future VR-based mental health interventions and establishes a methodologically sound foundation for subsequent efficacy-focused research.

CONCLUSION

This study presented SAVIRE, a portable virtual reality–based serious game designed to support exposure-oriented practice for adolescents with Social Anxiety Disorder. The system integrates CBT-informed exposure principles with immersive VR interaction, using Social Learning Theory and

Bloom's Revised Taxonomy as design heuristics to structure scenarios and interaction flow rather than as outcome models.

Evaluation results indicate that the SAVIRE prototype demonstrates high usability and a positive user experience. Adolescents reported an excellent mean System Usability Scale score (80.38), while expert reviewers provided favorable UEQ ratings (overall mean = 2.75), particularly in dimensions related to clarity and engagement. These findings suggest that the system's design supports ease of use, acceptability, and suitability for repeated interaction among adolescent users, highlighting the role of usability-oriented design in reducing interaction-related burden during exposure-oriented VR experiences.

A central contribution of this work is the demonstration of the feasibility of a standalone, portable VR serious game deployed on untethered hardware. By removing dependency on complex infrastructure, SAVIRE addresses practical barriers that have limited the scalability of many VR-based mental health systems, particularly in non-clinical or resource-limited contexts. The results support the potential of portability-focused VR design as a viable direction for accessible digital mental health tools.

This study was intentionally scoped as a usability- and design-focused evaluation rather than an assessment of clinical effectiveness. Limitations include a modest sample size and the absence of a control group. Future research should extend this work through controlled, longitudinal studies to examine therapeutic outcomes and sustained engagement, building on the usability and feasibility evidence established in this study.

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