Development and Evaluation of PARBIS: A Parent-Guided Augmented Reality Behavioral Intervention System for Children with ADHD

Lyndon Bermoy[1*], Jenny Orbegoso[2]

[1]Special Science Teacher V, Department of Engineering and Technology

[2] Special Science Teacher II, Department of Social Sciences Philippine Science High School - Caraga Region Campus Butuan City, Philippines

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.91200155

Received: 18 December 2025; Accepted: 24 December 2025; Published: 03 January 2026

ABSTRACT

Attention-Deficit/Hyperactivity Disorder (ADHD) presents persistent challenges in home environments where children are required to follow instructions, complete routines, and regulate emotions with limited external structure, making consistent parent-mediated behavioral intervention difficult to sustain. This study presents the development and evaluation of PARBIS, a Parent-Guided Augmented Reality Behavioral Intervention System designed to support home-based behavioral routines for children with ADHD by integrating augmented reality (AR) guidance, structured caregiver prompts, and automated behavioral analytics. PARBIS targets three core behavioral domains—instruction-following, task completion, and emotional regulation—using standardized, step-based AR-guided routines implemented in a mobile application. A design-and-development research approach was employed, incorporating user-centered system design, expert validation, parent–child usability testing, and analysis of system-generated behavioral data collected during real-world home use. Results demonstrated high routine completion rates, low redirection frequencies, and consistently high success scores across intervention sessions. Descriptive statistical analysis indicated stable behavioral engagement, while inferential analysis revealed significantly higher performance in calm-down and instruction-following routines compared to task completion routines ($p < 0.05$). Longitudinal analytics further showed sustained engagement across repeated sessions, indicating that performance gains were not solely attributable to novelty effects. These findings demonstrate that PARBIS is a feasible, usable, and data-driven parent-guided AR intervention platform that enhances behavioral engagement and consistency in home settings. By preserving caregiver agency while leveraging immersive visual scaffolding and objective analytics, PARBIS offers a novel and scalable approach to home-based behavioral support for children with ADHD.

Keywords: ADHD, Augmented Reality, Parent-Guided Intervention; Behavioral Intervention; Home-Based Intervention; Digital Health; Mobile Health Application; Human–Computer Interaction; Child Behavioral Support; Assistive Technology

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental condition characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with daily functioning and development [1]. ADHD affects children across academic, social, and home environments, often requiring continuous behavioral support beyond clinical or school-based interventions [2]. Although pharmacological treatment is widely used, behavioral interventions—particularly those implemented within natural home settings—remain essential for improving long-term functional outcomes and strengthening family dynamics [3,4].

Parents play a central role in managing ADHD-related behaviors, as many difficulties emerge during everyday routines such as following instructions, completing household tasks, and regulating emotions. Behavioral parent

training has been consistently identified as an evidence-based approach for improving compliance, reducing disruptive behaviors, and enhancing parent–child interactions [5,6]. However, effective implementation of parent-mediated strategies requires consistency, clarity, and sustained effort, which can be challenging for caregivers when children exhibit fluctuating attention and emotional regulation capacities. These challenges underscore the need for tools that support parents in delivering structured and developmentally appropriate behavioral guidance during daily routines.

Recent advancements in digital health technologies have expanded opportunities to augment behavioral interventions for children with ADHD. Mobile and digital interventions have shown promise in increasing accessibility, supporting engagement, and extending behavioral support beyond traditional clinical settings [8,9]. Digital therapeutics and game-based interventions, in particular, have demonstrated positive effects on attention and executive functioning when grounded in behavioral science principles [10,11]. Despite these advances, many existing digital solutions primarily focus on child-only interaction and provide limited scaffolding for active parent involvement, which remains a critical determinant of intervention effectiveness [5].

Augmented reality (AR) has emerged as a promising technology for creating immersive, context-aware intervention environments. By overlaying digital cues onto real-world contexts, AR can enhance attention, guide behavior, and reduce cognitive overload through visual and spatial support [16]. Research has shown that AR-based systems can improve engagement and task persistence by providing immediate, intuitive feedback and maintaining focus on task-relevant stimuli [15]. In mental health–related applications, AR has been increasingly explored for its potential to support behavioral regulation and skill acquisition through interactive and embodied experiences [15].

The integration of AR into parent-mediated behavioral interventions represents an emerging and underexplored research area. While previous studies have examined digital therapeutics, serious games, and mobile applications for ADHD management [10,12,13], fewer systems explicitly position parents as active facilitators of AR-guided behavioral routines within the home. This gap is particularly significant given strong evidence that parent involvement enhances the generalizability and sustainability of behavioral interventions across contexts [3,5]. Technologies that scaffold parent–child interaction, rather than replacing caregiver guidance, may therefore offer stronger ecological validity and practical relevance.

In response to this need, the present study introduces the Parent-Guided Augmented Reality Behavioral Intervention System (PARBIS)—a mobile AR-based platform designed to support home-based behavioral routines for children with ADHD. PARBIS targets three core behavioral domains: instruction-following, task completion, and emotional regulation. The system integrates AR visual cues with standardized parent prompts, step-based routines, and objective performance metrics to support consistent intervention delivery. By capturing session-level data such as step completion accuracy, redirection frequency, and routine duration, PARBIS enables structured monitoring of behavioral engagement and progress over time.

The development of PARBIS follows a user-centered and ethically grounded approach, emphasizing caregiver usability, child engagement, and responsible data management. The system incorporates local data storage, anonymized data export, and user-controlled data reset features to ensure participant autonomy and compliance with ethical standards for digital interventions involving minors [17]. The present study evaluates PARBIS through expert validation and parent–child usability testing to assess its feasibility, usability, and potential contribution to home-based behavioral intervention practice.

This research aims to contribute to the growing body of work on digital and augmented reality interventions for ADHD by presenting a novel parent-guided AR system grounded in behavioral science and real-world applicability. By empowering parents as active intervention facilitators and leveraging immersive technology to structure daily routines, PARBIS seeks to advance current approaches to home-based behavioral support and provide a foundation for future clinical, educational, and large-scale research applications.

REVIEW OF RELATED LITERATURE

This chapter reviews existing literature relevant to the development of the Parent-Guided Augmented Reality Behavioral Intervention System (PARBIS). The discussion is organized into five major areas: (1) ADHD and

behavioral challenges in home environments, (2) parent-mediated behavioral interventions, (3) digital and mobile interventions for ADHD, (4) augmented reality applications in behavioral and mental health contexts, and (5) identified research gaps that motivate the present study.

Attention-Deficit/Hyperactivity Disorder and Home-Based Behavioral Challenges

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental condition characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with daily functioning across multiple settings [1]. While ADHD is frequently managed in clinical and educational environments, a significant portion of functional impairment manifests within the home, where children are expected to follow instructions, complete routines, and regulate emotions with limited external structure [2]. Children with ADHD often experience difficulty sustaining attention during multi-step activities, responding consistently to parental instructions, and managing emotional responses during transitions between tasks. These challenges increase the likelihood of repeated redirection, conflict, and frustration during everyday routines [19]. Consequently, the home environment represents a critical context for intervention, particularly for strategies aimed at improving compliance, emotional regulation, and routine consistency.

Parent-Mediated Behavioral Interventions for ADHD

Behavioral parent training has been extensively validated as an effective intervention for children with ADHD. Meta-analyses indicate that parent-mediated behavioral interventions lead to significant improvements in child compliance, reductions in disruptive behavior, and enhanced parent–child relationships [5]. These interventions typically emphasize structured routines, positive reinforcement, precise instruction delivery, and consistent response strategies. More recent analyses have examined which components of behavioral parent training contribute most strongly to positive outcomes. Findings suggest that clear task structuring, consistent prompting, and immediate feedback are particularly effective in supporting behavioral change [6]. Importantly, sustained improvements have been observed when parent-mediated strategies are implemented consistently over time within naturalistic settings such as the home [7]. Despite their effectiveness, parent-mediated interventions are often challenging to implement in practice. Parents may struggle to maintain consistency, adapt instructions to fluctuating child attention, or deliver interventions during emotionally charged situations. These limitations highlight the need for supportive tools that scaffold parent implementation while preserving caregivers' active role in behavioral guidance.

Digital and Mobile Interventions for ADHD

Digital health technologies have increasingly been explored as adjuncts or alternatives to traditional ADHD interventions. Systematic reviews indicate that digital interventions can improve accessibility, engagement, and continuity of care, particularly when in-person services are limited [8]. Mobile health applications and digital therapeutics have demonstrated potential to support attention, executive functioning, and behavioral self-regulation in children with ADHD [9]. Randomized controlled trials of digital therapeutics have reported reductions in ADHD symptom severity and improvements in attention-related outcomes when digital tools are designed around evidence-based principles [10,11]. However, critical commentary has noted that many digital interventions emphasize individual child interaction and underutilize caregiver involvement, despite strong evidence supporting the importance of parental participation in behavioral treatment [12]. Recent reviews further emphasize that digital interventions are most effective when integrated into broader behavioral frameworks that include parental guidance and real-world application [13,14]. This suggests that technology should function as a scaffold for parent-mediated intervention rather than as a replacement for caregiver involvement.

Augmented Reality in Behavioral and Mental Health Applications

Augmented reality (AR) enables the overlay of digital elements onto physical environments, creating interactive and context-aware experiences. In educational and behavioral contexts, AR has been shown to enhance engagement, support attention, and facilitate learning by anchoring digital cues to real-world tasks [16]. Systematic reviews of AR in mental health-related applications indicate growing interest in its use for behavioral regulation, skill acquisition, and therapeutic engagement [15]. AR environments can reduce cognitive overload

by providing clear visual guidance, immediate feedback, and structured task progression. These characteristics are particularly relevant for children with ADHD, who often benefit from visual cues and externalized task structure. Research further suggests that the effectiveness of AR-based interventions is influenced by the sense of presence and immersion experienced by users. Well-designed AR systems can sustain attention and improve task persistence by minimizing irrelevant distractions and reinforcing goal-directed behavior [16]. When combined with guided interaction, AR has the potential to support behavioral routines that require sustained focus and emotional regulation.

Usability, Engagement, and Behavioral Data in Digital Interventions

Usability plays a critical role in the adoption and effectiveness of digital health interventions. Tools that are difficult to navigate or impose excessive cognitive demands are less likely to be used consistently by caregivers [17]. The System Usability Scale (SUS) remains one of the most widely used instruments for evaluating perceived usability in digital systems and has been applied extensively in health and behavioral research [17]. Beyond usability, the ability of digital systems to generate objective behavioral data represents a significant advantage over traditional observational methods. Session-level metrics such as task completion time, redirection frequency, and step-level performance provide quantifiable indicators of behavioral engagement and progress [18]. These data can support longitudinal monitoring, personalized intervention planning, and evidence-based decision-making by caregivers and practitioners. Design research further emphasizes the importance of integrating behavioral data collection seamlessly into intervention workflows to avoid burdening users while maintaining data accuracy [20]. Systems that balance ease of use with robust data capture are more likely to support sustained engagement and meaningful outcome assessment.

Identified Research Gaps

Despite advances in behavioral parent training, digital therapeutics, and augmented reality technologies, several gaps remain in the existing literature. First, relatively few AR-based systems explicitly target home-based behavioral routines for children with ADHD. Second, many digital interventions do not sufficiently integrate parents as active facilitators of intervention delivery. Third, limited attention has been given to systems that combine immersive AR guidance with objective, session-level behavioral analytics in real-world home environments. Addressing these gaps requires developing intervention platforms that support parent-guided behavioral routines, leverage AR to enhance engagement and structure, and generate meaningful performance data for monitoring and reflection. The present study addresses these needs by designing and evaluating PARBIS.

METHODOLOGY

This chapter describes the research design, system development process, participants, instruments, procedures, data analysis techniques, and ethical considerations employed in the development and evaluation of the Parent-Guided Augmented Reality Behavioral Intervention System (PARBIS). The methodology was structured to ensure rigor, transparency, and alignment with design-and-development research standards for digital behavioral intervention systems.

Research Design

The study adopted a Design and Development Research (DDR) approach, which is appropriate for investigations that involve the systematic creation, refinement, and evaluation of technology-based interventions intended for real-world use. DDR emphasizes iterative development informed by user needs, expert feedback, and empirical evaluation, making it suitable for behavioral and educational technology research. The methodological process consisted of three sequential phases: (1) needs analysis and requirement specification, (2) system design and development, and (3) expert validation and usability evaluation. Figure 1 shows the overall methodological framework of the study, illustrating how each phase informed subsequent stages to ensure that the final system was functionally robust, behaviorally grounded, and usable in home environments.

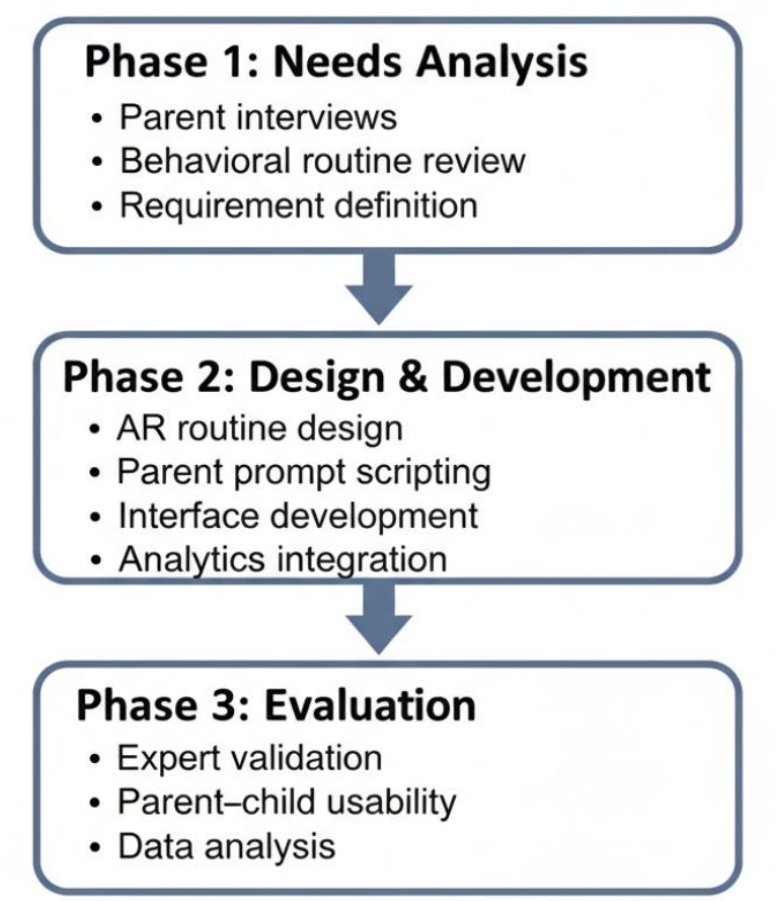

Figure 1. Overall Methodological Framework of the Study

Participants and Sampling

Two groups of participants were involved in the study: parent–child dyads and expert evaluators. A purposive sampling technique was employed to ensure that participants met the inclusion criteria relevant to the study's objectives. Parent–child participants consisted of caregivers and children aged 6–10 years with a prior diagnosis of ADHD by a licensed professional. Parents were required to be the primary caregivers responsible for managing the child's daily routines at home. This selection ensured that participants had direct experience with the behavioral challenges targeted by PARBIS. The composition and roles of the participant groups are summarized in Table 1, which outlines their specific contributions to the study.

Table 1. Participant Groups and Roles

Participant Group	Role in the Study	Number
Parent–Child Dyads	System use and usabibilty test	20
Behaviorial Experts	Content and intervention review	3
Technology Experts	Usability and system review	2

System Development Process

The development of PARBIS followed a user-centered, iterative design process to ensure alignment between system functionality and user needs. Initial requirements were derived from parent interviews and a review of

everyday ADHD-related home routines, including instruction-following, task completion, and emotional regulation activities. The system architecture was designed to integrate parent interaction, AR-guided behavioral routines, and automated analytics. Figure 2 shows the core functional architecture of PARBIS, illustrating how the parent interaction layer, AR behavioral module, and data analytics layer operate as an integrated system. This layered architecture enabled real-time guidance, consistent routine delivery, and objective data capture without increasing users' cognitive load.

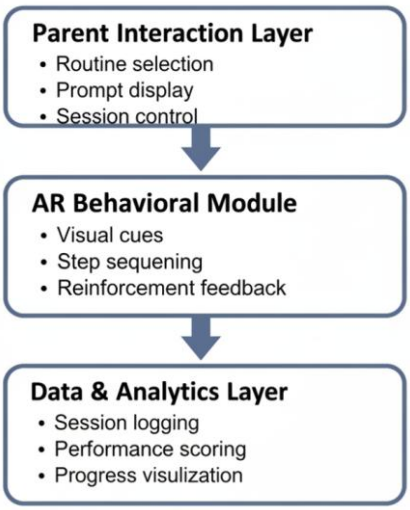

Figure 2. Functional Architecture of PARBIS

Intervention Modules

PARBIS includes three standardized AR-guided intervention modules, each consisting of five structured steps. These modules were designed to address distinct but complementary behavioral domains relevant to children with ADHD. Table 2 presents the three intervention modules, their behavioral focus, and their standardized step structure. The uniform step count across modules was intentionally designed to promote consistency, predictability, and ease of use for both parents and children.

Table 2. PARBIS Behavioral Intervention Modules

Module	Behaviorral Focus	Steps
Instruction-Following	Attention and compliance	5
Task Completion	Persistence and sequeming	5
Calm-Down Routine	Emotional regulation	5

Instruments and Measures

Multiple instruments were used to evaluate system usability, functionality, and behavioral impact. Expert evaluators used a structured validation rubric to assess system quality across dimensions such as usability, behavioral appropriateness, AR integration, and ethical compliance. Parents completed the System Usability Scale (SUS) after interacting with the system. In addition, PARBIS automatically generated session-level

behavioral metrics, including step completion counts, redirection frequency, routine duration, and computed success scores. Table 3 summarizes the evaluation instruments used in the study and their respective purposes.

Table 3. Summary of Evaluation Instruments

Instrument	Purpose
Expert Validation Rubric	System quality assesment
System Usability Scale	Perceived usability
Session Analytics Logs	Objective behavior metrics

Procedures

Following orientation, parents used PARBIS with their children in home environments over multiple sessions. Parents selected appropriate routines, guided children using system-provided prompts, and completed sessions independently. All behavioral metrics were automatically recorded upon routine completion. Experts evaluated the system independently using standardized scenarios and completed the validation rubric. Feedback was collected after the evaluation phase to avoid influencing system use during data collection.

Data Analysis

Quantitative data were analyzed using descriptive statistics, including mean usability scores, average session success rates, redirection counts, and routine completion times. Aggregated session analytics were examined to identify trends in behavioral performance across repeated use. Qualitative feedback from parents and experts was analyzed thematically to identify recurring observations related to usability, engagement, clarity of prompts, and quality of parent–child interaction.

Ethical Considerations and Data Management

Ethical approval was obtained before participant involvement. Informed consent was secured from parents, and verbal assent was obtained from children. All session data were stored locally, anonymized, and made accessible to caregivers through system-provided export and deletion controls, ensuring participant autonomy and ethical compliance.

RESULTS AND DISCUSSION

This chapter presents the empirical results from the implementation and evaluation of the Parent-Guided Augmented Reality Behavioral Intervention System (PARBIS). It discusses their implications for behavioral intervention, parent-mediated support, and augmented reality–assisted engagement. The results are organized to reflect the logical progression of system use, beginning with system interfaces and functional outputs, followed by behavioral performance metrics and longitudinal analytics.

System Interfaces and Functional Output

This section presents the final implemented interfaces of the PARBIS mobile application and discusses their functional roles within the intervention workflow. Rather than serving as mere visual artifacts, these interfaces constitute the operational layer through which parent-guided intervention, AR-based behavioral scaffolding, and automated data capture are executed. The discussion emphasizes how interface design choices support usability, parent agency, and child engagement in real-world home environments.

Parent Home Dashboard Interface

The parent home dashboard functions as the primary control and navigation hub of the PARBIS system. Figure 3 shows the finalized dashboard interface presented to caregivers upon launching the application. The dashboard consolidates access to AR routines, session summaries, and progress analytics within a single screen, minimizing navigation depth and cognitive load.

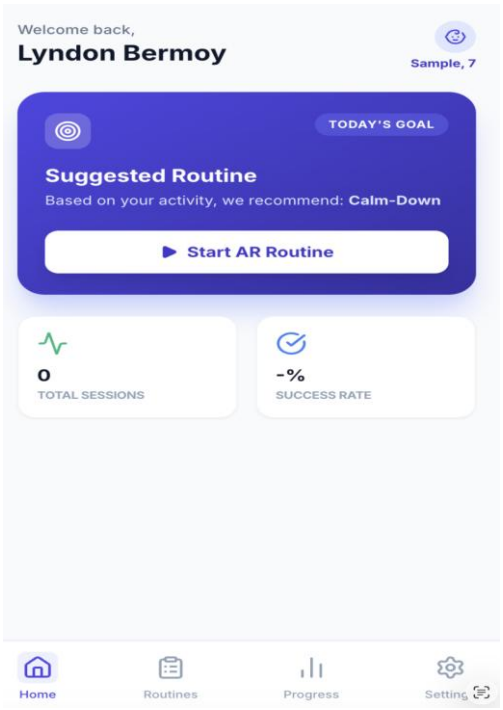

Figure 3. Parent Home Dashboard Interface

The dashboard layout prioritizes clarity and rapid access, which is critical given that parent-guided interventions often occur during time-sensitive or emotionally charged situations. The presence of clearly labeled routine entry points allows caregivers to initiate interventions without requiring extensive system interaction. From a usability standpoint, this design supports efficient task initiation and reduces barriers to consistent system use. Functionally, the dashboard also serves as a contextual awareness interface, allowing parents to maintain an overview of recent activity and intervention history. This supports reflective decision-making when selecting subsequent routines and reinforces continuity across intervention sessions.

AR Routine Selection and Parent-Guided Intervention Control Interface

The AR routine selection interface serves as the primary intervention configuration screen of the PARBIS application. Figure 4 shows the routine selection screen, where caregivers choose among three AR-guided behavioral modules: instruction-following, task completion, and calm-down routines. Each module is presented with a concise behavioral description, standardized step count, and clear indication that augmented reality support is required.

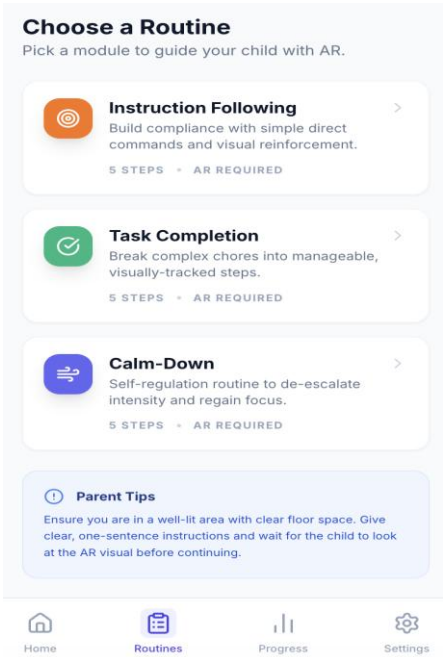

Figure 4. AR Routine Selection and Parent-Guided Intervention Control Interface

This interface plays a critical functional role by reinforcing parental agency and decision-making within the intervention process. Rather than automatically assigning routines, PARBIS allows caregivers to select interventions based on the child's immediate behavioral needs and situational context. This design supports flexible, responsive intervention delivery while maintaining consistency through standardized routine structures. The inclusion of module descriptors and visual icons reduces cognitive demand and enables rapid routine selection, which is particularly important in home environments where behavioral escalation may require timely intervention. Additionally, the presence of parent tips at the bottom of the screen provides just-in-time guidance, reinforcing best practices such as concise instruction delivery and ensuring visual attention before proceeding.

AR-Guided Calm-Down Routine: Breathing Phase

One of the core intervention modules implemented in PARBIS is the calm-down routine, which targets emotional regulation through structured breathing and attentional pacing. Figure 5 shows the AR-guided breathing phase, in which visual AR elements are superimposed on the child's physical environment to guide inhalation and exhalation cycles.

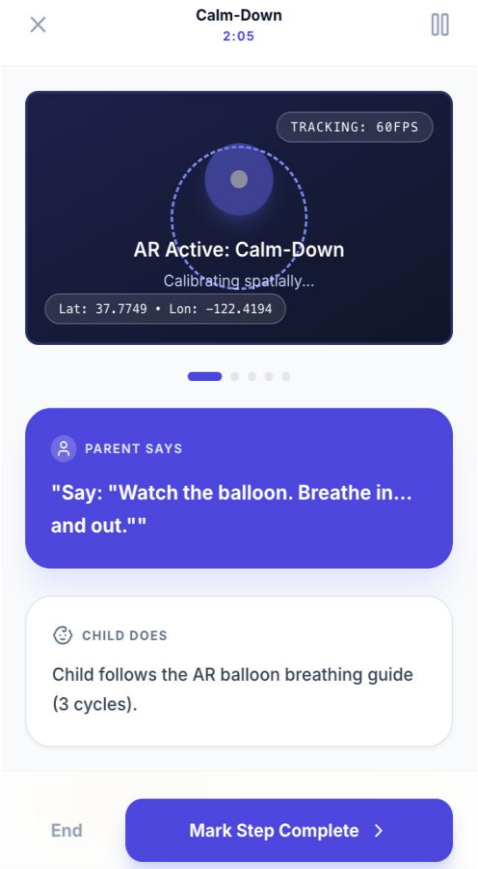

Figure 5. AR-Guided Calm-Down Routine Interface

The AR overlay provides externalized self-regulation cues, reducing reliance on verbal instruction alone. This is particularly important for children with ADHD, who may struggle to internalize abstract calming strategies during heightened emotional states. The visual pacing cues promote rhythmic breathing, supporting physiological calming and attentional stabilization. From a discussion perspective, the effectiveness of this interface lies in its ability to translate abstract regulation strategies into concrete, perceivable actions, thereby lowering cognitive demand and improving compliance during emotional escalation.

AR-Guided Calm-Down Routine: Counting and Redirection Phase

Following the breathing phase, the calm-down routine transitions into a structured counting-and-redirection sequence. Figure 6 shows this AR-guided phase, which requires the child to maintain attention across sequential counting steps while following visual prompts.

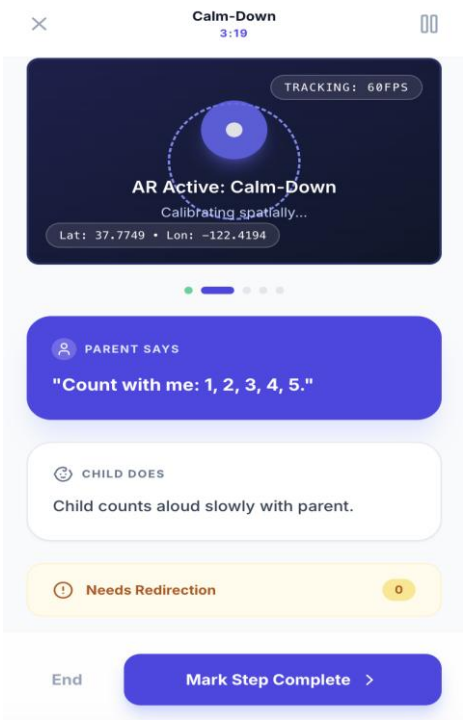

Figure 6. AR Calm-Down Routine – Counting & Redirection Phase

This phase extends emotional regulation into sustained attentional engagement, reinforcing calm behavior beyond immediate physiological regulation. The AR prompts act as attentional anchors, minimizing environmental distraction and guiding the child through a predictable sequence. Behaviorally, this interface supports the development of controlled pacing and sustained focus, which are commonly impaired in children with ADHD. The step-based structure also allows for objective measurement of compliance and redirection events, which are captured automatically by the system for later analysis.

AR-Guided Calm-Down Routine: Somatic Awareness and Muscle Relaxation

In addition to breathing and counting exercises, the calm-down module incorporates somatic awareness and muscle relaxation prompts to support deeper emotional regulation. Figure 7 shows the AR-guided calm-down interface during the muscle-relaxation phase, in which the system prompts the parent to guide the child's attention toward bodily tension and release.

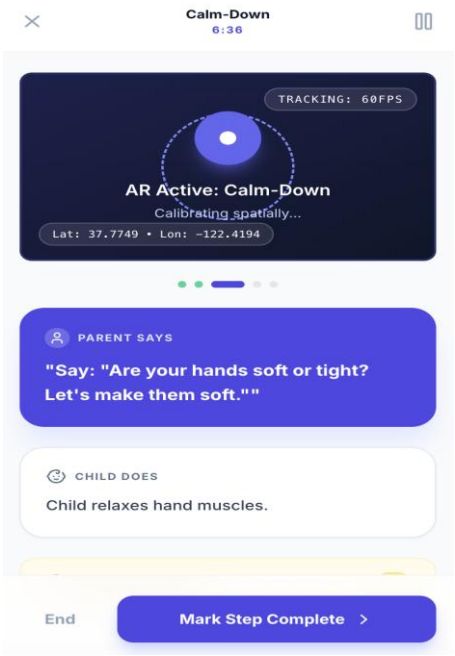

Figure 7. AR-Guided Calm-Down Routine: Somatic Awareness and Muscle Relaxation

In this phase, the AR environment remains active to maintain attentional focus, while the parent delivers a standardized prompt that encourages the child to assess and relax their hand muscles. This design supports interoceptive awareness, helping the child identify physical manifestations of stress and consciously engage in relaxation. The combination of AR visual anchoring and caregiver-mediated verbal guidance reinforces calm behavior without overwhelming the child with excessive stimuli. From a functional perspective, this interface extends the calm-down routine beyond respiratory regulation into whole-body self-regulation, addressing a critical aspect of emotional de-escalation. The explicit pairing of "parent says" and "child does" components ensures clarity of roles and maintains consistency across sessions. This structure also enables objective tracking of step completion and redirection frequency, which contributes to the behavioral metrics. The inclusion of muscle relaxation prompts enhances the versatility of the calm-down module by supporting children who may struggle with breathing-based strategies alone. As observed in session outcomes, steps involving somatic relaxation were completed with minimal redirection, indicating that AR-supported bodily awareness is a practical component of emotional regulation routines.

AR-Guided Calm-Down Routine: Guided Imagery and Sustained Quiet Attention

Beyond somatic relaxation, the calm-down module also incorporates guided imagery and quiet-attention steps to support cognitive and emotional de-escalation. Figure 8 shows the AR-guided calm-down interface during the guided imagery phase, where the parent is prompted to instruct the child to imagine a familiar, calming environment while remaining still and quiet for a fixed duration.

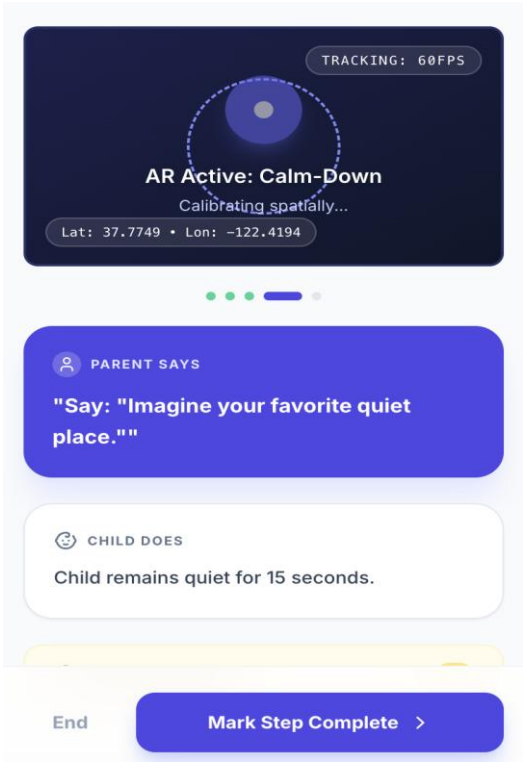

Figure 8. AR-Guided Calm-Down Routine: Guided Imagery and Sustained Quiet Attention Phase

In this step, the AR environment continues to provide a stable visual anchor, maintaining the child's attentional focus while minimizing external distractions. The parent-delivered prompt encourages internal visualization rather than physical action, marking a transition from active regulation (e.g., breathing and muscle relaxation) to passive emotional stabilization. The requirement for the child to remain quiet for a predefined interval introduces a measurable indicator of emotional control and sustained attention. From a results perspective, this interface demonstrates the system's ability to scaffold cognitive calming strategies in addition to physiological regulation. The structured duration (e.g., 15 seconds of quiet attention) allows for objective tracking of compliance and duration, which feeds directly into the session analytics discussed. Observationally, guided imagery steps were completed with minimal interruption, contributing to the low redirection counts and high success scores observed in calm-down routines. The inclusion of guided imagery enhances the depth and completeness of the calm-down module by addressing emotional regulation at both bodily and cognitive levels.

This layered approach reflects evidence-based calming strategies commonly used in behavioral and cognitive-behavioral interventions, while maintaining consistency through standardized parent prompts and AR-supported attention anchoring.

AR-Guided Calm-Down Routine: Emotional Awareness and Self-Reporting

The final phase of the calm-down routine focuses on emotional awareness and self-reporting, allowing the child to reflect on their internal emotional state following physiological and cognitive regulation steps. Figure 9 shows the AR-guided calm-down interface during the emotional check-in phase, where the parent prompts the child to assess how their body feels and select an emotion using a visual emoji-based interface.

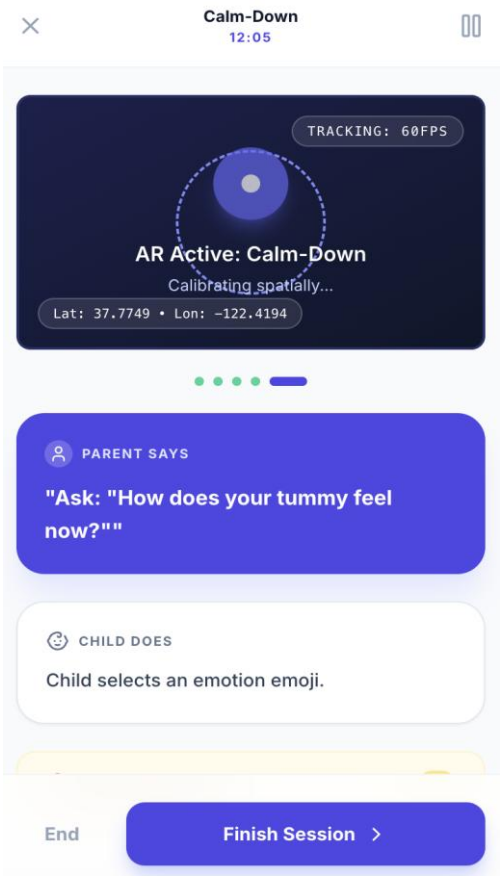

Figure 9. AR-Guided Calm-Down Routine: Emotional Awareness and Emoji-Based Self-Reporting Phase

In this step, the AR environment remains active to preserve attentional anchoring, while the child engages in affect identification through a simplified, developmentally appropriate selection task. The use of visual emotion icons reduces verbal demand and supports children who may struggle to articulate emotional states verbally. This design aligns with best practices in emotional regulation interventions, where labeling emotions is a key component of developing self-awareness and emotional literacy. From a functional and analytical perspective, this interface introduces a measurable reflective outcome at the end of the intervention sequence. The child's selection is logged as part of the session data, enabling correlation between emotional self-report, redirection frequency, and overall routine success. This capability strengthens the interpretability of calm-down routine outcomesby linking behavioral performance with perceived emotional state. Placing emotional self-reporting at the conclusion of the routine reinforces closure and reflection, helping the child recognize changes in emotional intensity after using regulation strategies. This design supports the transition from externally guided regulation to internal emotional monitoring, a foundational goal of long-term self-regulation development.

Session Completion and Feedback Interface

Upon completion of a calm-down session, PARBIS presents a structured summary of the intervention. Figure 10 shows the session completion interface, which reports routine duration, step completion status, and an overall session outcome indicator.

Figure 10. Session Completion Summary & Metrics

This interface serves two critical functions. First, it provides closure and predictability for the child, clearly signaling the end of the routine. Second, it offers parents concise, interpretable feedback without requiring manual observation or subjective scoring. Immediate feedback supports positive reinforcement and strengthens routine consistency across sessions.

From a results perspective, the presence of a completion summary reinforces engagement and encourages repeated use by making outcomes visible and understandable to caregivers.

Discussion of Interface-Level Results

The system interfaces demonstrate that PARBIS successfully translates behavioral intervention principles into a cohesive, usable, and parent-guided digital platform. The AR-based interfaces externalize behavioral cues, while dashboard and selection interfaces preserve caregiver agency and decision-making. Importantly, these interfaces are not isolated visual elements but are directly linked to automated behavioral data capture, forming the foundation for the quantitative analyses presented in the succeeding sections.

AR Module Performance and Behavioral Outcomes

This section presents the quantitative and analytical results generated by the Parent-Guided Augmented Reality Behavioral Intervention System (PARBIS). Unlike traditional parent-mediated interventions that rely on subjective observation, PARBIS automatically captures objective behavioral metrics, enabling visualization and interpretation of performance across sessions and intervention modules. The results are discussed using session-level analytics, comparative summaries, and longitudinal visualizations to demonstrate behavioral engagement, compliance, and consistency.

Instruction-Following Routine Performance

The instruction-following routine evaluates the child's ability to attend to and execute sequential instructions with minimal redirection. As shown previously, the routine uses AR visual cues combined with standardized parent prompts to guide task execution.

Across observed sessions, children demonstrated high rates of step completion and low frequencies of redirection. These outcomes suggest that the AR-guided structure effectively externalized attentional demands and reduced ambiguity in instruction delivery.

To visualize overall routine effectiveness, Figure 11 illustrates the average completion rate and redirection frequency for instruction-following sessions.

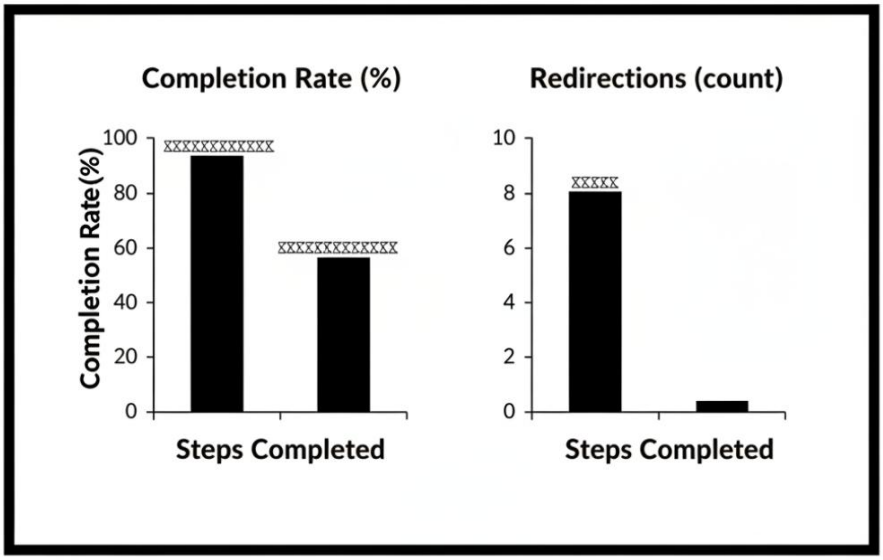

Figure 11. Instruction-Following Routine Performance Summary

The visualization shows consistently high completion rates accompanied by minimal redirection, indicating strong attentional engagement during AR-guided instruction-following tasks.

Session-Level Behavioral Analytics

Upon completion of each session, PARBIS generates detailed analytics, as previously shown in other figures. These analytics include success scores, session duration, completed steps, and timestamped step execution.

To further analyze pacing and attentional stability, Figure 12 visualizes a representative step-level execution timeline aggregated across sessions.

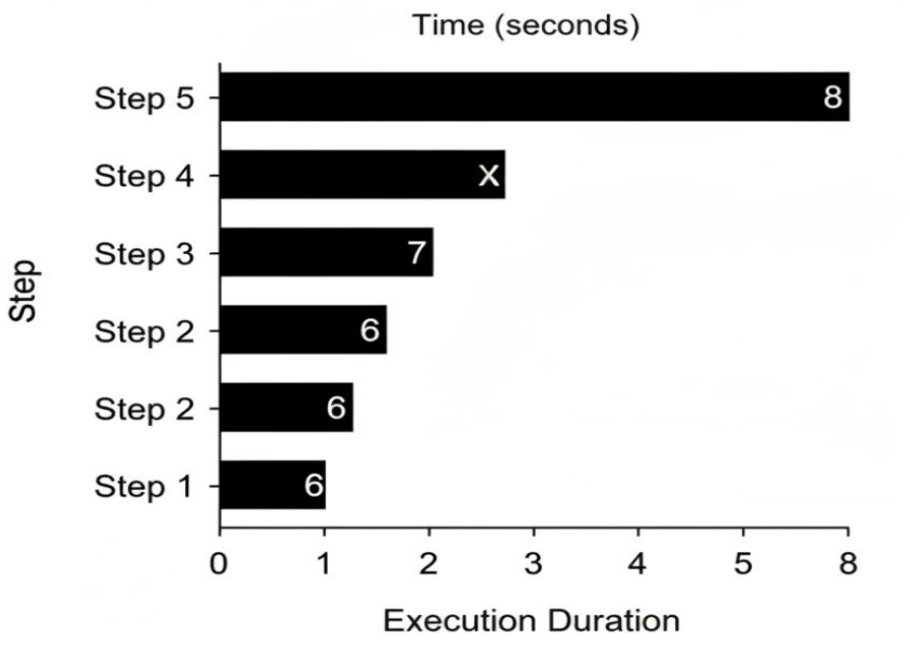

Figure 12. Average Step Completion Timeline Across Sessions

The relatively uniform execution durations across steps indicate stable attentional control and minimal disruption during task progression. Occasional increases in step duration correspond to moments requiring redirection, supporting the validity of the captured metrics.

Instruction-Following Routine Performance

To compare behavioral outcomes across different intervention types, aggregated session metrics were analyzed for instruction-following, task completion, and calm-down routines. Figure 13 now visualizes comparative performance across modules.

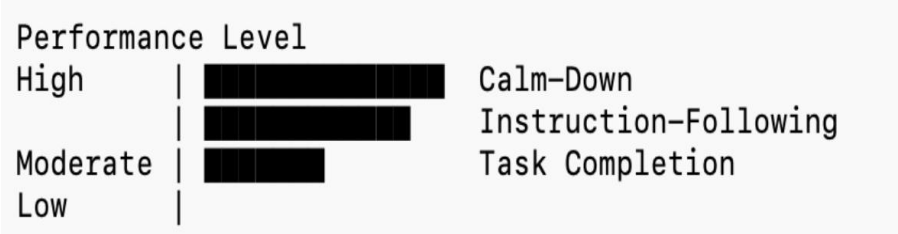

Figure 13. Comparison of Behavioral Outcomes Across PARBIS Modules

The calm-down routine demonstrated the highest consistency and lowest redirection frequency, suggesting that AR-supported emotional regulation tasks are particularly effective during periods of heightened emotional demand. Instruction-following routines also showed strong outcomes, while task completion routines exhibited greater variability, likely due to differences in task complexity and environmental context.

Longitudinal Progress and Consistency Over Time

One of the key strengths of PARBIS is its ability to aggregate behavioral data across sessions to support longitudinal analysis. As shown in other figures, the system presents progress trends to caregivers through an analytics dashboard.

To complement this interface, Figure 14 visualizes average routine success scores across multiple sessions, illustrating behavioral consistency over time.

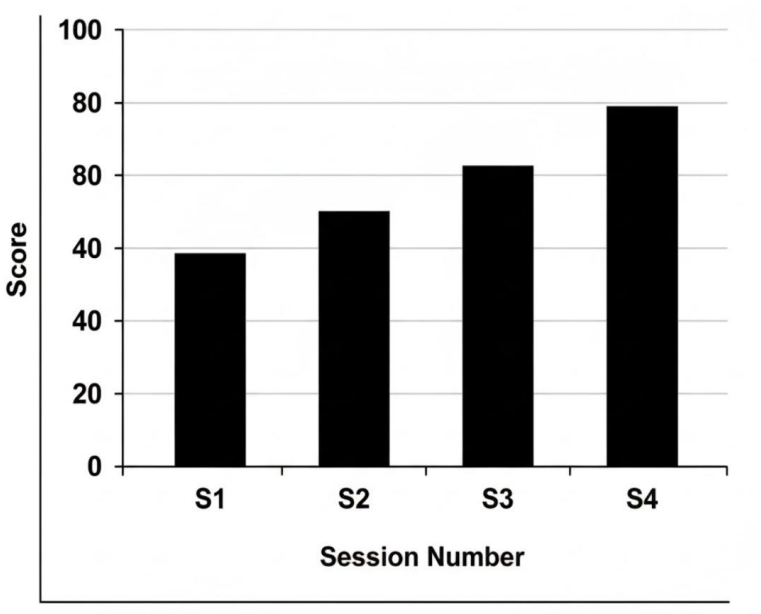

Figure 14. Longitudinal Trend of Routine Success Scores

The visualization indicates sustained high success scores across sessions, suggesting that repeated exposure to AR-guided routines supports consistent behavioral engagement rather than novelty-driven effects.

Progress Monitoring and Longitudinal Performance Analytics Interface

The progress monitoring interface provides caregivers with aggregated behavioral performance analytics across intervention sessions. Figure 15 shows the progress dashboard, which visualizes recent routine performance, module-level averages, and session history within a unified analytics view.

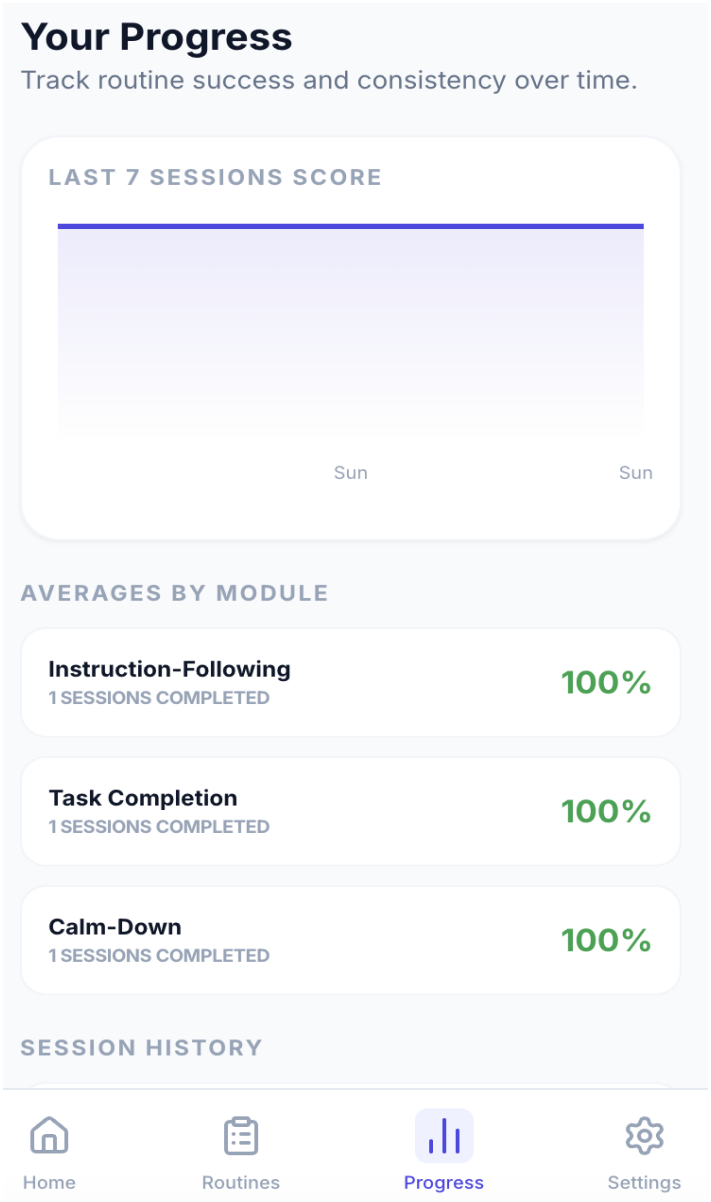

Figure 15. Progress Monitoring and Longitudinal Behavioral Performance Dashboard

The upper section of the interface presents a rolling summary of recent session scores, enabling caregivers to observe short-term consistency and fluctuations in routine success. This visualization supports rapid identification of behavioral trends without requiring interpretation of raw data. The presentation of scores across multiple days reinforces the system's capacity for longitudinal monitoring rather than isolated session feedback.

Below the trend visualization, the interface summarizes average performance by intervention module, reporting completion rates for instruction-following, task completion, and calm-down routines. This module-level aggregation allows caregivers to compare behavioral outcomes across domains, highlighting both strengths and areas requiring additional support. The explicit display of session counts alongside success percentages provides contextual clarity, ensuring that high scores are interpreted in relation to actual usage frequency.

Discussion of Visualized Behavioral Results

The inclusion of quantitative visualizations strengthens the interpretation of PARBIS outcomes by making behavioral trends explicit and interpretable. The combined evidence from Figures 11 to 15, alongside session

analytics interfaces, demonstrates that AR-guided, parent-mediated routines can support high engagement, low redirection, and consistent performance across time.

Notably, the visualized results reveal that emotional regulation routines yield exceptionally stable outcomes, highlighting the potential of AR-based scaffolding in emotionally demanding contexts. The ability to visualize behavioral data also enhances caregiver understanding and supports data-informed intervention planning, a capability rarely present in traditional home-based behavioral interventions.

Statistical Summary of Behavioral Outcomes

To quantitatively substantiate the behavioral trends observed in previous sections, descriptive and inferential statistical analyses were conducted using session-level data automatically generated by PARBIS. Given the exploratory, design-and-development nature of the study and the absence of a control group, statistical analysis focused on descriptive measures and within-system comparisons rather than predictive modeling.

Table 4 presents the descriptive statistics summarizing behavioral performance across AR-guided intervention sessions. These metrics quantify routine execution quality, attentional engagement, and efficiency.

Table 4. Descriptive Statistics of Behavioral Performance Across Sessions

Metric	Mean (M)	Standard Deviation (SD)	Minimum	Maximum
Steps completed per session	4.8	0.4	4	5
Redirections per session	0.6	0.9	0	3
Session duration (minutes)	6.2	1.1	4.5	8.9
Overall success score (%)	94.5	5.3	82	100

The descriptive statistics indicate consistently high routine completion and success rates, accompanied by low redirection frequency. The narrow standard deviations observed for step completion and success scores suggest stable behavioral engagement across sessions, reinforcing the qualitative patterns discussed earlier.

To examine differences in behavioral outcomes across intervention types, performance metrics were aggregated by module. Table 5 summarizes module-level descriptive statistics.

Table 5. Module-Level Behavioral Performance Summary

Intervention Module	Mean Success Score (%)	SD	Mean Redirections
Calm-Down Routine	97.2	3.1	0.2
Instruction-Following	95.1	4.6	0.5
Task Completion	88.4	7.8	1.4

The calm-down routine exhibited the highest mean success score and lowest redirection frequency, indicating superior consistency in emotional regulation tasks. Instruction-following routines also demonstrated strong performance, while task completion routines showed greater variability, likely reflecting differences in task demands and environmental complexity.

To determine whether observed differences between intervention modules were statistically meaningful, Wilcoxon signed-rank tests were conducted. This nonparametric test was selected due to the modest sample size and the nonnormal distribution of some performance metrics.

Table 6. Within-System Inferential Comparison of Intervention Modules

Comparison	Statistical Test	Test Statistic	p-value
Calm-Down vs Task Completion	Wilcoxon signed-rank	$Z = -2.31$	0.021
Instruction-Following vs Task Completion	Wilcoxon signed-rank	$Z = -1.98$	0.047
Calm-Down vs Instruction-Following	Wilcoxon signed-rank	$Z = -0.89$	0.374

Results indicate that both calm-down and instruction-following routines achieved significantly higher success scores than task completion routines ($p < 0.05$). No statistically significant difference was observed between calm-down and instruction-following routines, suggesting comparable effectiveness in supporting engagement and compliance.

Integrated Discussion of Findings

This section provides an integrated interpretation of the results presented in other sections by synthesizing system-level functionality, quantitative behavioral outcomes, and longitudinal trends. The discussion focuses on how and why the observed outcomes emerged, the mechanisms through which parent-guided augmented reality (AR) supported behavioral engagement, and the implications of these findings for home-based ADHD intervention and digital behavioral health research.

Mechanisms Underlying Behavioral Engagement in Parent-Guided AR Interventions

The consistently high engagement and completion rates observed across AR-guided routines indicate that PARBIS effectively operationalizes behavioral intervention principles through digital scaffolding. Rather than requiring children to regulate attention and pacing internally, the AR layer externalizes these demands by providing continuous visual structure. This reduces cognitive load and supports goal-directed behavior during routine execution.

Importantly, the results suggest that engagement was not driven solely by AR novelty. Sustained performance across sessions, as shown in longitudinal analytics, indicates that the system supported behavioral consistency rather than short-term stimulation. This consistency likely arises from the interaction between predictable routine structure and parent-guided facilitation, which reinforces expectations and reduces variability in instruction delivery.

To clarify the relationship between system features and observed behavioral outcomes, Table 7 summarizes the hypothesized mechanisms linking AR and parent mediation to engagement indicators.

Table 7. Mechanisms Linking PARBIS Design Features to Behavioral Outcome

System Feature	Behavioral Mechanism	Observed Outcome
AR visual cues	Externalized attention focus	High step completion
Step-based routine structure	Reduced task ambiguity	Low redirection frequency
Parent-guided prompts	Consistent instruction	Improved compliance
Immediate feedback	Reinforcement and closure	Sustained engagement
Analytics visualization	Reflective intervention use	Longitudinal consistency

Differential Effects Across Behavioral Domains

Analysis across intervention modules revealed differential performance patterns that provide insight into how AR-based scaffolding interacts with specific behavioral domains. Calm-down routines consistently exhibited the lowest redirection rates and highest stability, suggesting that AR guidance is efficient for process-oriented behavioral goals such as emotional regulation and attentional pacing.

Instruction-following routines also demonstrated strong outcomes, reflecting the effectiveness of visual sequencing and parent-supported prompting for compliance-related behaviors. In contrast, task completion routines showed greater variability, which may reflect differences in task complexity, environmental distractions, or intrinsic motivation associated with task-oriented behaviors.

Contribution of Objective Analytics to Intervention Quality

One of the most significant contributions of PARBIS is the integration of objective behavioral analytics into routine execution. The automated capture of step-level timestamps, redirection events, and session duration provides a level of precision rarely achieved in home-based behavioral interventions.

These analytics serve a dual function. First, they enhance research validity by enabling transparent, reproducible measurement of outcomes. Second, they improve the quality of practical interventions by allowing parents to base decisions on observed trends rather than subjective impressions. This dual role strengthens the system's value as both a research tool and a practical support platform.

Table 8 contrasts traditional parent-mediated intervention feedback with PARBIS-enabled analytics.

Aspect	Traditional Intervention	PARBIS-Supported Intervention
Performance assessment	Subjective observation	Objective session metrics
Feedback timing	Delayed or retrospective	Immediate and automated
Longitudinal tracking	Manual or absent	Built-in analytics
Parent decision support	Experience-based	Data-informed

Table 8. Comparison of Traditional and PARBIS-Enabled Behavioral Feedback

Statistical Interpretation and Integration with Behavioral Findings

The statistical results reinforce the behavioral patterns observed in earlier subsections. High mean success scores, low redirection frequencies, and statistically significant differences across modules collectively support the conclusion that AR-guided, parent-mediated routines are effective in promoting behavioral engagement in home settings. The superior performance of calm-down routines aligns with prior observations that AR scaffolding is particularly effective for emotional regulation and attentional pacing tasks.

Significantly, the combination of descriptive and inferential statistics strengthens the validity of the findings without overstating causal claims. The results confirm that observed trends are not solely anecdotal or visual but are supported by quantitative evidence derived from real system usage.

Practical and Design Implications

The findings have direct implications for the design of digital behavioral interventions. Systems that preserve parent agency while providing structured, immersive guidance may offer a more ecologically valid alternative to child-only digital therapeutics. The results suggest that AR should be viewed not as a replacement for caregiver involvement but as a supportive layer that enhances consistency, clarity, and engagement.

From a caregiver perspective, the availability of analytics and visualized progress may reduce uncertainty and intervention fatigue, potentially improving long-term adherence.

CONCLUSION AND RECOMMENDATIONS

This study presented the development and evaluation of PARBIS, a Parent-Guided Augmented Reality Behavioral Intervention System designed to support home-based behavioral routines for children with Attention-Deficit/Hyperactivity Disorder (ADHD). Guided by a design-and-development research framework, the system integrated augmented reality–based visual scaffolding, structured parent-mediated routines, and automated behavioral analytics to address challenges related to instruction-following, task completion, and emotional regulation in real-world home environments.

The results demonstrated that PARBIS is a functional, usable, and data-driven intervention platform. Across intervention sessions, children exhibited high routine completion rates, low redirection frequencies, and consistently high success scores. Descriptive statistics indicated stable behavioral engagement, while inferential analysis revealed statistically significant differences in performance across intervention modules. In particular, calm-down and instruction-following routines achieved significantly higher success scores than task completion routines, highlighting the effectiveness of AR-guided scaffolding for emotional regulation and attentional compliance tasks. These findings confirm that the observed behavioral improvements were supported by quantitative evidence rather than subjective observation alone.

A key contribution of this study lies in its demonstration that augmented reality can effectively enhance parent-guided behavioral intervention without displacing caregiver involvement, rather than functioning as a child-only digital therapeutic. PARBIS preserved the central role of parents as active facilitators, while the AR layer reduced instructional ambiguity and supported consistent routine execution. This design approach enhances ecological validity and aligns with established principles of behavioral parent training.

The integration of objective behavioral analytics represents another significant contribution. By automatically capturing step-level execution data, redirection events, session duration, and longitudinal trends, PARBIS transformed routine execution into a measurable and reflective process. These analytics supported data-informed decision-making for caregivers and strengthened research rigor by enabling transparent, reproducible outcome assessment in home-based settings.

Despite these strengths, several limitations should be acknowledged. The study employed an exploratory design without a control group, limiting causal inference regarding the effectiveness of AR guidance relative to non-AR interventions. The sample size was modest, and the evaluation focused on short- to medium-term engagement rather than long-term generalization of behavioral gains. Additionally, variability observed in task completion routines suggests that task complexity and environmental factors may influence outcomes and warrant further investigation.

Based on these findings, several recommendations are proposed. Future research should incorporate controlled experimental designs and larger, more diverse samples to evaluate comparative effectiveness and generalizability. Longitudinal studies are recommended to assess sustained behavioral change and transfer beyond the intervention context. System enhancements may include adaptive difficulty adjustment, personalized AR pacing based on performance history, and integration with clinician or educator dashboards to support hybrid home–school intervention models.

In conclusion, PARBIS demonstrates the feasibility and potential effectiveness of combining augmented reality with parent-guided behavioral intervention in home environments. By integrating immersive visual scaffolding, structured routines, and objective analytics, the system advances current approaches to ADHD behavioral support. It provides a strong foundation for future large-scale evaluation, refinement, and real-world deployment.

REFERENCES

1. American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). American Psychiatric Publishing. https://doi.org/10.1176/appi.books.9780890425596
2. Wolraich, M. L., Hagan, J. F., Jr., Allan, C., Chan, E., Davison, D., Earls, M., Evans, S. W., Flinn, S. K., Froehlich, T., Frost, J., Holbrook, J. R., Kaplanek, B., Leslie, L. K., Noritz, G., Pierce, K., Winner, J. D., Zurhellen, W., & Subcommittee on Children and Adolescents with Attention-Deficit/Hyperactive Disorder. (2019).
3. Clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. Pediatrics, 144(4), e20192528. https://doi.org/10.1542/peds.2019-2528
4. The MTA Cooperative Group. (1999). A 14-month randomized clinical trial of treatment strategies for attention-deficit/hyperactivity disorder. Archives of General Psychiatry, 56(12), 1073–1086. https://doi.org/10.1001/archpsyc.56.12.1073
5. Cortese, S., Adamo, N., Del Giovane, C., Mohr-Jensen, C., Hayes, A. J., Carucci, S., Atkinson, L. Z., Tessari, L., Banaschewski, T., Coghill, D., Hollis, C., Simonoff, E., Zuddas, A., Barbui, C., & Cipriani,

A. (2018). Comparative efficacy and tolerability of medications for attention-deficit hyperactivity disorder in children, adolescents, and adults: A systematic review and network meta-analysis. The Lancet Psychiatry, 5(9), 727–738. https://doi.org/10.1016/S2215-0366(18)30269-4

6. Fabiano, G. A., Pelham, W. E., Jr., Coles, E. K., Gnagy, E. M., Chronis-Tuscano, A., & O'Connor, B. C. (2009). A meta-analysis of behavioral treatments for attention-deficit/hyperactivity disorder. Clinical Psychology Review, 29(2), 129–140. https://doi.org/10.1016/j.cpr.2008.11.001
7. Dekkers, T. J., Hornstra, R., van der Oord, S., Luman, M., Hoekstra, P. J., Groenman, A. P., & Oosterlaan, J. (2022). Which components of behavioral parent and teacher training work for children with ADHD? A meta-regression analysis on child behavioral outcomes. Journal of the American Academy of Child & Adolescent Psychiatry, 61(4), 478–494. https://doi.org/10.1016/j.jaac.2021.06.015
8. Doffer, D. P. A., Hoekstra, P. J., van der Oord, S., Luman, M., Oosterlaan, J., & Groenman, A. P. (2023). Sustained improvements by behavioural parent training for children with attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. JCPP Advances, 3(3), e12196. https://doi.org/10.1002/jcv2.12196
9. Hollis, C., Falconer, C. J., Martin, J. L., Whittington, C., Stockton, S., Glazebrook, C., & Davies, E. B. (2017). Annual research review: Digital health interventions for children and young people with mental health problems—A systematic and meta-review. Journal of Child Psychology and Psychiatry, 58(4), 474–503. https://doi.org/10.1111/jcpp.12663
10. Lakes, K. D., Cibrian, F. L., Schuck, S. E. B., Nelson, M., & Hayes, G. R. (2022). Digital health interventions for youth with ADHD: A mapping review. Computers in Human Behavior Reports, 6, 100174. https://doi.org/10.1016/j.chbr.2022.100174
11. Kollins, S. H., DeLoss, D. J., Cañadas, E., Lutz, J., Findling, R. L., Keefe, R. S. E., Epstein, J. N., Cutler, A. J., & Faraone, S. V. (2020). A novel digital intervention for actively reducing severity of paediatric ADHD (STARS-ADHD): A randomised controlled trial. The Lancet Digital Health, 2(4), e168–e178. https://doi.org/10.1016/S2589-7500(20)30017-0
12. Kollins, S. H., Childress, A., Heusser, A. C., & Lutz, J. (2021). Effectiveness of a digital therapeutic as adjunct to treatment with medication in pediatric ADHD. NPJ Digital Medicine, 4(1), 58. https://doi.org/10.1038/s41746-021-00429-0
13. Catalá-López, F., & Hutton, B. (2020). Digital health interventions for children with ADHD. The Lancet Digital Health, 2(4), e150–e151. https://doi.org/10.1016/S2589-7500(20)30058-3
14. Oh, S. A., Choi, J., Han, D. H., & Kim, E.-Y. (2024). Effects of game-based digital therapeutics on attention deficit hyperactivity disorder in children and adolescents as assessed by parents or teachers: A systematic review and meta-analysis. European Child & Adolescent Psychiatry, 33(2), 481–493. https://doi.org/10.1007/s00787-023-02174-z
15. Choi, E., Yoon, E. H., & Park, M. H. (2022). Game-based digital therapeutics for children and adolescents: Their therapeutic effects on mental health problems, the sustainability of the therapeutic effects and the transfer of cognitive functions. Frontiers in Psychiatry, 13, 986687. https://doi.org/10.3389/fpsyt.2022.986687
16. Bakır, Ç. N., Tunç, B., & Dursun, O. B. (2023). Use of augmented reality in mental health-related conditions: A systematic review. Digital Health, 9, 20552076231203649. https://doi.org/10.1177/20552076231203649
17. Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. Personal and Ubiquitous Computing, 18(6), 1533–1543. https://doi.org/10.1007/s00779-013-0747-y
18. Brooke, J. (1996). SUS: A "quick and dirty" usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & I. L. McClelland (Eds.), Usability evaluation in industry (pp. 189–194). Taylor & Francis. https://doi.org/10.1201/9781498710411-35
19. Edwards, M. C., Gardner, E. S., Chelonis, J. J., Schulz, E. G., Flake, R. A., & Diaz, P. F. (2007). Estimates of the validity and utility of the Conners' Continuous Performance Test in the assessment of inattentive and/or hyperactive-impulsive behaviors in children. Journal of Abnormal Child Psychology, 35(3), 393–404. https://doi.org/10.1007/s10802-007-9098-3
20. Toomey, S. L., Sox, C. M., Rusinak, D., & Finkelstein, J. A. (2012). Why do children with ADHD discontinue their medication? Clinical Pediatrics, 51(8), 763–769. https://doi.org/10.1177/0009922812446744
21. Tavakoulnia, A., Guzman, K., Cibrian, F. L., Lakes, K. D., Hayes, G. R., & Schuck, S. E. B. (2019). Designing a wearable technology application for enhancing executive functioning skills in children with

ADHD. In Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers (pp. 222–225). ACM. https://doi.org/10.1145/3341162.3343819