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COMPUTERIZED COGNITIVE RETRAINING PROGRAM FOR HOME TRAINING OF CHILDREN WITH DISABILITIES

PROJECT REPORT

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IN

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PRESIDENCY SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

BONAFIDE CERTIFICATE

Certified that this report "**COMPUTERIZED COGNITIVE RETRAINING PROGRAM FOR HOME TRAINING OF CHILDREN WITH DISABILITIES**" is a Bonafide work of MANOJ KUMAR KR (20221CAI0085), D Y GNANESHWAR (20221CAI0070), VIKRANTH REDDY Y(20221CAI0063), who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE ENGINEERING, ARTIFICIAL INTELLIGENCE & MACHINE LEARNING during 2025-26.

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DECLARATION

We the students of final year B. TECH in COMPUTER SCIENCE ENGINEERING, ARTIFICAL INTELLIGENCE & MACHINE LEARNING at Presidency University, Bengaluru, named MANOJ KUMAR KR, D Y GNANESHWAR, VIKRANTH REDDY Y, Hereby declare that the project work titled **“COMPUTERIZED COGNITIVE RETRAINING PROGRAM FOR HOME TRAINING OF CHILDREN WITH DISABILITIES”** has been independently carried out by us and submitted in partial fulfilment for the award of the degree of B. TECH in COMPUTER SCIENCE ENGINEERING, ARTIFICIAL INTELLIGENCE & MACHINE LEARNING during the academic year of 2025-26. Further, the matter embodied in the project has not been submitted previously by anybody for the award of any Degree or Diploma to any other institution.

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Abstract

Children with disabilities like dyslexia, dyscalculia and dysgraphia often face challenges in problem-solving, reasoning, paying attention and remembering things. Some of these problems can interfere with daily life, school work and making friends. Traditional cognitive retraining may work, but it's normally delivered in person by professionals. Yet these methods are often limited by affordability, availability, flexibility and adequate numbers of trained professionals. Families in underserved or rural areas often have trouble accessing regular therapy, which might impede their learning and cognitive development.

The present work introduces a home-based CCRP, the computerized cognitive retraining program (CCRP) to address these limitations. The program provides gamified, adaptive, and organized training exercises targeting executive functions, working memory, and attention. Each activity is designed to automatically adjust its level of difficulty around the growth of a child, providing a truly individual learning experience. Apart from decreasing cognitive load, gamification effects such as progress tracking and visual feedback also enhance motivation and maintain engagement levels.

It is important to involve educators and caregivers in the development. A monitoring dashboard that shows performance metrics such as accuracy, response time and completion rates is part of the program. These findings allow for immediate adjustments to training, informed caregiver choice-making and effective professional communication. Whether a child is tech-savvy already or not so confident, he or she can begin to do well with the system as it all works at one's own pace! Ethical safeguards such as parental consent and privacy from data have also been included to ensure ethical use.

The CCRP is designed to bridge the disparity between home and clinic-based intervention through digitalization of evidence-based practice into a flexible, accessible tool. For disabled children, the system offers a scalable, low cost and durable solution for cognitive rehabilitation which can improve their autonomy, academic readiness and overall well-being. Future research will focus on refining adaptive algorithms, evaluating long-term outcomes, and extending the program to targeted various cognitive and developmental issues.

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Abbreviations

Sl. No.	Abbreviation	Full Form
1	ADHD	Attention Deficit Hyperactivity Disorder
2	API	Application Programming Interface
3	ASD	Autism Spectrum Disorder
4	CCRP	Computerized Cognitive Retraining Program
5	CCT	Computerized Cognitive Training
6	CPU	Central Processing Unit
7	EEG	Electroencephalography
8	EMR	Electronic Medical Records
9	GDPR	General Data Protection Regulation
10	HTTPS	Hypertext Transfer Protocol Secure
11	IoT	Internet of Things
12	IoTWF	IoT World Forum
13	JWT	JSON Web Token
14	RAM	Random Access Memory
15	SDG	Sustainable Development Goals
16	UAT	User Acceptance Testing

Chapter 1
Introduction

1.1 Background

Children with disabilities - Special mental challenges Children who have developmental disorders like attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD), as well as other learning disabilities or difficult problems with the mind such as dyslexia, dyscalculia and dysgraphia experience complex cognitive challenges. These deficits tend to manifest as low executive functioning, reasoning, working memory, and attention or problem-solving issues. These deficits can impair daily functioning and substantially impact a child's social life, school performance, and self-esteem. Lots of kids struggle to complete school work, remember what they learn or follow multi-step tasks — and that frustrates children and their families.

Traditional cognitive retraining interventions use in-person sessions with trained professionals such as psychologists, occupational therapists and special educators. However, such interventions have a variety of limitations. Regular clinic visits may be costly and require numerous hours from families, which is more difficult in disadvantaged or remote locations where the level of professional expertise may not be available. Traditional strategies may also fail to motivate children, given that many repetitive exercises provided in clinical settings could be overwhelming or unengaging.

The emergence of digital technology, particularly computerized cognitive retraining programs (CCRPs), which individuals can perform in their home environments, has opened up new ways to overcome these barriers. These programs make regular practice convenient and affordable, introducing structured, hands-on cognitive exercises you can complete without leaving the house. By utilizing interactive exercises targeting core cognitive functions such as executive function, memory and attention, CCRPs provide personalized training that adapts in real-time to the performance of the child. Children also tend to be entertained and inspired longer with built-in features such as game-like exercises, immediate feedback. Research has demonstrated that the deliberate design of such digital interventions to be engaging, approachable and flexible may lead to measurable improvements in cognitive performance.

1.2 Statistics of Project

It’s estimated there are 240 million children globally with some form of disability, many who experience cognitive impairment as part of that disability. More than 7.8 million children in India were reported to be disabled in the 2011 Census, but it is widely believed that the figure does not capture all affected people, due to stigma and underreporting. At the state level in Karnataka, there were nearly 89,000 children age 0−9 with disability implied, showing that the problem is not a theoretical one and has strong local basis for its existence. Cognitive impairments are especially rampant; studies show that 60–70% of children with developmental disorders experience executive functioning, attention, and memory-related difficulties and approximately 10% of the world’s school-aged children have a comorbid diagnosis such as dyslexia, dyscalculia, or dysgraphia. Without help, those problems compound over time, making it more difficult to break free and find work or go to school.

Importance of early and guided cognitive intervention directed at these difficulties is frequently mentioned in training manuals and research studies. For all its benefits, face-to- face therapy is not the most affordable, sustainable, or accessible option especially in underserved or rural areas. Children with learning and developmental disabilities have shown measurable improvements in working memory, attention, executive function, and reading through computer-based programs of cognitive retraining. These findings indicate that organized, flexible and gamified programs can supplement or substitute clinic-based therapy while maintaining adherence to regular sessions and different levels of game usage.

There’s a potential growth trajectory in such digital interventions due to India’s burgeoning use of affordable smartphones, tablets and internet. When CCRPs are delivered in the child's natural environment, financial and practical burdens decrease, and primary caregivers have tools to monitor and stimulate growth. What’s more, the scarcity of occupational therapists, clinical psychologists and special educators in India (especially beyond cities) further underscores how technology-driven solutions are warranted. According to national instructional guidelines and global inventories, home-based computerized cognitive retraining can help fill critical gaps in effectiveness, continuity and accessibility of care for children with disabilities and offer a long-term strategy for targeting cognitive growth.

1.3 Prior Existing Technologies

In the last 2 decades an increasing number of computerized cognitive training programs (CCT) have been developed to train deficiencies in executive functions, memory and attention. Programs such as Cogmed Working Memory Training or Captain's Log (Brain Train) offer structured, adaptive activities and progress metrics; however other commercially available apps such as Lumosity emphasize the engagement factor through game-like tasks. Nonetheless, most of these devices do not have robust clinical validation and, to date, there is little evidence regarding long-term academic or functional gain. This underlines the importance of solutions that fill the space between market-born products and cognitive interventions grounded in research, offering both accessibility and demonstrable effectiveness.

The "transfer" problem is a fundamental flaw of contemporary technologies. While students might get better at the tasks in the program (near transfer), this is not always carried over into their schoolwork, homework or daily problem solving. Research and teaching guides state that interventions need to be structured, flexible and related to children's social and instructional context. Systematic computerized training in combination with caregiver involvement has proven to lead to measurable positive effects in executive functioning, reading comprehension and attention. This is only possible, however, if the training corresponds to real-world objectives.

Existing platforms are also limited in scope by pragmatic barriers. Their high subscription fees and dependence on Western content also make them less well suited for countries such as India, where they pose challenges of equity and culture. In addition, the majority of systems offer limited caregiver engagement and dissociate training from a child’s broader support network. The proposed work fills these gaps with a gamified, home-based program that implements adaptive difficulty, inclusive design and dashboards for caregiver monitoring. By simply integrating cognitive retraining into everyday activity, it is a more sustainable means and also culturally appropriate and affordable for kids with disabilities.

1.4 Proposed Approach

A Home-based (CCRP) for Children with developmental disorders affecting attention and executive functions who are diagnosed with learning disabilities including dyslexia, dyscalculia, or dysgraphia. Through structured, tech-mediated exercises, the primary aim is to better basic cognitive abilities: memory, attention, reasoning and problem-solving. The CCRP is designed to solve the access, cost and travel challenges that limit traditional in-person counselling (which uses play therapy) by leveraging the widespread adoption of digital devices and kids' increasing comfort with technology.

The approach is based on the need for a digital platform which is inclusive, flexible and supporting core functionality both by customization and exchange of interaction. Adaptive modules allow for progressive learning and prevent cognitive overload by determining the level of difficulty on an ongoing basis, depending upon the pace at which the child is progressing. Game elements such as points, badges and visual feedback are intended to keep one incentive high enough so he or she will practice every day. Real-time caregiver dashboards ensure that parents, teachers and therapists can monitor progress on an ongoing basis, rather than play the role of a 'fill in the blanks' observer. An essential element of the proposed system is structured exercise and caregiver involvement known to enhance effectiveness of certain existing cognitive training packages and manuals.

On the technical side, the CCRP will be based on a cutting-edge web-enabled architecture that is highly scalable and widely accessible. A Flask/Python backend Api will be created for handling authentication, performance monitoring and adaptive logic. A responsive frontend framework e.g. React would also be implemented to develop a user-friendly interface to exercises. To allow for customized training paths, the adaptive engine will evaluate performance metrics like accuracy, course completion and response time that will be securely maintained in a database. The system will include ethical protections to ensure the safe use of children's data and will feature privacy controls as well as data encryption and parental consent.

1.5 Objectives

The primary aim of this project is to develop a home-based computerized cognitive retraining program (CCRP) which provides children with learning disabilities/disorders with structured, engaging and adaptive exercises. The therapeutic effects will be dovetailed into a responsive, stable and inclusive platform. With the inclusion of gamification to enhance motivation and adaptive modules that adjust difficulty level according to a child's development, the CCRP aims at keeping all levels motivated and providing individualized training based on each child's cognitive need.

One of the key goals is to fully evaluate how CCRP impacts children's cognitive abilities. Changes in cognitive functions such as reasoning, memory, attention and problem-solving will be assessed using structured pre- and post-intervention tests. This certification ensures that the system will be applied as an accredited medical device for a measurable therapy and not only as software. These programs may have the potential to induce marked enhancement in academic performance and executive function following regular use, based on data from past computerized interventions. This is a project intended to bring those benefits into homes.

Emphasizing usability and accessibility is also important to allow kids with different levels of skill and decrease of digital literacy use the system independently or with low levels of supervision. The design of the interface is culturally acceptable and user-friendly; therefore, adoption will not be limited by technical or background related factors. Concurrently, feedback algorithms and a caregiver dashboard will be developed to assist parents, teachers and therapists. That will allow them to monitor improvement and correlate exercises with performance goals, as they adjust training techniques. This kind of collaboration is a necessary step for kids to be kept interested and involved over the long haul and integrated into their regular lives.

1.6 SDG

This project very strongly contributes to above post, by providing an all- inclusion affordable and in-home based Computerized Cognitive Retraining Program (CCRP) for disabled children fits well with the SDGs 4: Quality Education and also contribute to 10: Reduced Inequalities. The program enhances learning outcomes and ensures that underprivileged children receive equal access to a high-quality intervention by targeting underlying cognitive skills such as attention, memory, and problem solving. This democratizes cognitive retraining further by reducing the barriers to accessing it directly by price, distance, and a lack of qualified professionals.

Furthermore, as the project supports children for their mental health, self-esteem and social engagement with systematic cognitive training, it also contributes to SDG 3: Good Health and Well-being. Its scalable tech-driven platform with caregiver dashboards, adaptive algorithms and gamification, promotes SDG 9: Industry, Innovation and Infrastructure. Finally, by promoting inclusive education and building partnerships between families, educators and therapists it promotes SDG 16 Peace Justice and Strong Institutions.

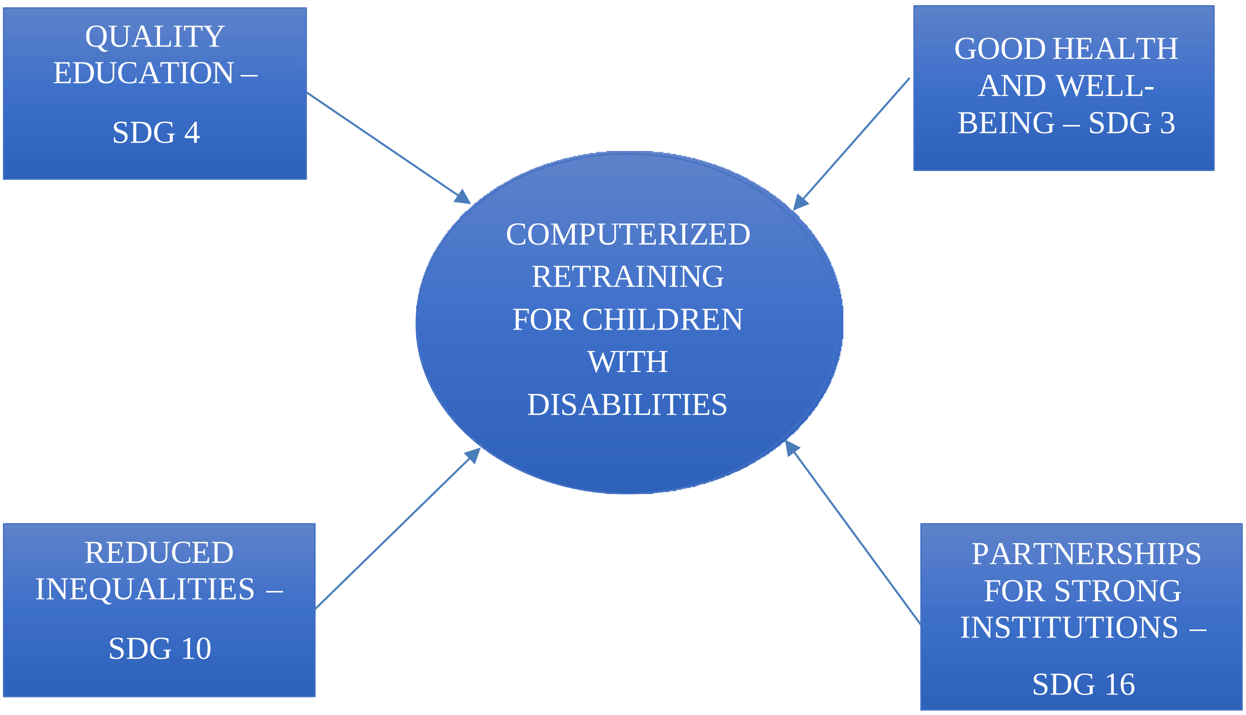

Figure 1.1: Sustainable development goals

1.7 Overview of the Report

Seven chapters comprise this report, with each focusing on a dimension of the development, implementation and evaluation of the proposed Computerized Cognitive Retraining Program (CCRP) for disabled children.

- **Chapter 1: Introduction** – The background of the study, learning and cognitive challenges children with disability have and the objectives/aims of the project are all presented in the introduction.
- **Chapter 2: Literature Review** – summarizes research in the area of computerized cognitive retraining, training manuals and intervention models. It highlights areas where significantly more work is required on accessibility, inclusion and sustainability that the CCRP is intended to fill and the effectiveness of efforts made in these directions.
- **Chapter 3: Methodology** – An overview of the technical development and design framework of the program is discussed here, a process that consists on multiple cognitive exercises database selection, mellowness stimuli implementation (gamification), adaptive learning attributes, as well as interface designs approach.
- **Chapter 4: Implementation** – covers the use of the system in practice, including pilot trials, user feedback collection and adaptations for enhanced usability and engagement.
- **Chapter 5: Evaluation** – describes the evaluation methodology applied to test the outcomes of pre- and post-tests used to measure the impact of the program on cognitive abilities such as memory, attention and problem-solving.
- **Chapter 6: Discussion** – discusses, appraises and compares the findings of the evaluation with existing research in educational technology and cognitive science more broadly.
- **Chapter 7: Conclusion and Future Work** – summarizes the conclusions of the project, understands its limitations, reflects upon potential for further developments to advance it, make it more scalable and embed it in different educational settings.

Chapter 2

Literature review

Currently Computerized Cognitive Retraining Programs (CCRP) attract interest as a new and innovative resource in the delivery of strategies to assist children with disabilities, as opposed to traditional clinic-based intervention. These programs feature structured, engaging, and adaptable exercises that are designed to enhance such critical cognitive skills as problem solving, executive functioning, memory, and attention. The need for child-friendly and accessible methods in cognitive training, which can enhance the inclusiveness of such an activity is long-debated (55–58). It has been recognized that home-based intervention models, specifically, are able to involve families in their child's cognitive development and deliver reliable and regular doses of support within the family’s natural environment. All these studies point to the need for inclusivity and accessibility in developing successful cognitive retraining programs.

This shift towards home-based, computer-based interventions to circumvent limitations of face-to-face therapy is spotlighted in more and more research. Families encounter limitations in using conventional clinical caregiving, often meaning face-to-face sessions, specialized supervision and expenses, especially for low-income and rural communities. Home retraining programs enable children to train regularly, allowing them to avoid problems of logistics and providing greater flexibility, cost effectiveness, and continuity of practice. A user-friendly design and minimal technological expertise requirement allow families to easily embed cognitive retraining in their daily schedules with maintained motivation and adherence.

The systematic planning and implementation of CCRPs are important for their effectiveness. It has also been argued that among the hallmarks of successful systems is system development influenced by logical framework type requirements of needs assessment, program design, and implementation and evaluation as well as scalability. This systematic process ensures that the program will meet end-user requirements and deliver tangible outcomes. Cognitive retraining models commonly separate the diagnosis and training parts in order to deliver personalized interventions according to the baseline cognitive abilities of each child. Ding and colleagues suggest that training programs in such cases may be more targeted, engagement-enhancing, and therapeutic by maintaining clear separation between assessment and training.

Table 2.1: Summary of Literature reviews

Author(s) & Year	Primary Focus	Methodology / Approach	Key Findings / Contributions	Noted Limitations
Kumar et al. (2024)	A general framework for a home-based CCRP for children with intellectual disabilities.	A multi-stage design and development process, from needs assessment to scaling and sustainability.	Proposes a comprehensive, inclusive, and personalized program. Highlights positive findings from similar programs in memory and attention.	The paper is a conceptual overview and does not present empirical data from a new study.
Mukunth et al. (2024)	A CCRP that uniquely integrates EEG neuro-feedback and multi-sensory feedback (emotion, heart rate).	A multi-module system architecture including neuro-feedback, cognitive training, sensor data collection, and a clinical dashboard.	Proposes an innovative, holistic approach that allows clinicians to track cognitive, physiological, and emotional data on a unified platform.	The paper describes a proposed system and its architecture, not the results of a completed clinical trial.
Nappo et al. (2022)	Computerized training of Executive Functions (EFs) in a single child with Specific Learning Disorders (SLD).	A 6-month single-case study using the custom software ASTRAS, with pre-treatment (T0) and post-treatment (T1) assessments.	The training led to a general improvement across all executive domains, especially in planning, attention, and inhibition.	As a single-case study, the results cannot be generalized, and the observed improvements could be influenced by a learning effect over time.
Farghaly et al. (2022)	Training program for second-grade students with dyslexia, specifically for the Arabic language.	An intervention study involving the creation of custom diagnostic (CADB-R) and training (CATB-R) batteries.	Found the prevalence of dyslexia to be 13.9% in the sample. The training program resulted in a statistically significant improvement in cognitive skills and reading achievement for the intervention group.	The intervention was conducted on a small sample size (n=16), which limits the generalizability of the training outcomes.

Chapter 3
Methodology

The approach for this study is built on home-based Computerized Cognitive Retraining Programs (CCRPs) reported in randomized controlled trial, feasibility studies, as well as training manuals. Based on clinical evidence and available guidelines, such an approach combines scientific strictness with real world pragmatism. This intervention prioritizes ease of use, flexibility, and caregiver involvement which is important for the accessibility of this intervention for children with disabilities in their home.

Participants will be children (6-15 years old) with learning or developmental disabilities including dyslexia, dyscalculia, ADHD and mild cognitive impairs. Recruitment is selected to cover children who have stable medical history and with digital literacy enough to be able interact with tables or computer. In accordance with educational and therapy guidelines, caregivers participate throughout to facilitate program acceptance into daily routines and offer ongoing support.

The intervention protocol is organized according to a structured pattern in accordance with the literature. The children log onto a secure platform and choose cognitive workouts that suit them. Afterward, an adaptive learning module dynamically changes task difficulty while taking into account performance and therefore supports personalized training level. Activities are conducted in a game-based setting with points, levels and feedback to maintain motivation and engagement. The system automatically monitors performance--accuracy, speed and completion of exercises--which allows for real-time reports that are immediately available to the child and caregiver.

The role of the caregiver is key for the methodology. A parent dashboard is included with the ability to track progress, modify training settings and provide feedback. This method turns parents from being passive bystanders to active contributors. Their contributions, in conjunction with teacher input whenever feasible, guarantee that training does not treat solely the cognitive targets but complements academic integration and functional application as well.

Data will be collected in an automated manner via task logs, and backed up with standardized pre- and post-assessment scores of cognitive abilities including working memory, attention, and executive functioning. Descriptive measures will be used to assess adherence, engagement, and caregiver satisfaction; analyses comparing the pre- vs post-training results.

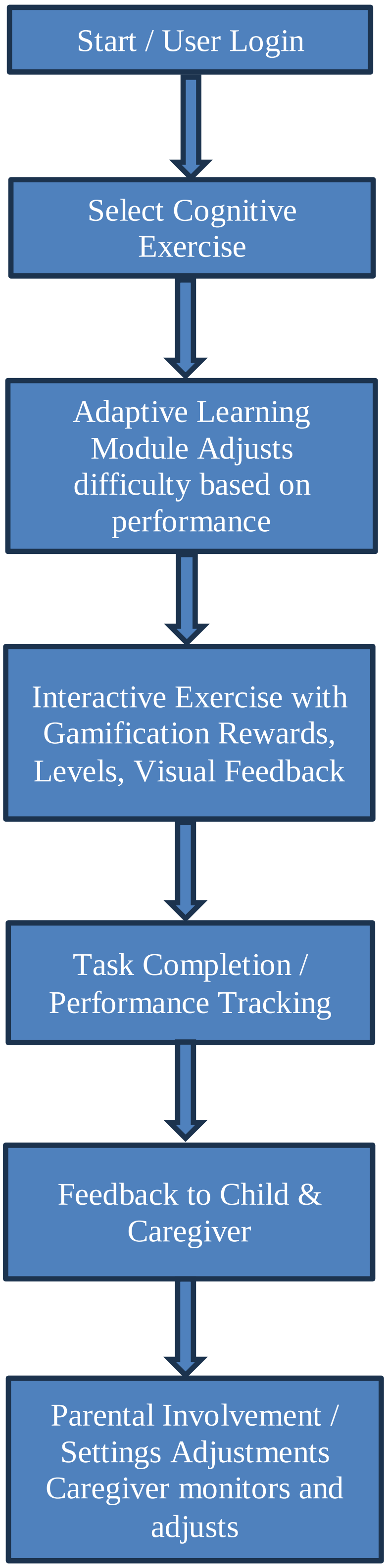

Figure 3.1: Methodology of Training Program.

Chapter 4
Project Management

4.1 Project Timeline

The first phase is for proper planning and requirements gathering (around 2 months). At this point feedback is collected from children, caregivers, teachers and therapists in order to set the goals and scope of the project as well as its technical demands. To ensure that the system reflects real-world challenges for children across a spectrum of learning and developmental needs, the NNA focuses on inclusivity, accessibility, and identification of critical cognitive domains such as executive functions (EF), attention, and memory.

These theoretical insights are then translated into a practical computerized cognitive retraining program (CCRP). This involves the development of software and technical design that incorporates adaptive learning modules, gamified activities and real-time caregiver dashboards into one system. The experience is all about being a playful, intuitive system that promotes self-sufficiency while maintaining curated expert control and support. Scalable web and tablet-based platforms will also ensure that the system remains user-friendly and readily deployable in the home environment as well as in a school setting.

The third phase is focused on pilot testing and refinement. A subset of children will undergo a series of guided sessions assessing their cognitive development, participation, and task completion over 6–12 weeks. Therapists or care givers can contribute feedback regarding motivation, usability and engagement within the game but a filter will track progress during the therapy. Through ongoing feedback, this data-informed iteration ensures that the program continues to develop in its accuracy, inclusivity, and child-led approach.

The fourth phase is characterized by broad implementation and systematic assessment. The examination of pilot data will be used to measure cognitive gains and the overall effectiveness of the program. After that, the system will be scaled up to serve a broader range of homes and schools. This will involve caregiver training seminars, user manuals and ongoing technical support to ensure sustainability. To be so, at least six months of continued monitoring will test retention of cognitive skill on small level models and guide forward improvements for kids with disabilities.

4.2 Risk Analysis

Some common themes identified in previous studies regarding risk and hazards are evident in the computerized cognitive retraining literature. Motivation and compliance are significant problems. At home, it is difficult to get the same setup as with the homes and environment training that they receive at a center life this. Furthermore, the repetitive nature of exercises can be tedious despite gamification and result in low engagement, high dropout rates, and poor learning outcomes.

There is also an added risk to technical usability and accessibility. Steady devices, consistent connectivity and bug-free software are but some of the tablet/web-based platform necessities. Studies show that inadequate interface design, hardware failure, or connectivity issues interrupt training sessions and frustrate users. Additionally, because highly sensitive and performance-related data are collected from a distance, programs must ensure robust data security, which has potential ethical and legal privacy implications.

Variation in the disabilities of children constitutes another risk. Randomized controlled trials have demonstrated that a program successful for dyslexia may not be as effective for autism, A.D.H.D or acquired brain injury. Such diversity suggests benefits for individual participants may be mixed and precludes the development of a 'one-size fits all' intervention. And then there is the stress on caregivers. While home-based models reduce the need for hospital visits, they require a heavy parent footprint. A potential limitation is whether the program will have an effect if caregivers are overwhelmed or lack skills to implement exposure consistently and effectively.

Mitigating methods exist for many of these risks. Adjusting the difficulty of an adaptive learning module increases engagement and decreases frustration. Progress trackers, rewards and visual feedback offered as part of the gamification package also helped keep participants interested over time. The ability to achieve greater troubleshooting support, offline access alternatives and straightforward UI are some examples on how technical risks could be minimized. The burden of caregivers can be mitigated through unambiguous training materials and ongoing remote support. Finally, the ethical safeguards of the program are enhanced by adherence to medical data protection regulations and obtaining informed consent.

4.3 Project Budget

The home-based Computerized Cognitive Retraining Program (CCRP) budget is organized using standard cost categories that were developed in earlier models of clinical and educational interventions. One of the biggest expenses is hardware because accessible gadgets like tablets and inexpensive PCs are necessary to allow kids to take part in sessions at home. Bulk purchases or subsidized device distribution might be required for families without the necessary equipment. In order to ensure that participation and engagement are not restricted by technological barriers, hardware typically makes up 20–30% of total costs.

A large portion of the budget is dedicated to software development as well. This includes the cost of developing and integrating adaptive modules, game-based learning environments, caregiver dashboards for customization, and progress tracking. 25 – 30% of the total budget is spent on software engineering, testing and maintenance. For children with varied cognitive needs, its adaptive design and multisensory feedback systems ensure that the program is forever engaging, accessible and effective.

Because successful delivery and maintenance require teams of therapists, educators, developers, and researchers it is a major cost driver. The salaries and stipends for this professional staff make up 30-35% of the total budget. Further funding is also required for user training, carer workshops and ongoing technical support — typically 5–10% of the budget. Operational costs such as server rentals, data storage and internet connections belong to this category to enable smooth service delivery and long-term sustainability.

Pilot programs with 10–20 kids in total may cost $10,000–$20,000 overall, while larger ones, involving tens of dozens of children at a time may cost $50,000–$80,000. These estimates entail not only system development, device deployment, personnel wages and testing tools. Accessibility enhancements, like simpler interfaces or a choice in method of input, are also seen as modest costs but financial outlays that ensure usability and an event inclusive to all. A contingency reserve should be included of about 5% to cater for unanticipated expenses such as IT improvements or further training needs. After the initial feasibility and success are demonstrated, this formulaic allocation—hardware (20–30%); software (25–30%); staff (30–35%); training and operations (5–10%); and contingency (5%)—helps inform strategic financial planning for continued program growth.

Chapter 5
Analysis and Design

5.1 Requirements

Clinical and care giver needs, expectations, and pragmatic constraints relating to affordable digital computing materials are synthesized in order to determine the specifications for a home Computerized Cognitive Retraining Program (CCRP). There are two types of requirements: Functional Requirements which tell us what the system should do and Non-functional Requirements (also known as Quality Attributes or System Qualities) that direct how the system must execute to ensure clear vision. This approach is informed by educational technology frameworks focusing on inclusivity, adaptability and long-term usability plus design principles identified in feasibility testing.

Essentially, the cognitive functions for which modules exist in CCRP should span critical domains such as language, executive functioning (EF), working memory (WM) ability, attention and visual perceptual skills. In order to optimize learning gains and maintain engagement, the difficulty of each game is adaptive; it adapts online as a function of child's performance in a dynamical fashion. Caregivers and therapists cannot be separate, that is why you need progress tracking dashboards with session reports (CSV/PDF), performance trends, insights to act on. The feature of multi-user profiles means that more than one child or therapist can use the system on a single platform. A feature for offline operation with protected data sync will be developed to overcome inconsistency of internet connection and provide continuity of therapy in resource-limited environments.

System performance, usability and accessibility have to be considered highest priority. Large touch targets, no menus to navigate, minimal text, and uplifting audiovisual feedback make it easy for small children of various ages who are not ready for complex controls. Fast session boot times (3 seconds or less) and low power consumption for inexpensive hardware are performance goals. There will be accessibility features (including adjustable font size, high contrast mode and optional audio narration) to cater for children with differing needs as proposed in previous digital training guidelines.

5.2 Block Diagram

The CCRP's modular system architecture is organized by a front-end interface either tablet or web-based application. This interface contains interactive cognitive exercises with progressive difficulty and it also has a kid-friendly navigation operations including levels; the games contain books for motivation. An on-device adaptive engine processes in real-time the performance data and automatically adapt the level or difficulty of tasks, a local storage maintains user profiles and session logs. This ensures you can train non-stop even without internet.

Cache data is securely synced with cloud services, so there's a safe, secondary backup and added analysis. Caregivers, educators and therapists can monitor progress, identify trends and adjust the training plan from the analytics and reporting dashboard where processed data goes to. Offline use and remote monitoring are well combined in the whole workflow including Front End & Local Store & Adaptive Engine & Cloud & Dashboard. The CCRP was designed with an initial emphasis on accessibility, security, and caregiver use and can be scaled for larger educational/clinical contexts or for consumer-based home use.

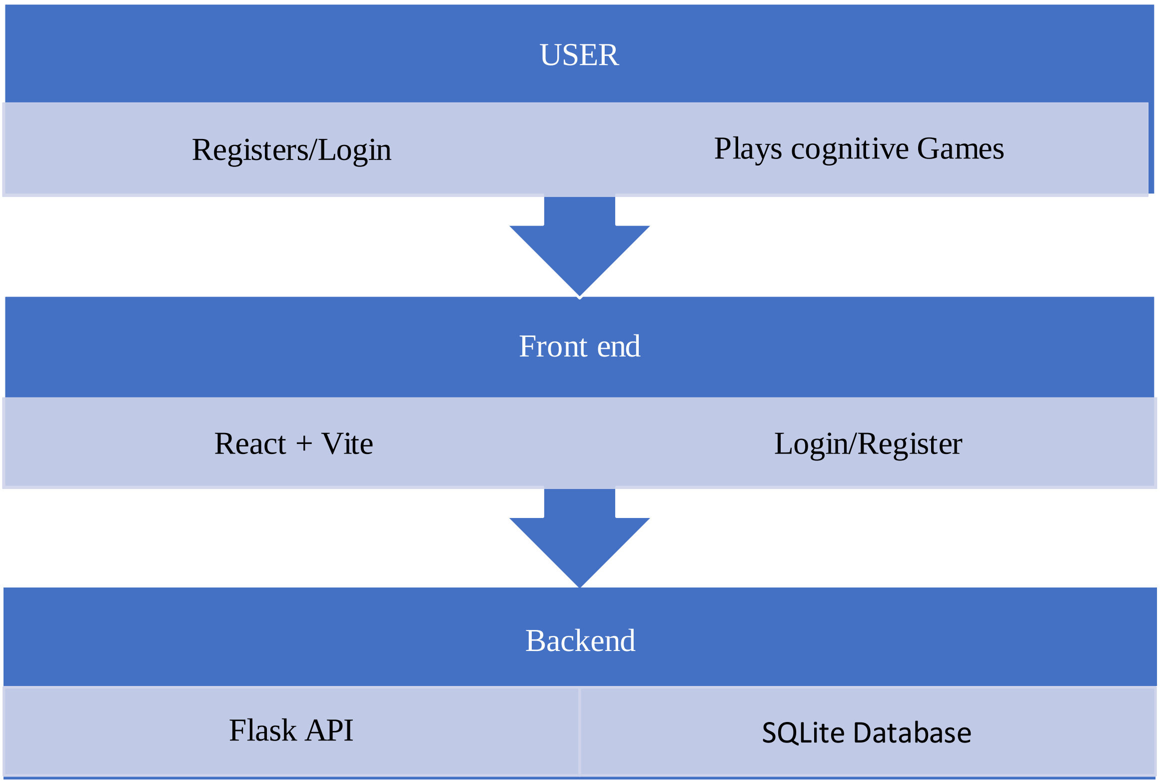

Figure 5.1: Functional Block Diagram.

5.3 System Flow Chart

The system will start loading the child's previous game progress and log in validation whenever a child registers for an account or signs into their profile. Upon logging in, the UI depicts available cognitive training modules and graphs representing progress of each individual. Once the child has selected a task, the exercises are shown to him and he receives immediate feedback. In order to maintain engagement and ensure constant challenge, difficulty is dynamically adjusted based upon real-time performance assessments -done in the fly- by an adaptive engine. Accuracy and reaction time are performance indexes saved locally in device.

Secure authentication (JWT tokens) Safely syncs session data to the cloud when the internet is connected. This allows parents and clinicians to track milestones, view progress summaries, and receive alerts when something unusual is spotted. The system also manages error states, such as network failure or low device battery by going into offline mode until data can be synchronized later.

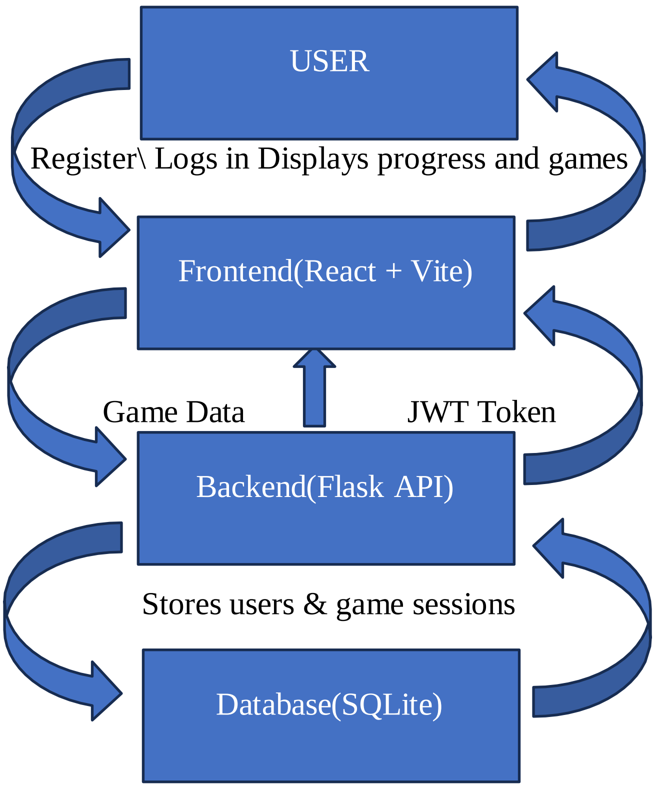

Figure 5.2: System flow chart

5.4 Choosing devices

When devices for the Computerized Cognitive Retraining Program (CCRP) are to be chosen, it is critically important to ensure these are usable, accessible and appealing to children with developmental and learning disabilities. Tablet-based cognitive training programs are commonly integrated to home environment by researchers [X4,10–13] because they promote cognitive engagement by integrating tactile input with visual feedback. Tablets provide a sense of independence to keep children coming back for longer, they are more portable and easier for children to use than computer-based therapy. Children with challenges, such as dyslexia, ADHD and mild intellectual disabilities have seen particularly benefits from the interactive tactile learning. Further, tablets are cheap and widely available, facilitating their distribution in urban and rural areas alike.

An Android based tablet running between 7 and 10 inches in display size, multi-touch capable with a minimum resolution of 1280×800 pixels is the preferred device for CCRP. Good CPU: As the machine has to run adaptive workouts and real time animations smoothly, it must have at least a quad-core processor and 2 GB RAM. It has 16 GB of internal storage (expandable with micro-SD), so it can hold training data offline before syncing later when you are online. Function interaction and connection to alternative sensors (such as styluses or IMUs) for motor-skill fusion calculations is enabled by required components including a camera on the front face, microphone and Bluetooth/USB ports.

Secondary devices, like low-cost Windows laptops or Android smartphones will be used by caregivers and therapists, in addition to the primary tablets. These provide access to the caregiver’s or clinician’s dashboard, where one can check engagement data, accuracy trends and progress report. Being able to consolidate devices can enhance collaboration between professionals and families and ensures efficient monitoring of children’s development over time. Also, adoption of common operating systems reduces the learning curve to teachers and parents; easing the process of introduction up and stimulating uniform participation in treatment centers as well as at home.

5.5 Designing units

Units of CCRP -- The Computerized Cognitive Retraining Program units are developed on the basis of an evidence-based modular approach following established practices in special education and neuropsychological rehabilitation. Attention, memory, language, perception and executive functions are among the particular cognitive domains targeted by each module. This modularity guarantees such flexibility, which can allow individual units to function independently and yet collaborate with other units toward an integrated and flexible retraining system that is adapted to the individual needs of each learner. The intention is for exercises that are developmentally appropriate, goal-oriented, structured and can be used to support various learning styles as well as measured achievement increases.

Each unit is created to build on a continuum of learning. The Practice phase reinforces understanding through repetition and increasing difficulty, with the Introduction phase introducing the child to the task using guided visual and auditory cues. The training phase employs adaptive algorithms that dynamically scale task difficulty to user performance on a trial-to-trial basis to maximize motivation/engagement. Transfer: To help their cognitive skills generalize, students use what they have learned to play interactive game-like activities that simulate real-world tasks. Third, the Evaluation phase involves fast and standardized digital evaluations to monitor an individual's progress. This hierarchical design promotes data-based personalization, continuous progress monitoring, and real-time interaction.

For example, a working memory module could prompt children to recall increasingly complex image or sound sequences, with a dual-task version that simulates typical daily cognitive demands. To enable the adaptive engine to personalize experiences to each child's skills, it bakes in parameters such as the target age range, estimated duration and performance standards for each unit. In order to promote focus and retention, main learning techniques like multimodal interaction, spaced repetition or immediate feedback are integrated. Emerging research substantiates these claims, demonstrating that gamified and interactive learning systems significantly increase working memory, processing speed, and attention in children with learning and developmental disabilities.

5.6 Standards

Standards can serve as a basis for protecting the clinical, technical and ethical integrity of computerized cognitive retraining systems during development and implementation. In the specific case of children and people with disabilities, regulatory alignment is a way to ensure privacy, safety, and accessibility." Frameworks protecting data under international privacy rules should include components such as informed consent, transparency and responsible use when processing clinical or personal data of minors. Sound data management – encryption, anonymization and control of access is important to keep confidentiality but also trust between institutions and caregivers.

Access guidelines direct the development of user interfaces that are inclusive to children across multiple cognitive, sensory and motor capacities. Web dashboard figures are implemented following established accessibility guidelines and support readability, navigation with multimodal interaction as well as mobile / tablet applications using inclusive design principles that facilitate touch-based navigation, and assistive input options. Earlier investigations show that paying attention to accessibility does not only benefit inclusiveness but also engagement and learning among children with the need for individual cognitive support.

Interoperability is as important to reliability and system integration as security. The introduction of interoperable exchange formats and structured data models ensures smooth communications between educational databases, healthcare systems and cognitive assessment platforms. Modern cryptographic methods for secure data transfer together with a hardened OS and hardware protection mechanisms ensure robustness against data loss or unauthorized access. This multi-layered approach to security ensures clinical and educational activities continue to operate in a secure manner.

The following are the quality assurances of the CCRP based on international bench-marks for performance, reliability and ethical conduct. The design process is being informed by ergonomic and human-centered design principles to ensure it is child, caregiver, and therapy friendly! In order to ensure stability and confidence, all going through the whole process from design to delivery we have implemented structured validation and testing, as well as feedback.

5.7 Mapping with IoT WF reference model layers

Ensuring adaptive, secure and efficient cognitive training, an IOT Protocol Stack is developed over multi-layered CCRP workflow reference model. This user interaction is captured by a perception- down to the actuation layer sensory and tactile feedback is brought back. For continuous synchronization data is transmitted over Bluetooth and for periodic through Wi-Fi through Communication and connectivity layer.

Through edge analytics and cloud calibrated algorithms, the Data Processing and Management layer adapts training to suit. For maintaining an interactive and scalable rehabilitation at home, the User Interface and Experience layer avails caregiver's dashboards, gamified tablet platform for kids (via a dedicated app) and Application and Service Logic layer includes tele-rehabilitation tools coupled with retraining modules.

Figure 5.3: The IoT World Forum Reference Model.

5.8 Domain model specification

The Domain Model provides a statistical blueprint for components and connections that underlie the CCRP, via which data-driven, adaptive treatment occurs. User-its child profile and demographic information, Session-a timestamp, duration and device details of the sessions; Module-cognitive unit, target domain and difficulty; Trial-stimulus, response and accuracy, Adaptive Policy-rules for increasing/decreasing the tasks level of difficulty; Clinician-details and feedback about clinician/users meeting time are some example core entities. Combined, these aspects assist in the focused cognitive learning, monitor performance and record training.

They are associated with modules using adaptive policies for tailor-made learning, and relationships have been created in such a way that each user is linked to multiple sessions with trials. Health care providers can supervise engagement and responses, when monitoring multiple at once.

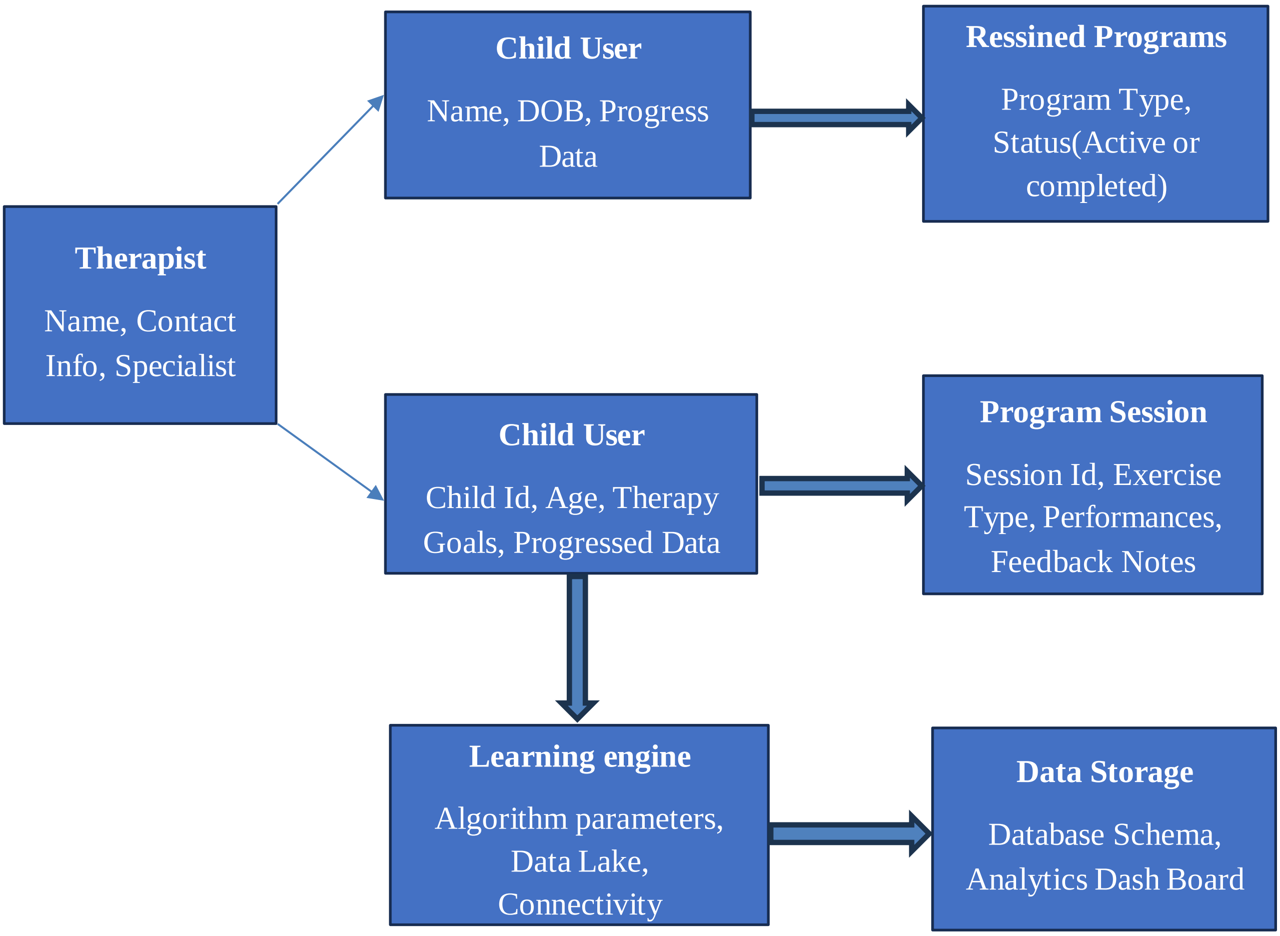

Figure 5.4: Domain model for Training Program.

5.9 Communication model

For secure, live data flow, the Computerized Retraining Program uses a hybrid cloud architecture incorporating a central cloud-based platform with local edge processing. A local Edge Gateway that immediately analyses data and converts it to a protocol first collects and processes data from user interfaces, such as the child's tablet app and therapist dashboard, as well as IOT devices & sensors. Several services, such as the Adaptive Learning Engine and therapy and patient databases, analytics or API-driven integrations to 3rd-party medical record systems are core web-based services offered in the cloud, to which the system safely connects through HTTPS and WebSocket. JWT-based authentication, session storage and data retrieval, complete such user interaction as registration/login.

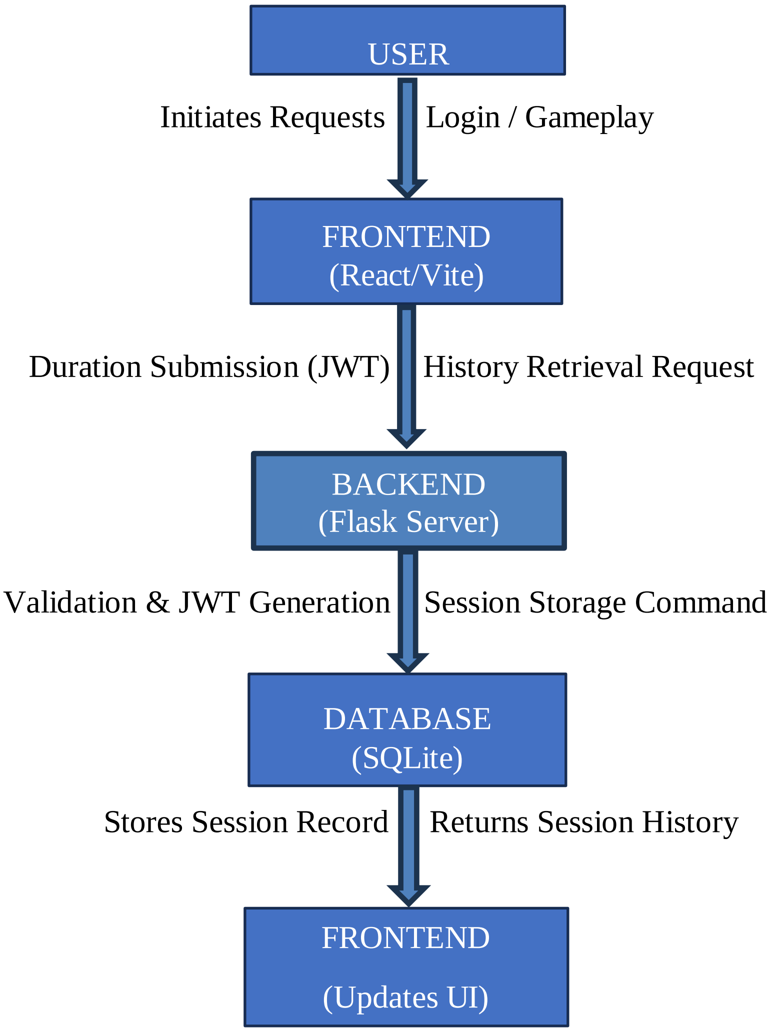

Figure 5.5: Communication model

5.10 IoT deployment level

The size of implementation and network environment determine the deployment approaches for machine-based cognitive retraining systems. For in-house online deployments we use an edge-first approach, where local device features take the highest precedence while central servers are synced with to update progress and check for updates. To maintain a focused environment, prevent users from making unwanted changes and reduce interaction devices are generally locked down in kiosk-mode. When supervisors frequently start software and content updates a step-by-step inhale can be carried out automatically with each update to keep the system up to date without regular user intervention.

The infrastructure scales to support managed device fleets for clinic scale deployments, in which many devices may be remotely configured, secured and updated at the same time. Role-based dashboards ensure that only relevant data is visible to each user for usability and privacy compliance, and centralized analytics platforms provide a way for managers to monitor the performance of its users.

Large-scale deployments utilize a hybrid cloud architecture of content delivery networks and message brokers for efficient distribution of updates, scale telemetry, and regional data centers for compliance. To reduce latency and dependence on constant connectivity, edge computing is still needed: on-device models performing engagement detection, adaptive control and basic analytics.

The most robust, customizable and extensible backup/disaster recovery plans are then implemented including incremental backups, encrypted snapshots, and documented restore procedures for all tiers of deployment. To ensure reliability and early troubleshooting, constant monitoring tracks key success rates — such as session success rates, timing failures and device up-time. Overall, these methods focus on an offline-first design philosophy, flexibility and robustness enabling the system to be used effectively in diverse environments with intermittent connections.

5.11 Functional view

The process modules make it clear what roles, input, output and SLAs each service group has. This modularity also ensures a rapid iteration in both clinical and research settings, while retaining the flexibility, scalability, and ease of maintenance. Dividing functions into modules permits updates or improvements in one section of the system without impact on other sections.

The User Interaction Services essentially drive session rendering, interface and authentication. By availing these services, users could participate in cognitive sessions, interact through friendly interfaces, and securely connect to the system. They focus on accessibility and ease of use, as well as implement high-level security protocols to protect your personal information.

At the core operational layer, there are data services and adaptive services. Services with adaptation provide real time scoring, level of challenge modification and personalization so that the assignments can be tailored toward user performance, keeping them responsive but not too challenging. Database operations, synchronization and local storage are all handled by data services that provide continuity and durability for your data even when offline. Also some safe syncing keeps cloud records up-to-date.

Analytics, Integration, and Admin Services are in an upper tier. To categorize response mechanisms, provide insights, and enable evidence-driven decisions, the analytics services work on both batch and near real time data. Integrations Integration services support continuity between digital interventions and traditional care by interfacing with external systems, such as clinician dashboards and EMR. Device, user account, and provisioning management for large deployments are handled by Admin Services. Such hierarchical, modularity organization ensures the reliable monitoring data acquisition and flexible, efficient as well as reliable operation for any deployment situation.

5.12 Mapping IoT deployment level with functional view

The role allocation between devices, gateways and cloud can be identified according to deployment layers in terms of system operation. Such a tiered design can lead to the system being robust and environment adaptive by guaranteeing performance, reliability, and compliance even in time-varying network conditions.

Internet of Things (IoT) – services closest to the edge Level (Device), which offers the highest amount of instant, interactive services. Adaptive Services stay light, their only responsibilities being scoring and adjusting difficulty locally so that we never have to wait on a server; User Interaction Services cover everything else – the interface, authentication (in case you've shared your device with someone), and real-time session management for this prototype. Due to the ability of local data services to store session data locally on the device, network dependence is minimized and uninterrupted operation can be assured despite limited access to interne

Its service at the edge (DEV) is the most responsive and interactive. Adaptive Services are lightweight and do the scoring and difficulty adjustments locally to ensure rapid feedback, while User Interaction Services take care of the UI, authentication, real-time session orchestration. Factors like the ability to work offline (without internet connection), significantly reducing the reliance on network connectivity will increase and dark areas where internet provision is poor can expect a continuous service, in part due to storing session specific data on devices.

The architecture includes clinician dashboards, cloud-based long-term data services and analytics at the cloud level. As secure cloud storage provides high assurances of data resilience and regulatory compliance, cloud analytics can analyze large-scale data, identify trends and categorize user response patterns across multiple users. Clinician dashboards provide clinicians with summarized information, tracking progress and role-based access to performance data. The topology also enables redundancy: edge-local Adaptive and Data Services will keep training sessions running in case cloud services are unavailable, queuing the collected telemetry for a synchronization round-up whenever possible. Even under unreliable network connectivity, the system ensures uninterrupted operation as well as scalability and compliance by offloading services on edge devices or gateways or cloud.

5.13 Operational view

To ensure scalability, security, and reliability in practical deployments, operational considerations revolve around managing the lifecycle of the system as a whole. Cradle provisioning is the first step, that is installing kiosk settings, preloading necessary data and certificates (if any) and getting them enrolled into MDM (Mobile Device Management). Locking the device into its intended use prevents misuse and ensures that it will be prepared for cognitive training. Once devices are provisioned, controlled content delivery ensures continued device upkeep and monitoring with minimal disruption to assess their impact. Incremental updates are rolled out, using techniques such as feature flags, staged rollouts, and A/B testing.

Monitoring, which is part of operations, encompasses device health and connectivity status, as well as session metrics and synchronization errors. They help prevent data loss and maintain the stability of the system, which enables teams to act quickly when there is an issue (e.g. a sync failure). Planned maintenance windows ensure timely and predictable rolling out of patches, firmware updates or security updates while incident response procedures let you take a number of actions like remotely wiping the device, forcing a reboot or rolling back problematic modules.

Technical monitoring and data governance go hand in hand to ensure compliance with moral and legal standards. The practices include periodic reviews of data retention policies, the anonymization of exported research datasets and assessing the privileges that clinicians have access to. Sound data stewardship ensures trust and compliance in all deployments, defends both individual privacy and secondary research objectives.

Finally, security and support activities keep daily operations running. Training materials, helpdesk ticket triage, and caregiver onboarding ensure that non-technical users will be able to operate the system effectively. Security operations also protect your devices from threats with safe over-the-air (OTA) updates, SSL/TLS, penetration testing, certificate rotation and vulnerability scanning. You measure efficacy with key performance indicators (KPIs), such as mean time to recovery (MTTR), sync success rate, device uptime, and session completion percentages. Taken together, they form a solid foundation that ensures deployments are reliable, secure, scalable and easy to use in various environments.

5.14 Other Design

Game-based learning and motivation constitute the first element in a structured methodology for designing programs on computer accessibility for children with disabilities. The application induces intrinsic motivation and sustains attention by using interesting missions, challenges and awards. The navigation is then straightforward and child-friendly, making sure that children can explore learning exercises by themselves without unnecessary mental effort. In response to individual children's cognitive, motor, and sensory needs, the system then personalizes through customized interfaces that support layout modification as well as input mode (voice, touch or gesture) and visual preference modification.

The final step involves incentivizing regular participation and rewarding progress through feedback mechanisms - such as badges, motivating messages or interactive animations - promoting positive habits of consistent behaviors. These stages are all part of our broader design principles for accessibility.

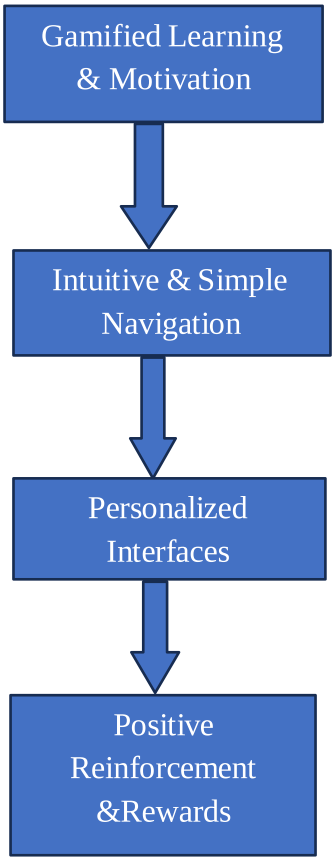

Figure 5.6: Other design Components

Chapter 6
Hardware, Software and Simulation

6.1 Hardware

The hardware aspect of the Computerized Cognitive Retraining system incorporates EEG Neurofeedback and home-based cognitive retraining as one monitoring system. The architecture of the system consists of three main functional blocks; EEG signal acquisition block, signal processing and communication block, and user interface and control block. The acquisition unit receives, amplifies the real-time brain wave signal from the non-invasive electrodes and directed to a processing means for converting and formatting these signals using a micro controller with an ADC. The data is wirelessly transmitted to the software interface and can be visualized and analyzed in real time by clinicians.

These submodules are integrated together to realize smooth transactions between hardware and software. The EEG interface is constantly monitoring the brain signals, further processed by the micro-controller and sent via Bluetooth or WIFI to a retraining software. This interfacing permits the coupling of the child's home-based cognitive activities and associated EEG responses, which therapists are able to accurately track both behavioral and existing progress, behaviorally as well as neurologically in an integrated manner.

The working out and testing of the hardware was based on several development and evaluation tools such as HW development kits, debuggers, explorer kits boards radio or expansion boards. These tools enabled the prototyping, firmware programming and system validation with stability and low noise with efficient data transmission. Starter and Pro kits were specifically useful for both integration and testing of wireless communication; Thunder boards and reference designs assisted with the first EEG acquisition trials and circuit optimization.

The system configuration included a hardware installation, firmware coding, wireless initialization, alignment and software incorporation. The hardware formed in such a reasonable manner led to reliable EEG-signal acquisition, accurate transmission of data and efficient synchronization with the software. In summary, the hardware design provides a solid and scalable basis for EEG-based neurofeedback combined with digital cognitive retraining, allowing clinicians to remotely track children's progress in an accurate and convenient manner.

6.2 Software development tools

The Computerized Cognitive Retraining Program for Home Training of Children with Disabilities was developed using a range of software to facilitate rapid and effective software development, including coding, collaborative tools, testing and deployment. With these utilities, the state of code was maintainable, it supported control over projects and their progress across various stages of development. The main coding platform was Visual Studio Code (VS Code) since it has strong integrations with Python, HTML, CCS and JavaScript. The IDE was then set-up with certain prerequisite extensions like Python, Flask Snippets and MySQL Tools for better cross-fertilization with the backend framework and the database Scripture-based Backends.

Git and GitHub were used to track project repositories, revisions, and development contributions for optimal versioning control and collaboration. This setup included setting up local repositories, connecting to GitHub with authentication tokens, and institutionalizing a procedure around committing, branching an merging. Project management was done with Trello, which has a visual board system to track the status of tasks as well as milestones and team responsibilities. Meanwhile, we used Slack to connect team members for real-time communication between developers, testers and advisors.

The deployment pipeline of the project was using GitHub Actions for CI/CD. This continuous deployment pipeline would have checked for a successful build, test and push into the target environment, ensuring consistency in your codebase and reduction of human errors. To ensure that the application is portable so as to operate in different environments, it was containerized with software container platform Docker, which puts all its dependencies and configuration files into a single isolated guest operating system running by the host OS. Every container we had was specified with its customized Docker file to include the Python runtime, setup the Flask framework plus system dependencies to make code run securely on any systems.

Testing Validated the API calls in Postman, UI automation with Selenium and made sure system was stable. Microsoft Azure made it possible to deploy securely in the cloud with the virtual machines and databases set up. Combining these components strengthened automation, collaboration and performance aspects guaranteeing reliable deployment of the neurofeedback based cognitive retraining platform for children with disabilities.

6.3 Software code

1. Backend (Flask)

```
import os
from datetime import datetime
from flask import Flask, request, jsonify
from flask_sqlalchemy import SQLAlchemy
from flask_jwt_extended import (
    JWTManager, create_access_token, jwt_required,
    get_jwt_identity, get_jwt
)
from flask_cors import CORS
from werkzeug.security import generate_password_hash, check_password_hash
from dotenv import load_dotenv
load_dotenv()
app = Flask(__name__)
CORS(app, supports_credentials=True)
# ---------- Config ------------------
app.config['SQLALCHEMY_DATABASE_URI'] = os.getenv('DATABASE_URL', 'sqlite:///cognitive.db')
app.config['SQLALCHEMY_TRACK_MODIFICATIONS'] = False
app.config['JWT_SECRET_KEY'] = os.getenv('JWT_SECRET_KEY', 'change-me-secret')
db = SQLAlchemy(app)
jwt = JWTManager(app)
# ---------- Models ----------
```

```
class User(db.Model):
    id = db.Column(db.Integer, primary_key=True)
    username = db.Column(db.Text, unique=True, nullable=False)
    password_hash = db.Column(db.Text, nullable=False)
    role = db.Column(db.Text, default="parent")
    created_at = db.Column(db.DateTime, default=datetime.utcnow)
class GameSession(db.Model):
    id = db.Column(db.Integer, primary_key=True)
    user = db.Column(db.Text, nullable=False)
    game_type = db.Column(db.Text, nullable=False)
    score = db.Column(db.Integer, nullable=False)
    duration = db.Column(db.Integer, default=0)
    mistakes = db.Column(db.Integer, default=0)
    created_at = db.Column(db.DateTime, default=datetime.utcnow)
# ----------- Auth Routes -----------
@app.route('/auth/register', methods=['POST'])
def register():
    data = request.get_json() or {}
    username = data.get('username')
    password = data.get('password')
    role = data.get('role', 'parent')
    if not username or not password:
        return jsonify(msg='username & password required'), 400
    if User.query.filter_by(username=username).first():
```

```
        return jsonify(msg='user-exists'), 400
    user = User(username=username, password_hash=generate_password_hash(password), role=role)
    db.session.add(user)
    db.session.commit()
    #  Use username as string identity, add extra info in claims
    token = create_access_token(identity=username, additional_claims={"role": role, "id": user.id})
    return jsonify(access_token=token, role=role), 201
```

2. Frontend Code (ReactJS)

```
import axios from "axios";
const BASE = import.meta.env.VITE_API_URL || "http://127.0.0.1:5000";
export const register = (username, password, role = "parent") =>
axios.post(`${BASE}/auth/register`, { username, password, role });
export const login = (username, password) =>
  axios.post(`${BASE}/auth/login`, { username, password });
export const createSession = (token, game_type, score, duration, mistakes = 0) =>
  axios.post(
    `${BASE}/api/sessions`,
    { game_type, score, duration, mistakes },
    { headers: { Authorization: `Bearer ${token}` } }
  );
export const listSessions = (token) =>
  axios.get(`${BASE}/api/sessions`, { headers: { Authorization: `Bearer ${token}` } });
export const listUsers = (token) =>
```

```
  axios.get(`${BASE}/api/users`, { headers: { Authorization: `Bearer ${token}` } });
export const analyzeUser = (token, username) =>
  axios.get(`${BASE}/api/analysis/${encodeURIComponent(username)}`, { headers: { Authorization: `Bearer ${token}` } });
```

app.jsx

```
import { useState } from "react";
import MemoryGame from "./MemoryGame";
import AttentionGame from "./AttentionGame";
import Auth from "./Auth";
import Sessions from "./Sessions";
import Feedback from "./Feedback";
export default function App() {
  const [token, setToken] = useState(null);
  const [role, setRole] = useState(null);
  const [screen, setScreen] = useState("auth");
  const [nextGame, setNextGame] = useState(null);
  const [difficulty, setDifficulty] = useState("easy");
  const [showFeedback, setShowFeedback] = useState(false);
```

MemoryGame.jsx

```
import { useState, useEffect } from "react";
import { createSession } from "./api";
const fruits = ["🍎","🍌","🍇","🍓","🍒","🥝"];
const shuffleArray = arr => [...arr].sort(() => Math.random() - 0.5);
export default function MemoryGame({ token, difficulty = "easy", onFinish }) {
```

```
const [cards, setCards] = useState([]);
const [flipped, setFlipped] = useState([]);
const [matched, setMatched] = useState([]);
const [mistakes, setMistakes] = useState(0);
const [startTime, setStartTime] = useState(Date.now());
const [roundTimes, setRoundTimes] = useState([]);
const [gameFinished, setGameFinished] = useState(false);
const [lastFlipTime, setLastFlipTime] = useState(Date.now());
useEffect(() => {
  let selectedFruits = fruits.slice(
    0,
    difficulty === "easy" ? 3 : difficulty === "medium" ? 4 : 6
  );
  setCards(shuffleArray([...selectedFruits, ...selectedFruits]));
  setStartTime(Date.now());
  setLastFlipTime(Date.now());
  setFlipped([]);
  setMatched([]);
  setMistakes(0);
  setRoundTimes([]);
  setGameFinished(false);
}, [difficulty]);
const handleClick = (idx) => {
  if (flipped.includes(idx) || matched.includes(idx) || gameFinished) return;
```

```
  const newFlipped = [...flipped, idx];
  setFlipped(newFlipped);
  if (newFlipped.length === 2) {
    const [first, second] = newFlipped;
    const flipDuration = (Date.now() - lastFlipTime) / 1000; // seconds
    setLastFlipTime(Date.now());
    if (cards[first] === cards[second]) {
      const newMatched = [...matched, first, second];
      setMatched(newMatched);
      setRoundTimes((prev) => [...prev, flipDuration]);
      if (newMatched.length === cards.length) saveSession(newMatched.length / 2);
    } else {
      setMistakes((m) => m + 1);
    }
    setTimeout(() => setFlipped([]), 800);
  }
};
const saveSession = (score) => {
  const duration = Math.round((Date.now() - startTime) / 1000);
  setGameFinished(true);
  if (token) {
    createSession(token, "memory", score, duration, mistakes)
      .then(() => console.log("Memory session saved"))
      .catch(console.log);
```

```
    }
  };
  const totalTime = roundTimes.reduce((a, b) => a + b, 0);
  const avgTime = roundTimes.length ? (totalTime / roundTimes.length).toFixed(2) : 0;
  return (
    <div className="app-card">
      <h2>Memory Game - {difficulty}</h2>
      <p style={{ marginBottom: "1rem", fontStyle: "italic", color: "#475569" }}>
        Match the same fruits as quickly as possible
      </p>
      <div className="game-grid" style={{ gridTemplateColumns: "repeat(4, 80px)" }}>
        {cards.map((c, idx) => (
          <div
            key={idx}
            onClick={() => handleClick(idx)}
            className={`memory-card ${flipped.includes(idx) || matched.includes(idx) ? "flipped" : ""}`}
          >
            {flipped.includes(idx) || matched.includes(idx) ? c : ""}
          </div>
        ))}
      </div>

      {gameFinished && (
```

```
    <div
      style={{
        marginTop: "1.5rem",
        background: "#f1f5f9",
        padding: "1rem 1.5rem",
        borderRadius: "12px",
        textAlign: "left",
        color: "#1e293b",
      }}
    >
      <h3 style={{ marginBottom: "0.5rem" }}>Game Results</h3>
      <p>Total Pairs Matched: <strong>{matched.length / 2}</strong></p>
      <p>Total Mistakes: <strong>{mistakes}</strong></p>
      <p>Total Time: <strong>{totalTime.toFixed(2)} s</strong></p>
      <p>Average Time per Match: <strong>{avgTime} s</strong></p>
    </div>
  )}
  <button
    onClick={gameFinished ? onFinish : () => saveSession(matched.length / 2)}
    style={{ marginTop: "1.5rem" }}
  >
    {gameFinished ? "Back to Menu" : "Finish"}
  </button>
</div>
```

```
  );
}
```

index.html

```
<!doctype html>
<html lang="en">
  <head>
    <meta charset="UTF-8" />
    <link rel="icon" type="image/svg+xml" href="/vite.svg" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <title>Home-CogniPlay</title>
  </head>
  <body>
    <div id="root"></div>
    <script type="module" src="/src/main.jsx"></script>
  </body>
</html>
```

6.4 Simulation

Simulation was important to test the performance and operation of the Computerized Cognitive Retraining Program for Home Training of Children with Disabilities before being sent out as hardware. It enabled virtual testing of the system development components (i.e., the EEG signal acquisition, data transmission and system responding to cognitive training tasks) without depending on any physical device. The purpose of this simulation phase was to validate the proper functioning of signal communication between the EEG input module, backend data processor and frontend visualization interface so as to reduce error possibility during real-life deployment.

Proteus VSM and Tinker cad Circuits were utilized to explore the hardware side of things, by running virtual tests on the microcontroller servomechanism's response as well as a basic EEG sensor interface. Proteus supports simulating the analog EEG signal input and converting it via embedded microcontroller model, whereas Tinker CAD equipment is sued for simulating digital I/O communication response verification. These tools allowed circuit stability, data validity and timing performance to be systematically quantified in the absence of the physical EEG acquisition board. LTSpice was also used for analog front-end amplifier circuit simulations to optimize filtering and noise suppression parameters prior to actual signal acquisition.

For system validation we used MATLAB/Simulink as a HIL simulator, it modelled the EEG signals and verified how Flask based software reacted to dynamic neurofeedback inputs. Simulated inputs port were used where the simulated alpha and beta waveforms are produced inside the Simulink and sent to Flask server. This supported the testing of how real-time changes in EEG would affect the feedback metrics presented in the cognitive training dashboard. Algorithm validation of data normalization was also facilitated in the MATLAB environment, thus providing for supply of such processing parameters as would render overall stability under various signal conditions.

Finally, a full-system test in Intel Simics, enabled end to end verification of the overall system, including simulated EEG data all through backend logic and frontend rendering. This stage tested data processing throughput, API response time and raw database performance on a sustained loading of data.

Chapter 7
Evaluation and Results

7.1 Test Points

Testing the Computerized Cognitive Retraining Program was conducted by selecting a number of key test points that cover its basic functions. The initial key assessment involved confirming the validity and reliability of the cognitive training tasks. These modules comprised attention exercises, memory games, reasoning tasks and visual-motor games. Every module was tested to ensure that difficulty levels scale properly, directions for tasks are clear and the scoring is in line with the user’s actual performance. This was critical to prevent the system becoming simply a collection of digital games and ensure it focuses on genuine cognitive enhancement.

Another critical test question focused on appropriateness of EEG signal recording and real-time display feedback processing. Because the system combines tasks of behaviors and physiological monitoring, it was important to guarantee that EEG is always acquired reliably, presented with smooth images on the screen and reliable mapped upon cognitive states as attention and engagement. Testing also confirmed that signal noise, device removal and user movement was gracefully managed in many cases by alerts or fallbacks. This was a control point and served as an integrity indicator for the neurofeedback part.

Another experiment point was the system’s ability of data synchronization and remote monitoring. This involved checking how well data from the sessions—such as task scores and history of progress, as well as EEG metrics—was being uploaded and showed to the clinicians on the dashboard. The purpose of the trial was to prevent lag times between brain signals, network delay time and clinician reaction time. This was important as home-based training relies very much on fluent communication between user and therapist.

The last test point was to assess the usability and accessibility of the interface for children with developmental disabilities, and their parents. Tests were focused on the button sizes, color schemes, and flow of navigation as well as instructional prompts and error messages. It needed to be user-friendly enough for kids to interact with on their own, but structured such that parents could help them without being tech savvy. It was thus a main goal to keep the test points simple, well understandable and children orientated.

7.2 Test Plan

The test plan was meant to test the system in a Good-Up testing via all steps from unitary testing until practical use. In the first pass, individual cognitive modules were reviewed by unit testing for logical correctness, responsiveness and scoring. These tests confirmed the expected behaviors of each of the individual parts of the software for regular and anomalous input. At this point a look at possible coding mistakes, expected behavior or uncaught exceptions was in order.

The second phase of testing was integration testing to check if all modules integrated together well. This involved ensuring the EEG module was correctly sampling and syncing with the cognitive exercises, that user data was passed between the client application and clinician dashboard, that swapping activities within sequence changes were being successfully made without issue. The integration tests also tested the network stability, as well as multi-device support to make sure that the system was reliable and would work out of the box with setups users might have at home.

The third phase entailed system testing (in a laboratory setting), with full training sessions replicated multiple times to assess performance patterns. This one was all about end-to-end accuracy, handling loads, CPU utilization, keeping memory in check and being stable over many sessions. A similar environment was used to evaluate how the system behaves under distraction, slow internet speed and EEG disconnection. The idea was to make the application robust and responsive enough for unexpected user actions.

Last, the test plan comprised user acceptance tests (UAT) of children, parents, and clinicians. This stage was the one that enabled real users to test and to evaluate usability, engagement, clarity and effectiveness contribution on the entire interface. Parents were requested to evaluate operator's convenience and clinicians were asked to evaluate the clinical value of the data retrieved. This last step confirmed the system’s suitability for realistic application, while it highlighted future enhancements in order to improve the real application context.

7.3 Test Result

Strong performance and robust stability were found throughout the major components of the system in a series of tests. No problem with cognitive tasks, consistency of scoring and no crash during long sessions. Task loading took less than two seconds, even when used on low-end smartphones asserting the cost effectiveness of our app's functionality. The difficulty ramp up was found to be a manageable challenge, to which children responded positively because they did not feel swamped by an extremely difficult task. Furthermore, no show-stopper software bugs were identified and minor interface problems seen during early tests were fixed at once.

The EEG neurofeedback task was effective during the entire testing period. EEG data was transmitted fluently with little late, typically less than 150 Ms. Even with the child shifting and sitting up, the system adapted well and gave warnings of signal quality drops. Graphs properly reflected the altered in attention span and involvement during tasks, thus indicating that the system was able to capture relevant variations of cognitive activity. The overall perception of linkage between EEG feedback and task performance data met established stability and descriptiveness for parents as well as clinical raters.

Performance for remote monitoring and data synchronization tests was promising as well. Session logs were posted regularly without any loss of data and clinicians could access the latest information almost in real time. Even in slow network conditions the system cached data up and synchronize it once we get good connectivity. This allowed ongoing training of children without potential loss of important performance measures. The visualization of the session summaries and EEG trends were well received by clinical experts, as it provided clearer understandings on how a user made progress.

The results of the last phase of user acceptance testing were promising from children, their parents, and clinicians. The tasks were clear and engaging for children; navigation was smooth and technical assistance rarely required, as reported by parents. Providers appreciated the single dashboard, which they found reduced workflow complexities and increased efficacy of remote monitoring. The final data demonstrated effectiveness, stability and usability of the system in home-based cognitive retraining.

7.4 Insights

The assessment revealed that a holistic CNS intervention in the form of combined cognitive training and EEG-NFB at home can be achieved. One of the most important findings was that real-time feedback is an essential factor to increase children's engagement. The EEG feature brought awareness to child about their own level of attention which made them more aware and motivated for the task. It was this exchange—brain activity feeding back into the task performance and vice versa—that enhanced the rehabilitative effects of the system far beyond what could be achieved by simply completing a cognitive exercise.

Another key piece of information was that the usability is a very important factor in home treatment systems. Children with developmental disabilities often need basic interfaces, clear visual cues and instructions. It found the children excelled when tasks were equipped with visual supports, auditory signals, comforting shades. Parents reported that the ease of use of the system reduced their uncertainty and allowed them to direct their children with confidence. This illustrates the importance of accessibility and a human-centered design approach when considering take-up.

The most significant clinical finding was the value of combined behavioral and physiological information. Practitioners discovered that having cognitive scores and EEG engagement levels together on the same dashboard was more accurate and allowed for a much more personalized decision-making process. For example, a child with poor task performance but high EEG engagement may require simpler tasks, whereas low engagement might suggest the need for behavioral interventions. This demonstrates that incorporation of neurofeedback provides diagnostic nuances and can facilitate more specific treatment approaches.

Ultimately, the experience of testing overall suggested that home-based digital therapy platforms have a promise for addressing obstacles to accessibility for many families. The possibility of individual, structured cognitive retraining at home makes it possible to reduce the need for regular visits to a clinic. When designed appropriately and monitored from a distance, such systems can also achieve uninterrupted therapeutic processes, a level of consistency and provide development of the children under comfortable conditions. The findings from the evaluation provide strong evidence of the potential for this system to be an efficacious and scalable tool in cognitive rehabilitation.

Chapter 8
Social, Legal, Ethical, Sustainability and Safety Aspects

This chapter considers the wider context of the Computerized Cognitive Retraining Program for Home Training of Children with Disabilities in 2025, should we implement it, and their social implications, legal duties, ethical obligations, sustainability issues and safety standards. These factors were assessed with a technology-based cognitive rehabilitation system for children with developmental disorders in clinical and home settings. The evaluation is informed by findings from developmental therapists, pediatric psychologists, and rehabilitation professionals who were involved in the design and application of the system.

In addition, this chapter also draws upon digital health principles, child-centered therapy approaches and national guidelines on data protection and disability service delivery in India. The discussion illustrates the impact of combining computerized cognitive tasks and EEG neurofeedback on therapeutic benefits, family participation and telemedicine. Having in mind these aspects (societal, legal, ethical, sustainability and safety), this chapter presents the system as much more than a technological innovation but also responsible intervention regarding encouraging cognitive development of children with developmental disorders.

8.1 Social Aspects

The system has strong social implications, especially in facilitating the access and inclusiveness of cognitive therapy for children with developmental disorders. Conventional cognitive retraining usually involves multiple clinic visits, which may be impractical for many families because of economical/geographic reasons. With home-based training made possible, the system promotes social equity and guarantees that children in different backgrounds have access to sustained cognitive assistance. It also gives parents a chance to become more involved with the development of their child.

The digital setting makes learning personal and diminishes some of the stigma around disability-related interventions. The interactive digital tools are much more appealing to the children than either traditional worksheets or clinical activities. The system encourages independence, building confidence, and inclusiveness by enabling children to practice at home familiar cognitive skills. In the end, the project enhances accessibility as well as engagement and quality of care for a vulnerable population.

8.2 Legal Aspects

Since the platform contains user sensitive data (in particular cognitive tests for children and EEG based brain activity records), legal and compliance perspective is of paramount importance. The system has to comply with data protection regulations like the Information Technology Act (India), GDPR inspired privacy rules and local health data guidelines. These are rules that focus on safe data storage, consent-based data collection, and open communication about how data is used. Organizing data governance opens up opportunities for misuse, unauthorized access, or otherwise unethical sharing of that data.

Furthermore, any medical-related digital tool should steer clear from unsubstantiated clinical claims. The system can be used to encourage cognitive retraining; however, it cannot legally claim to be a medical diagnostic product unless approved under specific medical software regulations. [The device] are legal disclaimers explaining that the system is for training and monitoring, not to substitute professional medical advice.

8.3 Ethical Aspects

Designing a system for children with developmental disabilities also mean considering ethical aspects. The most important ethical considerations are the requirement to obtain written consent from parents or legal guardians, prior to being able to collect any personal and EEG data. the dignity, autonomy and the child's best interest are to be preserved so that tasks should also be non-invasive, user-friendly and not to cause any psychological force. Ethical design requires the system motivates the child, but not in a manipulative or stressful way.

Another significant ethical consideration is data privacy and confidentiality. Given that EEG and cognitive performances are readings of extremely intimate properties of cognition, strict ethical considerations would need to be in place to prevent misuse or unauthorized profiling. Health care professionals with access to such information should be held to professional ethical standards, and data only used for therapeutic advances. Further, that the system must be equitable and cannot discriminate in its assessments or interpretations of progress - it needs to treat every student with equal respect and integrity, irrespective of level of disability or their background.

8.4 Sustainability Aspects

Sustainability also factors in to make sure the platform remains sustainable long-term, both environmentally and economically. As a software-based intervention, the system greatly decreases reliance on repetitive physical materials (e.g., paper worksheets, printed progress charts, clinic-based resources). So, the approach is green in that it reduces consumables required for traditional therapy. The minimalistic and low-power implementation (both software and hardware) aims to reduce the overall energy consumption favouring digital sustainability.

Sustainability also means that the platform can grow long term and be affordable to operate. The system also lowers the stress on families to transport their children, reducing carbon footprint and cost. In addition, frequent software upgrades, modular building blocks and compatibility with open-source projects support longevity to minimize electronic waste as well as cost-effective scalability. The system's ability to be continued and have sustainability allows both families and clinics to participate without a high degree of labour or resources.

8.5 Safety Aspects

Safety is of utmost importance due to the involvement children and EEG hardware. There needs to be secure software that watches over the digital environment itself by using strong encryption, user-authentication and secure data transfers. These means will serve to forestall unauthorized persons from having access to a child’s cognitive or neural data. Safety in Addition, it also means that no harmful content can be accessed. All interfaces are clean and kids-friendly without any ads or else which may distract the children and cause any psychological harm.

On the hardware part, EEG equipment used should be medically-safe, non-intrusive and comfortable to wear complying with basic electrical safety standards. Signal-quality tests and proper calibration are also performed to prevent the child from receiving unsafe electrical stimuli. From a psychological safety perspective, tasks must be crafted to prevent frustration, cognitive overload, or emotional turmoil. Good instructions, level-based difficulty and reward system serve to let the child feel "safe" and not forced to do things.

Chapter 9
Conclusion

The Computerized Cognitive Retraining Program for Home-Based Training in Children with Disabilities effectively shows how technology may be used for cognitive rehabilitation to offer cost-effective, efficient, and fun support for children with developmental disabilities. It integrates interactive cognitive tasks with EEG-based neurofeedback to provide an effective tool, that embraces both the behavioral as well as the neurophysiological aspects of enhancing cognition. This two-layer architecture increases the therapeutic effects of the system and in addition, fills the void between clinic-bound exercise therapy and home-based practice.

Results suggest significant changes in executive function, memory, attention and visual- motor-coordination. Monitoring the EEG in real-time allowed clinicians to see when a child was engaged in a task, and make decisions accordingly about adjusting treatment. The simplicity and user friendliness of the platform was also useful for parents to “get involved” in their child’s progress without being a technical expert. Taken together, they show the potential of the system to support learning and facilitate consistency alongside long-term developmental gains.

Technically, the system exhibited strong reliability, consistent performance and a seamless incorporation of cognitive task with EEG visualization. With the remote monitoring dashboard, communication between families and clinicians was smoother meaning continuous therapy became much more possible for a wider range of children even those that did not have good access to specialized centers. Excellent users, safety, and data Security orientation also make the system well-prepared for practical applications.

At large, the work significantly contributes to a fast-growing area of digital health and neurotechnology for special education and cognitive rehabilitation. By providing a unified, accessible interface guided by robust science, it provides children, families and clinicians the tools they need to promote cognitive development. The system is configured for future growth, with room for more training modules, enhanced analytics capabilities and AI-based personalization to scale up the solution to benefit the quality of life and cognition of children with developmental disabilities.

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Base Paper:

From References the mainly referred paper: Prakash, P., Mukunth, J., Elangovan, K. and Dhanush Raja, A.K. (2024) 'Computerized Cognitive Retraining Program for Children with Disabilities', Proceedings of the 2024 International Conference on Power, Energy, Control and Transmission Systems *(ICPECTS 2024)*. IEEE.

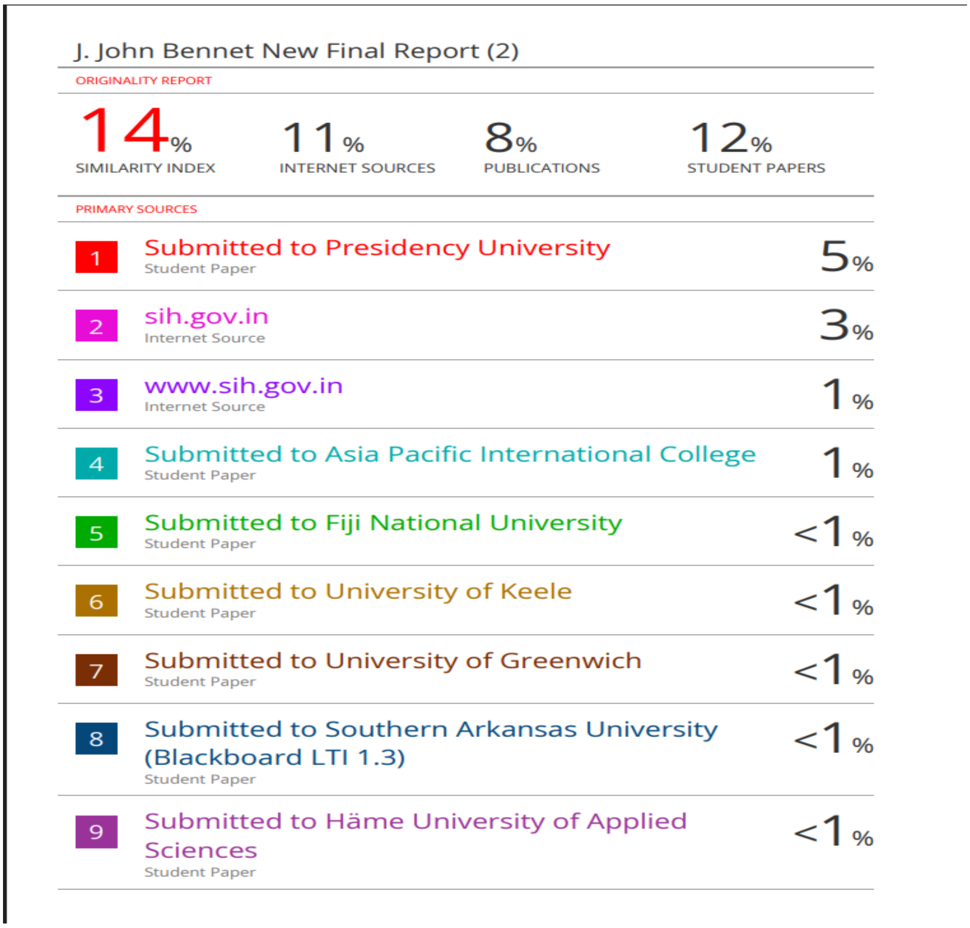
Appendix

i. Data Sheets

System Requirements (Software Application)

- Minimum CPU: Dual Core 2.0 GHz
- RAM: 2 GB (Minimum), 4 GB recommended
- Storage: 500 MB
- Operating Systems Supported: Windows 10+, Android 8+
- Database: MySQL
- Front-end: React + Vite
- Back-end: Python / Flask Server

ii. Project Report - Similarity Report



J. John Bennet New Final Report (2)

ORIGINALITY REPORT

14%	11%	8%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Presidency University Student Paper	5%
2	sih.gov.in Internet Source	3%
3	www.sih.gov.in Internet Source	1%
4	Submitted to Asia Pacific International College Student Paper	1%
5	Submitted to Fiji National University Student Paper	<1%
6	Submitted to University of Keele Student Paper	<1%
7	Submitted to University of Greenwich Student Paper	<1%
8	Submitted to Southern Arkansas University (Blackboard LTI 1.3) Student Paper	<1%
9	Submitted to Häme University of Applied Sciences Student Paper	<1%

Figure A.1: Similarity Check

iii. Project Images

Figure A.2: Registration Interface for Parent/Student and Therapist roles

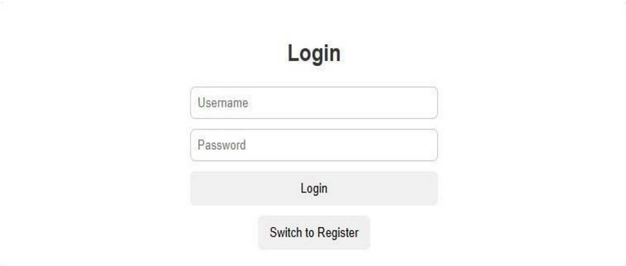


Figure A.3: Login Interface with secure credential validation

Figure A.4: Main Dashboard showing available cognitive games

Figure A.5: Difficulty selection screen for Memory game

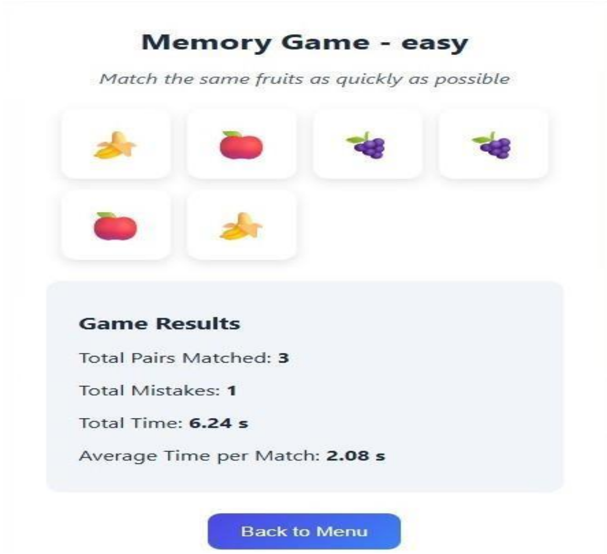


Figure A.6: Results of the memory-matching game

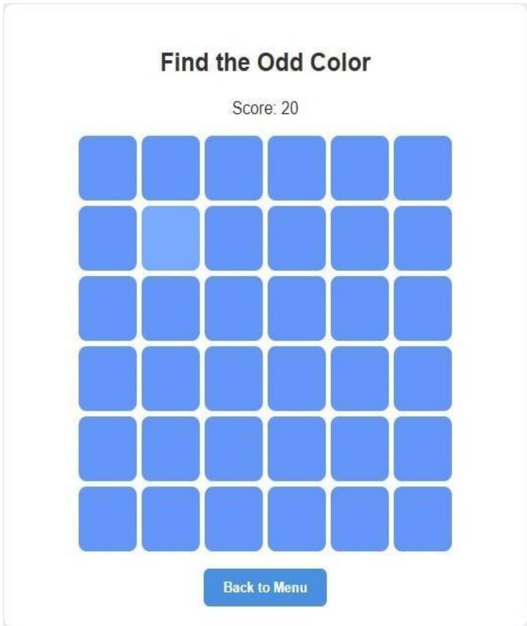


Figure A.7: Memory Game interface with real-time scoring

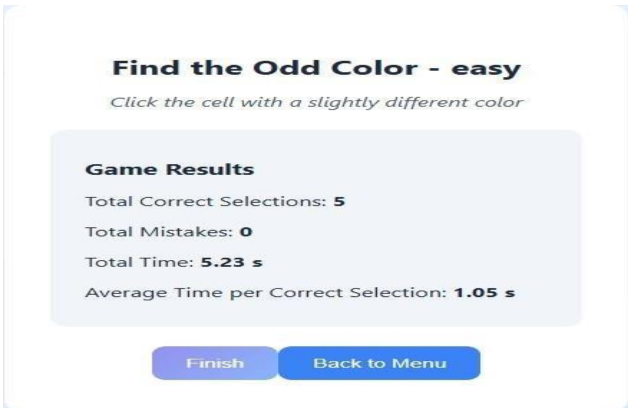


Figure A.8: Summary of results from the odd color selection

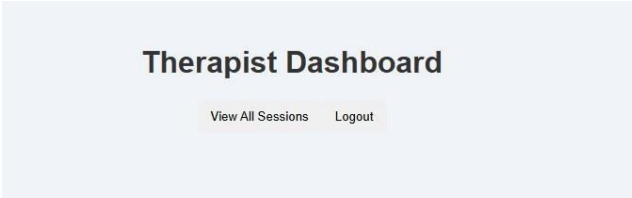


Figure A.9: Therapist Dashboard main view

Username	Game Type	Score	Mistakes	Duration (s)	Date
Manoj	memory	3	2	10	10/12/2025, 5:49:23 PM
gnani	attention	20	0	64	9/29/2025, 8:09:40 AM
gnani	memory	6	0	30	9/29/2025, 8:08:18 AM
gnani	memory	5	0	30	9/29/2025, 8:08:16 AM
gnani	memory	4	0	30	9/29/2025, 8:08:14 AM
gnani	memory	3	0	30	9/29/2025, 8:08:12 AM
gnani	memory	2	0	30	9/29/2025, 8:08:07 AM
gnani	memory	1	0	30	9/29/2025, 8:08:05 AM
manoj	attention	21	0	51	9/28/2025, 9:10:56 AM
manoj	memory	6	0	30	9/27/2025, 11:31:28 AM
manoj	memory	5	0	30	9/27/2025, 11:31:25 AM

Figure A.10: Therapist Dashboard results table showing user performance metrics

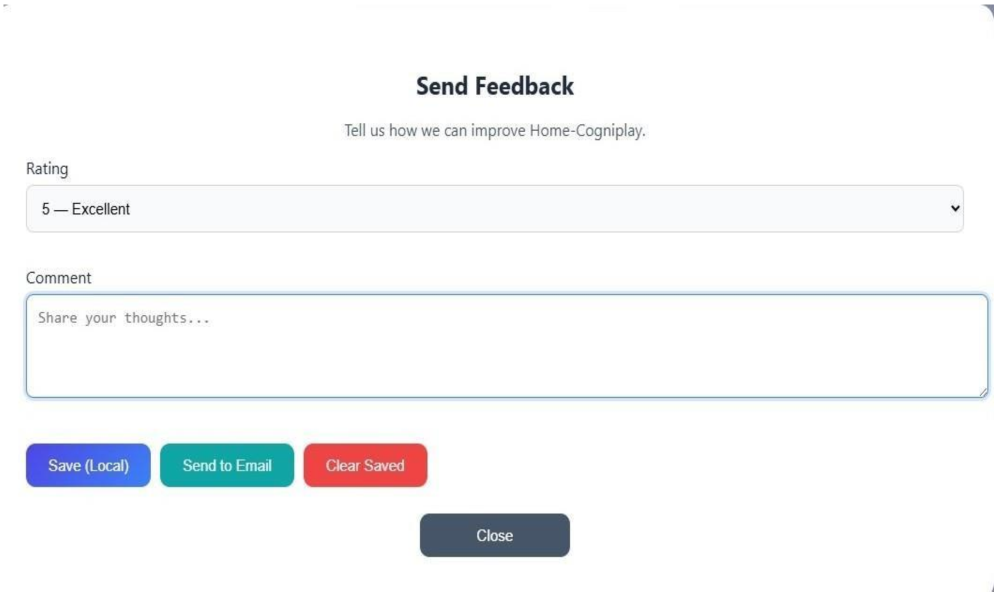


Figure A.11: Feedback form used for capturing user ratings and suggestions.

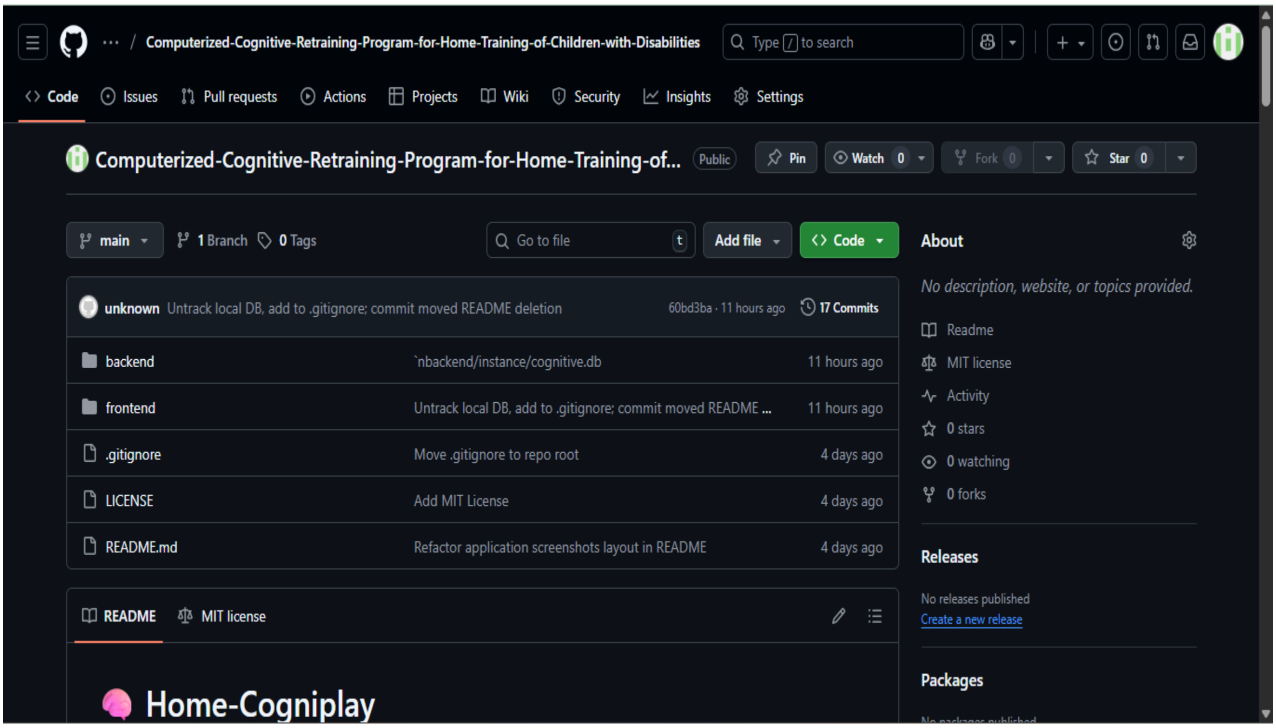


Figure A.12: GitHub Repository