

# MCI Cognitive Care App: An AI-Powered Personalized Platform for Cognitive Training in Mild Cognitive Impairment

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*Abstract- Mild Cognitive Impairment (MCI) is a transitional neurological condition characterized by measurable cognitive decline beyond normal aging while preserving independence in daily activities. Individuals diagnosed with MCI face an elevated risk of progression to dementia, highlighting the importance of early and adaptive intervention. This paper presents the MCI Cognitive Care App, an AI-driven digital cognitive training platform designed to deliver personalized cognitive rehabilitation through adaptive gameplay. The system integrates a suite of cognitive exercises targeting memory, attention, processing speed, and executive function. Personalization is achieved using a reinforcement learning framework based on an Epsilon-Greedy Contextual Bandit algorithm, enabling real-time adaptation of task difficulty, hint frequency, and task sequencing. The platform is implemented as a fully functional prototype comprising a React.js frontend, Node.js backend, and Python-based AI engine. Gamification mechanisms and a multi-role dashboard support sustained engagement and collaborative monitoring by patients, caregivers, and clinicians. A pilot observational evaluation demonstrates improved engagement, smooth difficulty progression, and positive usability outcomes, indicating the feasibility of AI-driven personalization for scalable cognitive rehabilitation.*

*Index Terms—Mild Cognitive Impairment, Reinforcement Learning, Contextual Bandits, Cognitive Training, Digital Health, Gamification*

## I. INTRODUCTION

Mild Cognitive Impairment (MCI) represents an intermediate stage between normal cognitive aging and dementia, characterized by noticeable decline in memory, attention, and executive function without significant impairment in daily activities [1]. Longitudinal studies indicate that individuals with

MCI have a substantially higher probability of developing Alzheimer's disease or related dementias if intervention is delayed [3]. Consequently, early and sustained cognitive training is critical for slowing disease progression and maintaining quality of life.

Traditional cognitive rehabilitation methods rely primarily on static paper-based or fixed computerized exercises. While such approaches may yield short-term benefits, they lack personalization and adaptability, often resulting in reduced engagement over time [2]. Recent digital cognitive training platforms provide interactive experiences but frequently employ linear difficulty progression and offer limited integration with caregivers or clinicians [4].

Advances in artificial intelligence, particularly reinforcement learning (RL), enable systems that adapt continuously to user behavior. When combined with gamification and collaborative care, such systems can deliver personalized cognitive rehabilitation while maintaining motivation and clinical relevance. This paper introduces the MCI Cognitive Care App, a fully implemented research prototype integrating RL-based personalization, senior-friendly design, and multi-role collaboration. The primary contributions of this work are:

- Design of an adaptive cognitive training platform tailored for individuals with MCI.
- Application of an Epsilon-Greedy Contextual Bandit model for real-time personalization.
- Integration of gamification strategies to enhance long-term engagement.

- Development of a collaborative ecosystem for patients, caregivers, and clinicians.
- Pilot observational evaluation demonstrating feasibility and usability.

## II. RELATED WORK

Cognitive training interventions for MCI have been widely studied. Belleville et al. demonstrated that structured cognitive training can improve memory and executive function in individuals with MCI [1]. BaharFuchs et al. conducted a systematic review confirming the effectiveness of targeted cognitive rehabilitation in improving attention and memory retention [2].

More recent studies emphasize the importance of personalization. Hampstead highlighted that static cognitive training paradigms often fail to generalize improvements and advocated for adaptive and individualized approaches [4]. Reinforcement learning has emerged as a promising methodology in neurorehabilitation, with Stasolla et al. reporting improved engagement through adaptive difficulty modulation [5].

Gamification has also been shown to significantly improve adherence in digital health interventions. Lumsden et al. reported higher participation rates among older adults using gamified cognitive training systems [6]. Additionally, mobile platforms enabling caregiver and clinician involvement have demonstrated improved monitoring and intervention efficiency [7]. Despite these advances, few systems integrate reinforcement learning based personalization, gamification, and multi-role collaboration into a unified platform, which this work aims to address.

## III. SYSTEM ARCHITECTURE

The MCI Cognitive Care App adopts a modular architecture consisting of three primary layers.

### A. User Interface Layer

The frontend is implemented using React.js and TypeScript, optimized for elderly users through large icons, high-contrast layouts, simplified navigation, and minimal textual complexity. The interface

supports both web and mobile platforms, ensuring accessibility and consistency.

### B. Application Backend

The backend is built using Node.js and Express.js to manage authentication, user roles, and secure API communication. MongoDB is used to store user profiles, gameplay logs, and analytics. Role-based access control ensures appropriate data visibility for patients, caregivers, and clinicians.

### C. AI Personalization Engine

The AI engine is implemented in Python using TensorFlow. It processes real-time performance data and applies reinforcement learning to dynamically adapt cognitive training parameters such as difficulty level, hint frequency, and task sequencing.



Fig. 3.1 System Architecture of the MCI Cognitive Care App.

## IV. METHODOLOGY

### A. Cognitive Training Framework

The platform includes multiple cognitive exercises designed to stimulate key domains including short-term memory, attention, processing speed, executive reasoning, and spatial cognition. Each interaction generates performance metrics such as accuracy, response time, error rate, and task completion.

### B. Reinforcement Learning Model

Personalization is achieved using an Epsilon-Greedy Contextual Bandit algorithm. The system observes a contextual state vector comprising recent performance trends, engagement indicators, and session history, and selects actions corresponding to task difficulty and support level.

The reward function is defined as:

$$R = w_1 \cdot \text{Accuracy} + w_2 \cdot \text{Engagement} - w_3 \cdot \text{ErrorRate} \quad (1)$$

This formulation balances cognitive challenge with motivation while minimizing frustration.

### C. Adaptive Decision Strategy

With probability  $\epsilon$ , the agent explores alternative task configurations to avoid stagnation. With probability  $1-\epsilon$ , it exploits the configuration yielding the highest expected reward. This strategy enables smooth difficulty transitions and prevents cognitive overload.

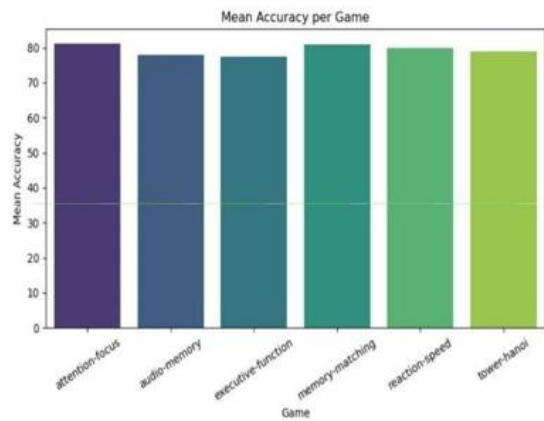


Fig. 4.1 Accuracy Per Game and collection process.

## V. IMPLEMENTATION

The system is implemented as a fully functional prototype and includes secure onboarding with baseline cognitive assessment, gamification features such as badges and streaks, analytics dashboards for progress visualization, and multi-role access for collaborative monitoring. All data are anonymized and transmitted using encrypted channels.

## VI. EVALUATION PROTOCOL

The system was evaluated using a pilot observational study aimed at assessing feasibility, usability, and engagement trends rather than clinical efficacy. Participants identified with MCI interacted with the platform in a controlled, lab-scale environment over multiple sessions spanning several weeks. Evaluation metrics included session duration, task completion rate, difficulty progression patterns, and engagement consistency.

## VII. RESULTS AND DISCUSSION

The pilot evaluation revealed improved consistency in session completion over time. Gamification elements contributed to sustained engagement, particularly among users with initially lower adherence. The reinforcement learning engine enabled smooth difficulty progression, reducing cognitive overload compared to static systems.

Table I

Comparison of static and adaptive cognitive training systems

Metric	Static Systems	Proposed System
Difficulty Progression	Fixed	RL-based Adaptive
User Engagement	Moderate	High
Session Completion	Lower	Higher
Cognitive Overload	Frequent	Reduced
Personalization	None	Context-aware
Clinical Monitoring	Limited	Dashboard-based

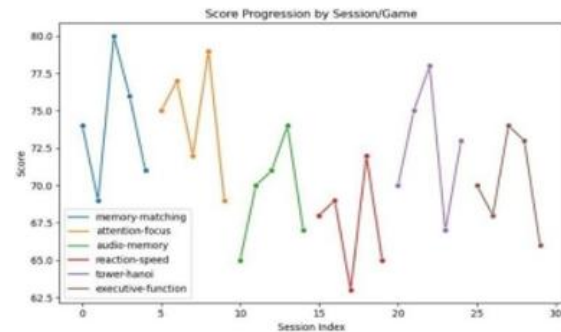


Fig 7.1 Sample performance analysis chart. Score Progression per session

## VIII. ETHICAL AND PRIVACY CONSIDERATIONS

The system was designed with privacy and ethical considerations as core requirements. No personally identifiable information was stored, and all data were anonymized. The platform is intended as a supportive digital therapeutic tool and does not replace clinical diagnosis or treatment.

## IX. LIMITATIONS AND THREATS TO VALIDITY

The study was conducted as a pilot observational evaluation with a limited participant pool and without standardized neuropsychological outcome measures.

Results should therefore be interpreted as indicators of feasibility and engagement rather than clinical efficacy. Future work will address these limitations through larger controlled studies.

#### X. CONCLUSION AND FUTURE WORK

This paper presented the MCI Cognitive Care App, an AI-powered personalized cognitive training platform for individuals with Mild Cognitive Impairment. By integrating reinforcement learning, gamification, and collaborative care, the system addresses key limitations of traditional cognitive rehabilitation tools. Future work will focus on large-scale evaluations, expansion of cognitive exercises, integration of wearable data, and exploration of advanced personalization models.

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