A Conceptual Architecture for Building Intelligent Applications for Cognitive Support in Dementia Care

Ana Beatriz Silva[1*] abeatriz.cms@gmail.com

Vítor Santos[1] [0000-0002-4223-7079],

[1] NOVA Information Management School (NOVA IMS), Campus de Campolide, Universidade Nova de Lisboa, 1070-312 Lisboa, Portugal

* Corresponding author

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A Conceptual Architecture for Building Intelligent Applications for Cognitive Support in Dementia Care

Ana Beatriz Silva[1] and Vítor Duarte dos Santos[2]

[1,2] NOVA Information Management School, Lisboa, Portugal
abeatriz.cms@gmail.com; vsantos@novaims.unl.pt

Abstract. In response to the growing global aging population and the expected rise in dementia cases, this research addresses the critical need for innovative technological solutions in elderly dementia care. With a focus on alleviating the imminent strain on healthcare systems, this study advocates for leveraging technology to create tailored solutions, ranging from user-friendly wearable alarms to the integration of cutting-edge service robots. Emphasizing the importance of patient-centered design, this research aims to discern key factors in cognitive aging care, steering the development and implementation of digital solutions. Beyond proposing an intelligent model for brain aging, this work aspires to transcend academic boundaries by fostering a wider community interest in mental health discourse. Furthermore, it seeks to empower and assist caregivers through the integration of advanced technologies, including AI-driven tools, cognitive screening applications, and remote assessments.

Keywords: First Dementia, Elderly, Digital Solutions, Conceptual Architecture, Artificial Intelligence.

1 Introduction

In the current landscape, mental health care is a focal point of extensive interest and research, aligning with the United Nations Sustainable Development Goals' emphasis on enhancing healthcare and overall well-being. Globally, the aging population is projected to double by 2050, resulting in an estimated 152 million individuals afflicted by dementia.

The impending surge in demand for specialized healthcare services, particularly for those aged over 80, emphasizes the urgency to address the strain on healthcare systems. Projections indicate that by 2030, the costs associated with dementia care will escalate, necessitating adaptable services from urban centers (1) (2).

Despite the escalating demand, there remains a notable dearth of innovation in information and technology tailored to chronic diseases, notably dementia, among the elderly (3) (4). However, the potential for leveraging technology looms large, promising the development of automated therapeutic and telehealth solutions designed for older adults and individuals with dementia (1).

Recent studies have introduced conceptual architectures for digital solutions specifically targeting dementia patients, advocating for the implementation of successful

guidelines (5) (6) (7). A spectrum of technologies aims to augment diagnosis and enhance patients' quality of life, spanning from wearable alarms to emerging service robots(8) (9).

Acknowledging the distinct requirements of the elderly demographic, emphasis is placed on enhancing the usability and adoption of digital solutions. This necessitates a focus on specific design features and a patient-centered approach, vital for surmounting engagement barriers (10).

This study centers on identifying pivotal factors within cognitive aging care, driving the imperative to design and deploy digital solutions tailored for elderly individuals grappling with dementia. This encapsulates the central exploration and objective of this research.

The escalating discourse on mental health coincides with an imminent technological revolution. Proposing an intelligent based model that influences brain aging could captivate healthcare, research, and pharmaceutical sectors, and can profoundly impacting society and individual lives. This research aims not only to introduce a conceptual architecture but also to stimulate community interest in these critical topics. Additionally, exploring tailored digital solutions for elderly dementia patients supports caregivers, enabling independent living while maximizing the efficiency of dementia care workers and caregivers through technology like AI, cognitive screening tools and remote assessments.

2 Methodology

This investigation adopts the Design Science Research (DSR) methodology, primarily focused on developing and evaluating IT artifacts within socio-technical systems, emphasizing the creation of practical and innovative solutions (11). DSR encompasses a thorough process involving artifact development, research contribution, design assessment, and dissemination of findings (12) (13).

This study utilizes DSR to craft a conceptual architecture for a digital solution tailored to address dementia-related health issues in the elderly. It commences with an extensive review of AI systems in healthcare and dementia care, identifying key features for an AI-based architectural model derived from established theories. The model's effectiveness is assessed through expert interviews and survey analysis to uncover implications and limitations. This iterative process integrates pertinent concepts and existing solutions, aligning with established theories to foster an innovative approach.

Guided by DSR principles, the comprehensive development of this AI-driven solution involves a meticulous literature review and feature definition grounded in existing theories. This foundational work aims to create an innovative solution specifically designed to address cognitive decline associated with aging and dementia. Through a systematic approach embedded in DSR principles, this research strives to create an effective and well-founded solution for this critical healthcare challenge.

3 Dementia and Health Information Systems

3.1 Dementia Overview

An in-depth review was conducted to analyze existing design methodologies for digital solutions targeting dementia.

Dementia presents a significant challenge for the elderly worldwide, leading to disability and increased dependency. The World Health Organization projects a staggering rise in dementia prevalence, estimating around 50 million current cases of dementia, a number expected to reach 152 million by 2050. Low and middle-income countries bear a disproportionate burden, hosting nearly two-thirds of these cases (14). This upsurge in dementia imposes a substancial economic strain, amounting to an estimated cost of USD 818 billion on the global economy.

Given the rapid growth of the elderly demographic, particularly those aged over 90, there is an urgent imperative to address their distinct healthcare needs and enhance overall well-being(15) (16) (17).

Dementia, characterized by cognitive decline and persistently deteriorating physical and psychological symptoms, demands prolonged care that strains healthcare systems and caregiving families. The escalating prevalence of dementia worldwide accentuates the urgency to mitigate its impact on aging populations and the broader healthcare landscape (18) (19).

3.2 Information Systems for Mental Diseases

The rapid advancements in computerized cognitive treatments have revolutionized traditional therapies, spawning new multimedia systems to aid health and independent living among older adults. Adaptations of these interventions for devices like smartphones, tablets, and PCs offer cost-effective means to maintain cognitive function in mild cognitive impairment and healthy older individuals. Digitally delivered interventions enhance cognition, memory, attention, and social functioning through tailored exercises on portable devices, providing immediate feedback and adapting to individual performance.

Recent research focuses on the effectiveness of computerized cognitive therapies, including exploring virtual reality training for early-stage cognitive decline. Health Information Technology (HIT), covering electronic health records and telemedicine, streamlines healthcare by reducing redundancies, errors, and chronic care expenses while facilitating remote collaboration (20) (21) (22).

The surge in digital healthcare for cognitive impairment involves apps, games, and virtual/augmented/mixed reality, leveraging big data/AI and smart home/telemedicine innovations. These assistive technologies aim to improve patient independence, safety, social interaction, mood, and overall quality of life, easing caregiver strain through remote patient monitoring and emphasizing accessibility for all (23).

In the 21st century, AI-driven technologies like assistive robots, smart sensors, and mHealth applications are transforming dementia therapy, caregiving, health monitoring, and social interactions. These technological innovations potential to revolutionize

dementia care and patient well-being, marking significant advancements in healthcare for dementia.

3.3 Brain and Cognitive Games

Brain and cognitive games have emerged as potential strategies to counteract cognitive decline in the elderly by stimulating various brain areas and improving cognitive functions like attention, memory, and processing speed (24) (25) (26). Extensive research has been dedicated to exploring both the advantages and limitations of employing these games to mitigate the risk of dementia among older adults.

The development of applications intended for dementia mitigation heavily depends on the careful construction of these games. Factors such as game type, frequency, duration, intensity, challenge level, and alignment with specific cognitive domains play pivotal roles in their design (27). Ensuring user-friendly interfaces and providing regular progress feedback stand as crucial elements for effectively boosting motivation and sustaining engagement among users.

While studies consistently highlight the positive impact of cognitive training through these games, there's a pressing need for more extensive and well-designed research endeavors. The current limitations in study sizes and durations emphasize the necessity for comprehensive investigations aimed at precisely determining the effects of brain games on dementia and cognitive decline in the elderly.

4 Conceptual Architecture for Cognitive Support in Dementia Care

In the realm of developing a digital solution, the role of software architecture cannot be overstated. It serves as the guiding framework that shapes organization, facilitates interaction, and ensures seamless maintenance, thereby establishing essential constraints for the overall design and development process.

Building upon insights gleaned from an extensive literature review and an understanding of the context surrounding mental health disorders, a comprehensive architecture tailored for dementia care has been delineated. This foundational framework, versatile in its instantiation, serves as a conceptual architecture poised to address the intricate needs of this specific population.

Central to this conceptualization is a focus on catering to the unique usage requirements of individuals grappling with dementia. Recognizing the diversity and nuances of this demographic, the architecture is meticulously crafted to encompass the distinctive functional needs of users, underscoring the paramount importance of user-centric design.

In the pursuit of developing effective and user-friendly dementia applications, a deep comprehension of the functional requirements specific to this user group is imperative. This understanding forms the bedrock upon which the architecture is erected, ensuring that the resultant digital solution aligns seamlessly with the nuanced needs of those navigating the challenges of dementia.

4.1 Functional Requirements

Functional requirements describe what the application should do, in terms of its intended purpose and features, and focus on the functionality and capabilities of the application.

The application development should prioritize key components, such as the ones listed below:

- Tracking and Monitoring: Including features for activity, sleep, medication, and mood tracking enables caregivers to observe and respond to changes in the patient's health and behavior effectively.
- Cognitive Training and Brain Games: Incorporating activities like memory games and puzzles to stimulate cognitive functions is crucial for improving memory, attention, and slowing down dementia progression.
- Communication Features: Enabling video, voice, and messaging options between patients, caregivers, and healthcare professionals reduces social isolation and ensures better healthcare management.
- Reminders and Alerts: Customizable prompts for medications, appointments, and daily tasks help users adhere to schedules and remember important information, enhancing overall care.
- Personalization Features: Customizable interfaces, font sizes, and color schemes cater to users with varying cognitive abilities, enhancing accessibility and ease of use.
- Access to Support and Resources: Providing links to healthcare professionals, support groups, and educational materials ensures efficient care management and improves the quality of life for both patients and caregivers.

Overall, the requirements should be focused on providing support and assistance to users with cognitive impairment, while also considering the needs and preferences of caregivers. By providing these features, the application can help improve the quality of life for dementia patients and make caregiving more manageable.

4.2 Conceptual Architecture

While design requirements specify software behavior, system architecture outlines the system's structure. The solution's software architecture meticulously incorporates modules, interfaces, and connections, ensuring an efficient system.

The conceptual architecture diagram presented bellow (figure 1) serves as a guide for the design and implementation of the digital software, providing a visual representation of the architecture modules.

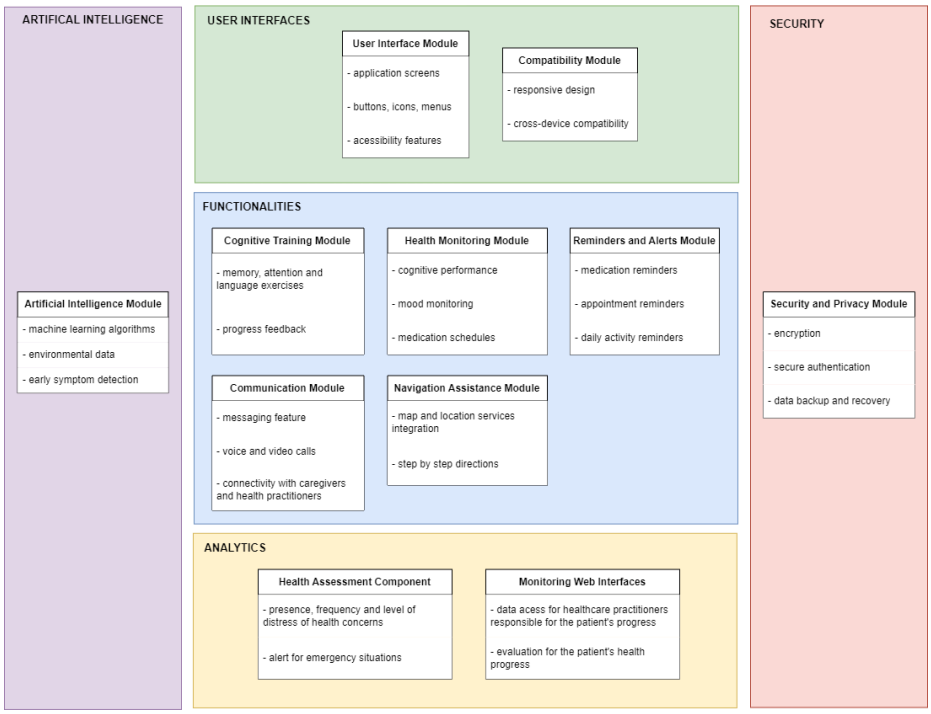

Fig. 1. Conceptual Architecture Diagram

User Interface Module: this module is responsible for managing the user interface of the application. It includes the design of the application screens, buttons, icons, and menus to ensure that they are user-friendly, accessible, and intuitive.

Cognitive Training Module: this module provides various exercises and activities to improve cognitive abilities such as memory, attention, and language skills. It includes designing activities that are challenging yet achievable and providing feedback on progress.

Health Monitoring Module: this module is responsible for tracking the patient's health data relevant to dementia and mental health, such as cognitive performance, mood, and medication schedules. It includes designing a user interface that allows the patient and caregiver to easily input and view this information.

Reminders and Alerts Module: this module is responsible for providing reminders and alerts for appointments, medication schedules, and daily activities. It includes designing a notification system that is easily understandable and can be customized to the patient's needs.

Navigation Assistance Module: this module is responsible for assisting the patient with navigation and directions, especially when going to unfamiliar places. It includes integrating with map and location services and providing step-by-step instructions.

Communication Module: this module is responsible for providing communication features to help patients stay connected with their loved ones and caregivers, as well as

healthcare practitioners. It includes designing features such as messaging, voice, and video calls that are easy to use and accessible.

Compatibility Module: this module is responsible for ensuring that the application is compatible with different devices and operating systems. It includes designing the application to be responsive to different screen sizes and device capabilities.

Security and Privacy Module: this module is responsible for ensuring the security and privacy of patient data. It includes designing security features such as encryption, secure authentication, and data backup and recovery mechanisms.

Artificial Intelligence Module: this module assumes a pivotal role in the conceptual architecture by enabling the system to adapt and learn from diverse data sources. Leveraging advanced machine learning algorithms, including those operating on patient records, environmental data, sensor readings, and user interactions, this module enables the system to provide personalized and context-aware support tailored to the unique needs of individuals affected by dementia. Additionally, this module facilitates intelligent decision-making processes by generating valuable insights and recommendations through continuous analysis of data from multiple sources. These outputs offer valuable guidance to healthcare providers, caregivers, and individuals with dementia, thereby supporting optimized care, early symptom detection, and personalized interventions. The AI module's capacity to dynamically adapt to evolving user needs and preferences enhances the overall effectiveness and efficiency of the digital solution in addressing the challenges posed by dementia in the elderly population.

By implementing this conceptual architecture, the digital solution has the potential to significantly enhance the lives of elderly individuals affected by dementia. Through the seamless integration of these modules within the conceptual architecture, the proposed solution strives to offer a holistic and innovative approach to dementia care, providing crucial support to elderly individuals and their caregivers.

4.3 Prototype

Developing an application prototype requires thorough planning and consideration of key aspects. First, defining the purpose, target audience, and functionalities is crucial. Gathering requirements from stakeholders follows, leading to the design of the software's architecture and user interface. Then, the development, testing, and debugging stages ensure the software meets requirements before deployment.

Afterwards, ongoing maintenance and support become essential to keep the software updated, secure, and efficient. User-centered assessments help refine the application based on users' feedback and interaction satisfaction. To build a prototype targeting dementia in the elderly, understanding user needs and functionality is paramount.

The prototype should feature various modules like login, home, memory games, reminders, messaging, personalized settings, activity tracking, caregiver dashboard, and help and support screens. Each screen should prioritize simplicity, using clear graphics and easily readable fonts for improved accessibility and ease of use.

5 Conclusion

This study has proposed a functional architectural model for a digital solution targeting elderly patients with dementia. The proposed architecture addresses the critical characteristics identified in the literature and provides a conceptual architecture for the development of a reliable, scalable, and user-friendly application.

Despite its comprehensiveness, this study presents several limitations. Firstly, the proposed architecture requires empirical validation and user feedback to ensure its real-world effectiveness and usability. Empirical studies involving a diverse sample of elderly individuals with dementia are necessary to refine the digital solution based on user experiences.

Secondly, technological constraints might hinder implementation. Compatibility issues and the need for continuous adaptation to evolving technologies, such as artificial intelligence or IoT devices, may challenge the digital solution's functionality. Resource availability, including funding and technical expertise, is crucial for sustainable development, deployment, and maintenance of the solution.

Ethical concerns regarding privacy, data security, and the ethical implications of technology substituting human interaction should be carefully addressed. Lastly, the evolving nature of dementia care necessitates ongoing research and adaptation to incorporate new findings and guidelines.

Acknowledging and addressing these limitations will refine the proposed conceptual architecture, ensuring better care for elderly individuals with dementia.

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