Designing Interactive Mobile UIs for Detecting Dementia

Husna Asmaul, Masuk Shopnil Masrur, Islam Iyolita, Sultana Zinia, Tabassum Rima Tasnim, Shariar Sazid, Azad Nasreen, Islam A.K.M. Najmul, Islam Muhammad Nazrul

This is a Camera ready version of a publication

published by Association for Computing Machinery

in Proceedings of the 11th International Conference on Communities and Technologies (C&T '23)

DOI: 10.1145/3593743.3593767

Designing Interactive Mobile UIs for Detecting Dementia

Asmaul Husna
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh
asmaulhusna815@gmail.com

Masrur Masuk Shopnil
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh

Iyolita Islam
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh

Zinia Sultana
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh

Tasnim Tabassum Rima
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh

Sazid Shariar
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh

Nasreen Azad
LUT University
Lappeenranta, Finland

A.K.M. Najmul Islam
LUT University
Lappeenranta, Finland

Muhammad Nazrul Islam
Department of CSE
Military Institute of Science and Technology
Dhaka, Bangladesh
nazrul@cse.mist.ac.bd

ABSTRACT

Dementia, being one of the leading causes of death worldwide, necessitates extensive research to develop specific types of diagnosis and treatments. Because it is a neurological disorder, it affects more than one region of the body and impairs the proper functioning of the entire nervous system. Numerous studies throughout the years have laid the path for the development of better technology to precisely diagnose and treat dementia. Keeping all of these considerations in mind, the research proposes a mobile application comprised of intuitive and interactive user interfaces (UIs) for determining the presence and severity of dementia in a person. To attain this objective, firstly, human factors due to dementia were revealed through literature review. Then, six activities or games were designed and implemented through the design of interactive UIs; and finally, we assigned scores to each activity to assess the revealed symptoms, detect dementia, and measure the severity of dementia.

KEYWORDS

Dementia, dementia symptoms, user interface, detection, mobile UI

ACM Reference Format:
Asmaul Husna, Masrur Masuk Shopnil, Iyolita Islam, Zinia Sultana, Tasnim Tabassum Rima, Sazid Shariar, Nasreen Azad, A.K.M. Najmul Islam, and Muhammad Nazrul Islam. 2024. Designing Interactive Mobile UIs for Detecting Dementia. In *Proceedings of ACM Conference (Conference'17).* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

Conference'17, July 2017, Washington, DC, USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Dementia is a syndrome in which there is a deterioration in cognitive function [8]. Although it mainly affects older people, it is not an inevitable consequence of aging [10]. Around 55 million people have dementia worldwide, with over 60% living in low and middle-income countries [46]. The number of dementia cases increases by 10 million every year [37]. And, it is anticipated that this figure will increase to 78 million by 2030 and 139 million by 2050 [40]. Dementia is identified as the seventh primary cause of death in all diseases and one of the major factors resulting in disability and dependence of elderly people [23].

Dementia can start with forgetting things like appointments and names, getting lost in familiar places, and having trouble in communicating. People with early dementia may also wander and ask the same questions over and over [36]. In the later and more severe stages of dementia, people may have trouble recognizing, need help with daily tasks, and may experience changes in behavior, such as aggression. Alzheimer's is the most common type of dementia, accounting for 60-70% of cases [29]. While age is widely recognized as the most influential risk factor for dementia, not everyone will develop the condition as a consequence of aging. Moreover, it's important to acknowledge that dementia can affect individuals of any age, and up to 9% of cases are attributed to young onset dementia, which refers to the onset of symptoms before the age of 65 [44]. To reduce the risk of cognitive decline and dementia, it is important to exercise, eat healthily, control weight, avoid smoking and excessive drinking, and maintain healthy levels of blood pressure, cholesterol, and blood sugar. Other factors that increase the risk of dementia include depression, social isolation, cognitive inactivity, and air pollution exposure [20, 30].

Intelligent or smart solutions have led to better personalized care for people with different types of dementia like Parkinson's Disease or Alzheimer's Disease [32]. In recent years, various ICT applications and services have been developed to address memory challenges and improve brain performance in individuals with dementia. The goal of these applications is to use software tools to detect and slow the progression of Alzheimer's Disease, while also creating cost-effective assistive systems [27, 31].

Dementia is a complex and debilitating disease that poses significant challenges in its detection and prevention. Despite the best efforts of psychologists and healthcare professionals over the years, accurately detecting dementia has remained elusive [17]. This is due, in part, to a lack of experienced personnel, limited availability of information, and prevailing social stigmas around mental health. It has been observed that people prefer not to be diagnosed for dementia due to social stigma in developing countries like Bangladesh. An mobile application can be used to accurately detect dementia without the person being aware of being tested. An application interface providing good user experience can be more acceptable and understandable for any person [5]. So, adopting interactive mobile health applications may not only help extract the user's actual scenario but also achieve patient satisfaction with a good user experience [15, 25]. However, with the advent of modern information technology, we are better equipped to detect it earlier, estimate its severity, and offer better care to those affected. By leveraging modern technologies in the areas of detection, diagnosis, and primary prevention, individuals can be provided interventions that improve patient outcomes. Adapting a smartphone based solution can be cost-effective, time-saving, and efficient approach [3]. This would benefit families, communities, and healthcare systems alike. Again, the effectiveness of such a system depends on proper balancing between usability and system functionality [26]. Therefore, the objective of our study is to design an interactive and user-friendly mobile application for determining the presence and severity of dementia in an individual.

This article is organized as follows: a brief review of the related research is depicted in Section 2. In Section 3, the research methodology is described, including the study procedures. Section 4 presents a detailed exposition on the conceptual design, defining scores of each activity for dementia patients, and the development of the prototypical application. The core results, implications, limitations, and avenues for future research are presented in Section 5.

2 LITERATURE REVIEW

We thoroughly analyzed the prior research, and found several detection techniques such as using unsupervised cognitive assessments, inductive transfer learning, analyzing acoustic patterns, and machine learning, among others. Next, we provide an overview of the most promising approaches for detecting and assessing dementia, which can be useful for healthcare practitioners and researchers seeking to stay up-to-date with the latest advancements.

In [34], Perin et al. discussed that the unsupervised assessments were able to detect cognitive impairment in individuals at risk for Alzheimer's disease and that the assessments were reliable over time. The study also suggested that web-based registries can be an effective way to identify individuals at risk for Alzheimer's disease and to monitor changes in their cognitive health over time. The findings have implications for the development of web-based tools for identifying and monitoring People who are more likely to develop Alzheimer's disease. In another study [24], Mirheidari et al. described the development of an Intelligent Virtual Agent (IVA), which were capable of conducting a cognitive assessment through conversation with the user. The IVA was tested on a group of older adults, and it was able to detect early signs of dementia with high accuracy.

H Rubiani et al. presented a system that utilizes received signal strength indicator (RSSI) for activity recognition in order to detect early signs of dementia [38]. The system was designed to monitor the movements and activities of elderly individuals in their homes for the detection of changes in activity patterns. The collected data was then used to identify early signs of cognitive decline and dementia. The authors proposed that their system had numerous advantages over other methods, such as low cost, non-invasiveness, and ease of use, and holds great potential for early detection and monitoring of cognitive decline and dementia. Another method of detection was found in a study [39], which discussed the use of inductive transfer learning for the detection of Alzheimer's dementia and its severity. The authors proposed a deep learning model that is trained on multiple data modalities, including MRI scans, cognitive assessments, and demographic information. The model is designed to transfer knowledge from one modality to another, allowing for improved performance in detecting early signs of Alzheimer's dementia. The authors evaluated the performance of their model on a dataset of individuals with and without Alzheimer's dementia, and the results showed that their model outperformed existing methods in detecting dementia and predicting its severity.

Moisés et al. presented a systematic review on the use of smart conversational agents for the detection of neuropsychiatric disorders, including depression, anxiety, and dementia [33]. The authors described the current state of the art in the field, highlighting the smart conversational agents as a tool for early detection and monitoring of these disorders. This review analyzed the methodologies used in previous studies and discussed the advantages and limitations of using smart conversational agents for the detection of neuropsychiatric disorders. The authors concluded that smart conversational agents showed promising results in detecting early signs of these disorders and have the potential to improve the accuracy and efficiency of screening and monitoring in clinical practice. López et al. explored the use of cognitive games on smart TVs for patients with Parkinson's, Alzheimer's, and other types of dementia [22]. The authors conducted a study to evaluate the usability and effectiveness of games for patients with dementia, and collected data from the patients' interactions with the game. Through the use of various statistical analysis techniques, including descriptive statistics, linear regression analysis, and cluster analysis, the authors were able to analyze the collected data and identify patterns and trends. The results of their analysis showed that the cognitive games were well-received by the patients and provided useful data for assessing cognitive abilities.

Hernandez et al. described the development of a system to detect anxiety manifestations by analyzing acoustic patterns in patients with dementia [12]. The authors noted that anxiety was a common symptom in patients with dementia, and that detecting anxiety could be difficult due to the communication challenges faced by patients with the disease. The developed system used a combination of acoustic sensors and machine learning algorithms to identify patterns in the patient's speech and vocalizations that may indicate anxiety. The authors reported that their system achieved promising results in identifying anxiety manifestations in patients with dementia. The very same authors in another study, described the design of a smart microphone system that uses machine learning algorithms to detect anxiety in patients with dementia [13]. The system was designed to be non-intrusive and passive, allowing for continuous monitoring of patients in their natural environment. The authors discussed the technical details of the system, including the design of the microphone array, data collection and preprocessing, and machine learning algorithms used for anxiety detection. The article also described the study design for evaluating the system and its performance in detecting anxiety in patients with dementia.

Juneja et al. discussed the use of Internet of Medical Things (IoMT) devices in early detection and care of dementia [16]. The authors presented a roadmap that outlines the key challenges, opportunities, and solutions in the application of IoMT in the detection, management, and prevention of dementia. They also highlighted the importance of a multidisciplinary approach involving healthcare providers, caregivers, and technology developers to address the complex challenges of dementia care. Liu et al. discussed the design concepts of electronic medical tools [21] for the early detection and assessment of dementia. The authors explored various technologies that could be used to develop these tools, including wearable devices, smartphones, and electronic health records. They also discussed the importance of developing tools that were easy to use and non-invasive, and that could provide accurate and reliable data to healthcare professionals for the early detection and assessment of dementia. The article provided an overview of the key design principles that should be considered when developing these tools and offered some recommendations for future research in this area.

Despite numerous studies on the detection, diagnosis, and probable prevention of dementia, practical implementation of such systems remains limited in many parts of the world. Existing systems are often expensive, require high technical expertise, and are tailored to specific types of dementia. Furthermore, most current systems may not be applicable for the developing countries as the designs do not address the unique economic and contextual factors. Intuitive mobile UIs that consider these factors and address the unique challenges of detecting and diagnosing dementia are needed. Therefore, this research aims to develop an easily understandable mobile UI to aid in the early detection and severity analysis of dementia.

3 METHODOLOGY

The development of a system for detecting dementia involved a comprehensive approach that took into account various factors such as causes, effects, and demographics of affected individuals. The process can be broadly divided into six steps. Firstly, the motivation and problem statement was identified. Next, a number of articles as well as online materials were reviewed to gain a deeper understanding of the disease, including studying patients from diverse age groups and levels of severity, which helped to identify prominent features that define the three classes of severity and common techniques used by professionals to detect dementia. Then, some activities were designed to evaluate the different functionalities of the brain and determine the presence of dementia. After that, a scoring system with numerical value was also proposed, where each activity was given a certain weight. Based on this score, the presence and severity of dementia in a patient could be determined. A prototypical UI was developed where the appropriate responses of the participants for each activity can be recorded. The interface was designed in a way that it did not indicate to the participant that it was a cognitive activity, but rather a fun activity to engage in.

4 DESIGN AND DEVELOPMENT OF THE FRAMEWORK

This section briefly describes the design of the framework and the development of the prototype. Firstly, the symptoms of dementia were revealed through content analysis; then activities were designed to detect the symptoms; thereafter scores were defined for each activity for assessment. Finally, a prototype was developed using mobile application development tools.

4.1 Revealing The Symptoms

While there may be various opinions on how to categorize dementia and its associated symptoms, existing research identified three main categories that are widely accepted by both the Alzheimer's Association [4] and the Alzheimer's Society [41]. These categories are commonly referred to as mild or early, moderate or middle, and late or severe stages of the disease. The classification along with the diseases are shown in Figure 1.

4.2 Proposed Activities

The key features of the proposed system center around the user-friendly cognitive activities and the decision-making algorithm. These activities are designed to be easily taken by the user, and the algorithm categorizes the user's cognitive states.

Through analysis of the methodologies used to detect and categorize the extent of dementia, it was discovered that these existing methods mainly focus on six key cognitive activities as included in the proposed conceptual framework (see Figure 1).

- **Memory Activity:** Memory loss is a key symptom of dementia [6], it is crucial that the system assesses the participant's ability to recall both short-term and long-term memory. In the early stages of the disease, individuals may experience difficulty recalling recent events or conversations, and they may struggle to remember names, places, and faces. As the disease progresses, memory loss becomes more severe, and individuals may lose the ability to recognize familiar people or places, recall important events in their life, or carry out routine activities such as dressing.

  The Memory Activity assesses a participant's ability to remember common things such as faces, objects, addresses, or songs. This activity determines how long the participant can

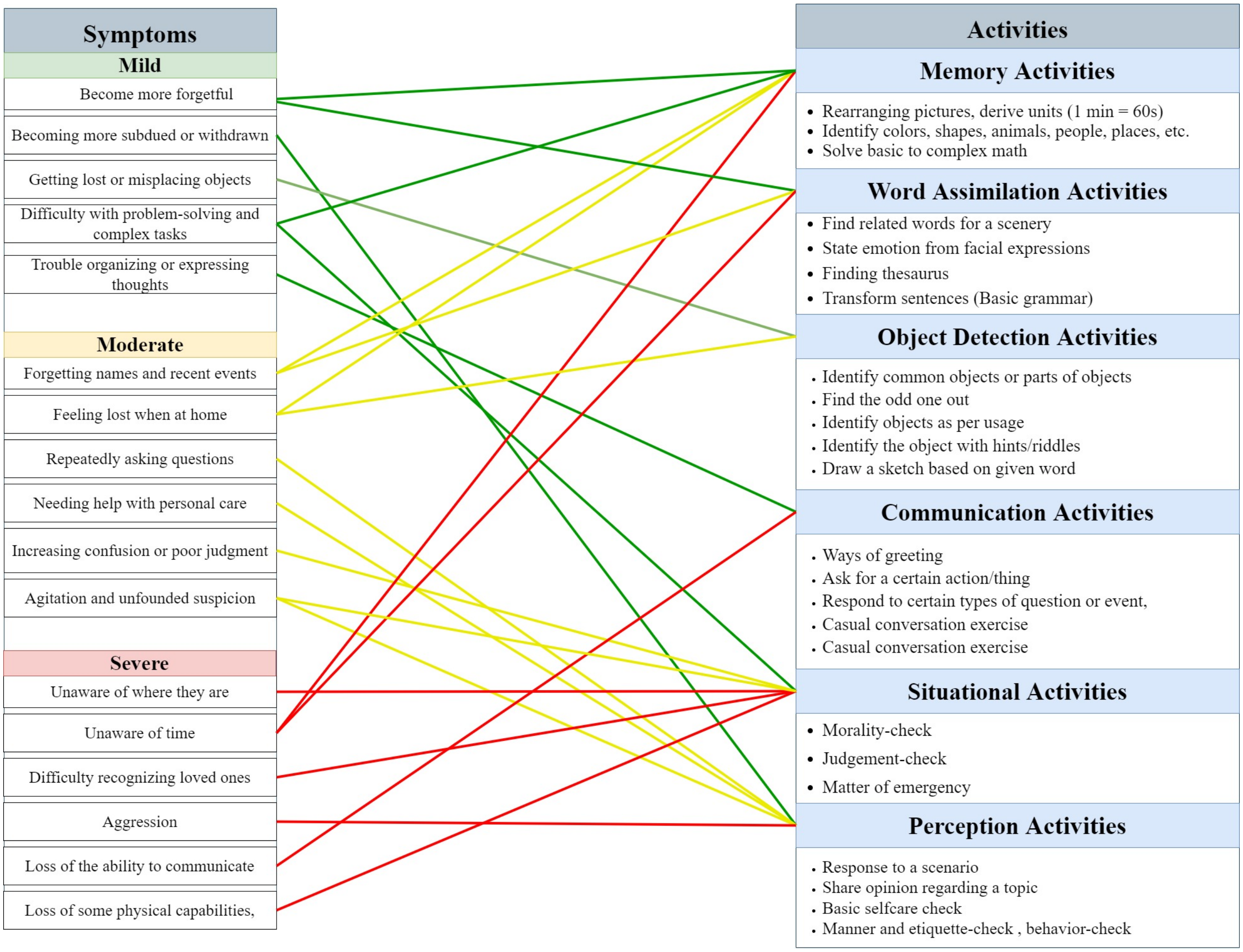

Figure 1: Concept Mapping for Designing Dementia Detection System

retain information. It shares some similarities with MemTrax, a visual screening tool designed to assess and monitor memory and cognitive function [42]. The activities involve arranging a set of previously shown pictures, deriving units of measurement, identifying colors and people, and answering math or history questions. Progression to the next activity is contingent upon answering all questions correctly [see Figure 2(a)]. The system presents a unique activity where users are shown a series of pictures in a particular sequence for approximately 30 seconds [see Figure 2(b)]. After this period, the pictures disappear, and the user is required to arrange them in the same order as displayed before. Correct picture placement are notified to the user using a green background along the border of the picture while the wrong answer is shown using red. Points are awarded for successful completion of the activity, while incorrect placements or delayed responses lead to deductions.

- **Word Assimilation Activity:** Hearing loss can be one of the symptoms of dementia and is mostly found in people of old age who also suffer from linguistic dilemmas which slowly disrupt their cognitive performance [18]. The Word Assimilation activity evaluates a participant's communication abilities. It examines how well the participant can assemble words to communicate and his/her depth of language skills. The activity typically instructs the participant to find similar words, change sentences, transcribe audio into text, and other related activities. If the success rate is below 50%, the activity is considered a failure, and the participant is given a limited number of attempts to answer all questions correctly [see Figure 2(c)]. After completing the allotted attempts and answering all the questions, the activity progresses to the next stage.
  Word Assimilation activity as an audio-based activity, the user is presented with a 1–2-minute audio clip and asked to

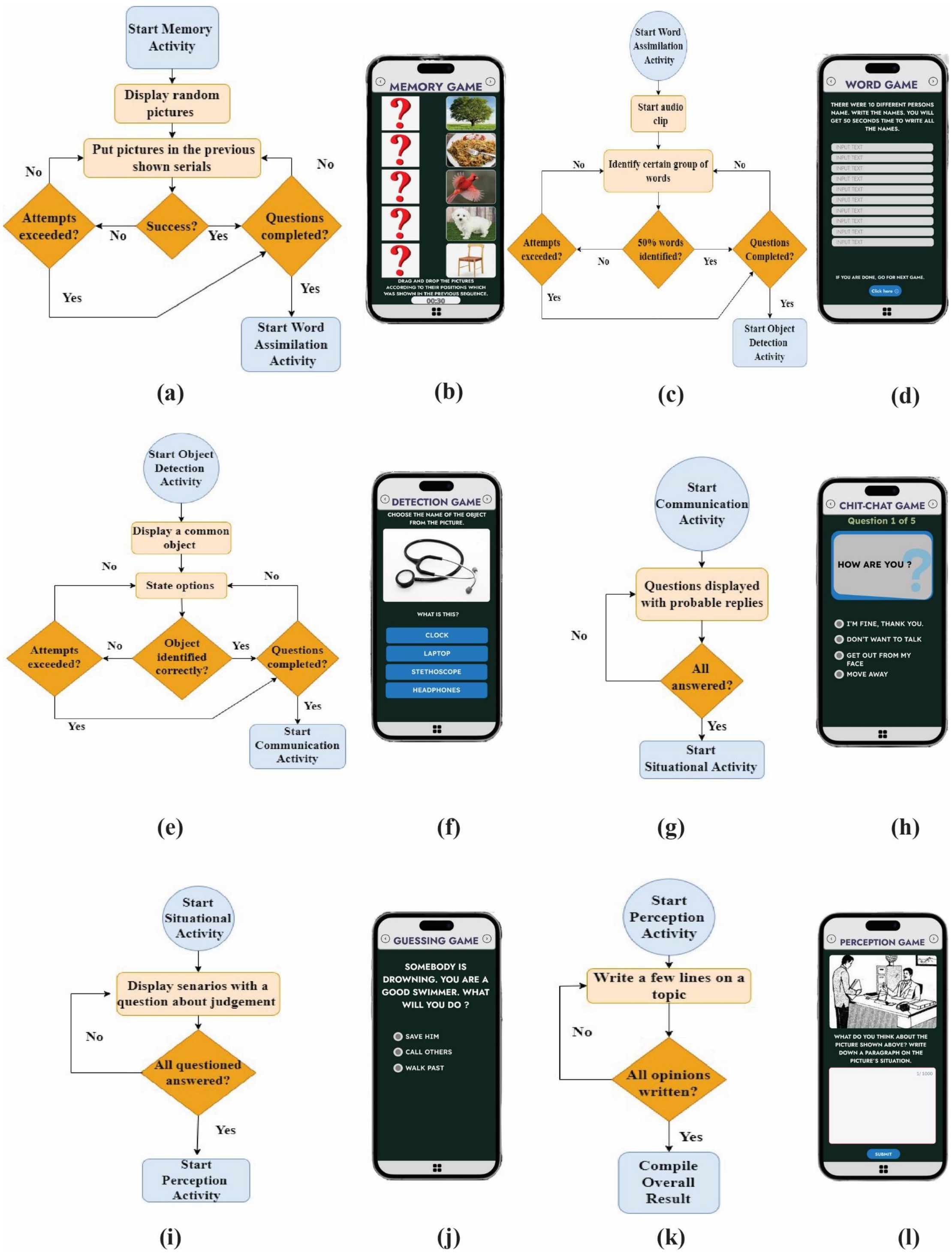

Figure 2: (a) Flow chart for memory activity (b) UI for memory activity (c) Flow chart for word assimilation activity (d) UI for word assimilation activity (e) Flow chart for object detection activity (f) UI for object detection activity (g) Flow chart for communication activity (h) UI for communication activity (i) Flow chart for situational activity (j) UI for situational activity (k) Flow chart for perception activity (l) UI for perception activity

listen carefully [see Figure 2(d)]. Following this, the user is required to identify a particular group of words from the clip and write down ten words in the provided blank box. The user's success is determined by the number of words they can correctly identify within 60 seconds and the number of attempts they make. If the user fails to identify more than 50% of the words or exceeds the time limit, the activity is repeated. This process ensures that the user has sufficient time to listen to the audio clip and accurately identify the required words. This activity is designed to assess the user's auditory memory and ability to recall specific details from an audio stimulus. This can be a crucial aspect of cognitive function, particularly for individuals at risk of or with dementia, as auditory memory plays a vital role in daily communication and cognitive processing. Therefore, incorporating this activity into the system could provide a more comprehensive evaluation of the user's cognitive abilities.

- **Object Detection Activity:** The use of object detection has widely been a means to detect dementia, especially among people of old age [19]. The objective of the overall activities is to evaluate the participant's ability in specifying an object shown in front of him/her. The Object Detection Activity assesses the participant's ability to identify certain objects and distinguish them from others. This activity not only measures a person's memory but also their analytical abilities. The activity prompts the participant to identify common objects or their parts, identify outliers, discern their probable uses, or even draw an object based on a given hint. If a question is answered incorrectly, the participant is given additional chances to answer correctly [see Figure 2(e)]. Once all questions have been answered, the activity comes to an end.
  This activity presents the user with a series of images and each having four possible name options, and the user is required to correctly identify the appropriate name for each object. Success in this activity is dependent on the user's ability to accurately identify all of the objects within a 25-second timeframe [see Figure 2(f)]. In the event that the user is unable to complete the activity within the allotted time, the activity is repeated. This activity evaluates the user's ability to recognize and name objects, which is a crucial aspect of cognitive function, particularly for individuals at risk of or with dementia. As such, it provides valuable insights into the user's cognitive abilities and can contribute to a more comprehensive assessment of their overall cognitive health.
- **Communication Activity:** As dementia may have significant effects on a person's ability to communicate, it is essential to include a activity that evaluates this capability in order to detect the presence and severity of any cognitive impairment [11]. Previous studies and activities have demonstrated the ways in which dementia can disrupt the normal flow of communication skills in an individual, highlighting the need for a comprehensive evaluation of cognitive function.
  The Communication Activity consists of conversations where the participants get to choose an appropriate reply. It evaluates how a person behaves with others and how they express their feelings. By using greetings or asking simple conversational questions with multiple probable answers, the activity calculates the values of each response provided by the participant and progresses to the final activity [see Figure 2(g)] The activity presents the user with a set of five hypothetical conversational questions, along with a list of responses. The user is required to select the appropriate response for each question within a 70-second time-frame [see Figure 2(h)]. The activity is completed once all questions have been answered. Through this activity, the user's ability to comprehend and respond appropriately to conversational cues are evaluated, which is an important aspect of cognitive function. By assessing the user's ability to understand and respond to a range of conversational scenarios, this activity provides valuable insights into the user's overall cognitive abilities, particularly their communication and social skills. As such, it can be a useful tool for evaluating cognitive function and identifying cognitive impairments.
- **Situational Activity:** Several studies on dementia have explored the impact of a situational model and how patients respond to it [45]. While the activity included in the system has significant differences, it shares the goal of examining an individual's cognitive abilities in relation to a particular situation. The Situational Activity presents the participant with specific dilemmas to gauge their judgment, sense of morality, and reliance on intuition. The activity primarily assesses a patient's moral standards and judgment through various scenarios that often ask for the participant's opinion and evaluation. The options for opinions are typically presented as either right or wrong, and the participant must answer all questions correctly to proceed to the next activity [see Figure 2(i)].
  The activity presents the user with various scenarios or situations and poses questions related to the given context. The user is required to select the appropriate options that best answer the questions based on their judgment within an 80-second time-frame [see Figure 2(j)]. The activity continues until all the questions have been answered. This activity aims to assess the user's ability to reason and make decisions based on given scenarios, which is a critical aspect of cognitive function. By evaluating the user's judgment in response to different situations, this activity can provide valuable insights into their cognitive abilities, including their ability to problem-solving and think critically.
- **Perception Activity:** Assessing a participant's own perception can be a critical factor in detecting the presence of dementia [7]. By including activities that evaluate perception, the system can classify the degree of dementia. As such, the Perception Build-Up Activity delves into the participant's inner thoughts. It seeks to understand the participant's views on life, certain events, people, and activities, providing insight into how the participant views the world in their own way. The activities evaluate not only a person's response time, but also their knowledge, level of self-care, behavior, manners, and etiquette. This is accomplished by recording all responses to the questions posed to the participant [see Figure 2(k)].

Table 1: Score Distribution

Ser	Activities	Total Points	Time Score			Activity Score		Weight	Final Score
			Activity Time (sec)	Point	Scoring	Point	Scoring		
1	Memory Activity	10	40	5	Per 8 seconds deduct 1 point	5	Add 1 point for each correct option	1.250	12.50
2	Word Assimilation Activity	15	60	5	Per 12 seconds deduct 1 point	10	Add 1 point for each correct option	0.500	07.50
3	Object Detection Activity	10	25	5	Per 5 seconds deduct 1 point	5	Add 1 point for each correct option	1.000	10.00
4	Communication Activity	15	70	5	After 30s deduct 1 point for each 10s	10	2 points (based on options) for each question.	1.250	18.75
5	Situational Activity	15	80	5	After 40s deduct 1 point for each 10s	10	2 points (based on options) for each question.	1.500	22.50
6	Perception Activity	10	540	5	After 300s, deduct 1 point for each 60s	10	Evaluation based on keyword match: > 75% word hit = 5 points 60-74% word hit = 4 points 45-59% word hit = 3 points 30-44% word hit = 2 points 15-29% word hit = 1 points < 14% word hit = 0 point	2.875	28.75
Grand Total									100

During the activity, the user is presented with a topic or situation and instructed to read it carefully. Once they have understood the topic, they are provided with a blank sheet to write their opinions or thoughts about the topic within a time limit of 9 minutes [see Figure 2(l)]. The system then terminates the activity once the user submits their response. This activity not only evaluates the user's ability to comprehend a given topic or situation but also their critical thinking skills and ability to express their thoughts and opinions coherently and effectively. The activity can provide valuable insights into the user's cognitive and communicative abilities, which can be used to detect the presence and severity of dementia.

By implementing these six key activities, the proposed system will be able to detect and categorize a participant's cognitive states. The decision-making algorithm of the system will then provide an assessment of the participant's condition in a user-friendly manner.

4.3 Defining Scores to Activities

An empirical study was carried out to define score to each activity to determine the level of dementia. Table 1 shows the scoring for the activities for cognitive assessment.

4.3.1 Participant Profile: To define the scores, a series of activities were conducted on a diverse group of participants who were invited through emails and phone calls. A total of 20 participants with various degrees of cognitive impairment were invited. Among them, 3 were healthy individuals (having no dementia symptoms) and rest 17 had mild to severe symptoms of dementia. 3 were below the age of 10 years, 5 were between 11 to 20 years, 5 were from 20 to 35 years of age and the rest were above 70 years.

4.3.2 Study Procedure: The study sessions were conducted by following these steps:

- The participants were briefed about the purpose of the study. They were also briefed about the whole study procedure.
- Consent was taken in printed form to ensure privacy and confidentiality.
- The whole session was recorded (both audio and video) for further analysis.

4.3.3 Data Analysis And Findings: The scoring system was designed to not only focus on the options selected by the user, but also on the time taken to select them (Table 1). This was deemed crucial, as dementia can impact not only an individual's thought process but also the reaction speed and accuracy of their mind [2]. The number of points awarded for each activity was determined based on the time taken, with the points ranging from 10 to 15. The system has implemented a deduction of points for delayed responses in each activity, with varying time limits for each activity. The options chosen by the user are given a score of 1 point, except in cases where there are partially correct options in situational or communication activities, which may be awarded 2 points. In the perception activity, the calculation of the score is based on finding common keywords between the user's response and a collection of keywords associated with the specific question stored in the system. The more the number of keywords in common, the higher the score assigned to the user's response. To determine the appropriate weighting for each activity, careful consideration was given to the relative importance of each activity in detecting and monitoring dementia. Research has consistently shown that perception is a primary indicator of dementia [43], and accordingly, it was given the highest weight. The results of the activities taken by the selected individuals indicated that over 97% of healthy individuals scored above 85, while those with mild symptoms had a minimum score of approximately 60, and elderly individuals with visible signs of dementia scored slightly over 30.

Table 2: Categorization for level of dementia

Ser	Obtained Score	Category
1	85-100	Healthy
2	60-85	Mild Dementia
3	30-60	Moderate Dementia
4	00-30	Severe Dementia

4.3.4 Categorization: Based on the score the user obtains from the games, four categories were designed to define a user (Table 2). If a person makes 85 to 100 score, he/she will be defined as a *Healthy* person while a *Mild Dementia* will be considered for the score of 60 to below 85. Again, if a person achieves score of 30 to below 60, he will be defined as *Moderate Dementia* patient and in case of 00 to below 30, it will be *Severe Dementia.* After the completion of the game, the user will be given with the decision in accordance with the achieved score. Suggestions from clinical psychologists, from a well-known Dementia Care organization that focuses on dementia research and diagnosis, were also considered to fine tune the activities and scoring.

4.4 Development of the Prototype

The prototype was designed and developed using Flutter, an open-source mobile app development framework that uses the Dart programming language and Android studio. For every activity, a single interactive UI was developed. This system was developed through several mobile games on activities that measure completion time for each game on activity. For example, one of these games is the Perception game, which presents patients with a scenario and asks them to describe what they see. Based on the patient's response, the game calculates a score. The score for each patient is based on how many of the keywords they correctly identify. This score provides feedback to patients on their performance and can help them identify areas where they need improvement. Overall, the proposed mobile games on activity provide an engaging and effective way to measure patients' cognitive abilities and provide feedback on their performance.

4.5 Comparison with Existing Diagnosis Tools

At present, the detection and treatment of dementia primarily rely on traditional medical approaches such as clinical assessments, cognitive testing, and pharmacotherapy [9]. While these approaches have shown success in managing the symptoms of dementia, there is a notable lack of technological tools and interventions available for early detection and intervention. Despite the growing interest in developing innovative solutions for detecting dementia, the current landscape of available technologies is relatively limited. Cognitive assessments such as the Mini-Mental State Examination and Montreal Cognitive Assessment remain the gold standard for diagnosing dementia, with imaging techniques such as MRI and PET scans used to detect brain changes associated with the condition [1]. While there are promising developments in the use of wearable devices and mobile applications for tracking cognitive function and behavior, their efficacy and reliability for detecting and diagnosing dementia are still being evaluated. As such, medical treatments such as medication and therapy remain the primary approach for managing the symptoms of dementia [35].

Our proposed system for detecting dementia through mobile UI has the potential to make a significant impact in this field. One of the key advantages of the proposed system for detecting dementia through mobile UI is to offer early detection and intervention for individuals with cognitive impairment. By providing accessible and easy-to-use cognitive tests and games, the system can empower individuals to monitor their cognitive function and detect early signs of dementia before seeking medical attention. The proposed system uses games and cognitive tests that users can play without realizing they are being tested for dementia. This approach reduces user anxiety, which can lead to more accurate and reliable data collection. By providing a user-friendly interface, the system enhances the user experience and promotes engagement.

5 DISCUSSION AND CONCLUSION

The research developed an interactive mobile interface that incorporated six cognitive activities designed to identify the presence of dementia and categorize its severity into three different states. The severity symptoms were identified through an extensive review of scientific research articles, as well as consultation with expert professionals in the field of dementia research and treatment. The cognitive activities were specifically designed to assess different cognitive functions that are affected by dementia, including memory, perception, communication, language and situational assessment. The scoring system used in these activities was developed based on previous works related to the topic of this research, ensuring that the results obtained were both reliable and valid.

The use of our proposed system could lead to earlier detection of dementia, allowing for early interventions and improved outcomes. Early detection is particularly important as it can provide individuals with more treatment options and help them to plan for their future care. The mobile interface provides a convenient and accessible way for individuals to track their cognitive abilities over time. This could be particularly beneficial for individuals who may not have access to specialized healthcare services or who may be reluctant to seek medical help. By tracking their cognitive abilities, individuals could detect any changes or decline in their cognitive function, allowing for early intervention. The development of an interactive mobile interface for detecting dementia could reduce the burden on healthcare systems. By providing a simple and easy-to-use tool for dementia detection, healthcare providers could diagnose and manage the condition more efficiently, freeing up resources for other areas of need. Lastly, the research also has implications for the development of future technologies for dementia management and treatment. By incorporating cognitive activities and assessments into mobile applications, researchers and healthcare providers could develop more personalized and effective treatment plans for individuals with dementia.

Although the development of an interactive mobile interface for detecting dementia is a promising approach, there were some limitations in the research that need to be considered. One limitation is the categorization of dementia into three types, which may be much broader in real life. As dementia is a complex condition that can manifest in many different ways, it may be difficult to accurately classify it into just three categories. Future research could consider more detailed categorization based on specific symptoms and cognitive impairments. Second, while the cognitive activities used in the mobile interface were developed based on previous research and consultations with expert professionals in the field, the framework upon which the activities were built was not publicly tested or verified. This lack of validation could affect the accuracy of the results obtained through the mobile interface. Further assessment and validation of the cognitive activities and the framework used to develop them would help to address this limitation. The user interface that was developed may not be as attractive or user-friendly for individuals of all ages and abilities. The UI was primarily designed with a focus on functionality, rather than aesthetics. Additionally, involving a diverse group of individuals for usability evaluation of the system and incorporating user feedback could help to improve the usability and accessibility of the interface. Designing a more engaging and visually appealing UI would be more appealing to users of all ages and cognitive abilities.

Cultural factors carries carry significant implications for both participants and UI designers [14]. Cultural differences are may impact the way participants interpret and respond to the scenarios presented in the activities [28]. For example, certain cultural beliefs or values may influence how a participant perceives a particular scenario, which could impact the accuracy of their responses. Again, language barriers could also be a challenge, particularly if participants speak a different language than the one used in the UI. This could impact the accuracy of the scores and make it more difficult to provide feedback to participants. Accessibility issues for elderly participants could also be a challenge. Some elderly participants may have difficulty using mobile devices or understanding the instructions provided in the games. This could impact their ability to complete the games accurately and could limit their participation in the study. Future research may focus to implement a variety of strategies to address the limitations and challenges related to cultural differences, language barriers, and accessibility issues in implementing the proposed system. For example, to address cultural differences, scholars could conduct research to identify common cultural beliefs and values that may impact participants' interpretations of the scenarios presented in the games. To address language barriers, scholars could incorporate multilingual options into the games, allowing participants to select their preferred language.To address accessibility issues for elderly participants, researchers could design games that are more intuitive and user-friendly, with larger text and buttons that are easier to read and navigate.

REFERENCES

[1] Edoardo Nicolò Aiello, Fabrizio Pasotti, Ildebrando Appollonio, and Nadia Bolognini. 2022. Equating Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) scores: conversion norms from a healthy Italian population sample. *Aging Clinical and Experimental Research* 34, 7 (2022), 1721–1724.

[2] Daniela Andriuta, Momar Diouf, Martine Roussel, and Olivier Godefroy. 2019. Is reaction time slowing an early sign of Alzheimer's disease? A meta-analysis. *Dementia and Geriatric Cognitive Disorders* 47, 4-6 (2019), 281–288.

[3] Ifath Ara, Tasneem Mubashshira, Fariha Fardina Amin, Nafiz Imtiaz Khan, and Muhammad Nazrul Islam. 2022. Towards Developing a Mobile Application for Detecting Intoxicated People through Interactive UIs. In *Proceedings of International Joint Conference on Advances in Computational Intelligence: IJCACI 2021*. Springer, 209–222.

[4] Alzheimer's Association. 2021. Stages of Alzheimer's. https://www.alz.org/alzheimers-dementia/stages.

[5] Moumita Bhowmik, Fardeen Ashraf, Tashfia Fatema, Faria Habib, Md Lutful Kabir, Iyolita Islam, and Muhammad Nazrul Islam. 2022. Evaluating Usability of Mobile Financial Applications Used in Bangladesh. In *Advances in Design and Digital Communication III: Proceedings of the 6th International Conference on Design and Digital Communication, Digicom 2022, November 3–5, 2022, Barcelos, Portugal*. Springer, 161–176.

[6] Andrew E Budson and Paul R Solomon. 2016. Memory loss. *Alzheimer's disease, and dementia (second edition) Chapter* (2016), 5–38.

[7] Jiska Cohen-Mansfield, Aleksandra Parpura-Gill, and Hava Golander. 2006. Salience of self-identity roles in persons with dementia: Differences in perceptions among elderly persons, family members and caregivers. *Social Science & Medicine* 62, 3 (2006), 745–757.

[8] Tom Dening and Malarvizhi Babu Sandilyan. 2015. Dementia: definitions and types. *Nursing Standard (2014+)* 29, 37 (2015), 37.

[9] Howard H Feldman, Claudia Jacova, Alain Robillard, Angeles Garcia, Tiffany Chow, Michael Borrie, Hyman M Schipper, Mervin Blair, Andrew Kertesz, and Howard Chertkow. 2008. Diagnosis and treatment of dementia: 2. Diagnosis. *cmaj* 178, 7 (2008), 825–836.

[10] L Gustafson. 1996. What is dementia? *Acta Neurologica Scandinavica* 94 (1996), 22–24.

[11] Rowan H Harwood, Rebecca O'Brien, Sarah E Goldberg, Rebecca Allwood, Alison Pilnick, Suzanne Beeke, Louise Thomson, Megan Murray, Ruth Parry, Fiona Kearney, et al. 2018. A staff training intervention to improve communication between people living with dementia and health-care professionals in hospital: the VOICE mixed-methods development and evaluation study. *Health Services and Delivery Research* 6, 41 (2018).

[12] Netzahualcoyotl Hernandez, Matias Garcia-Constantino, Jessica Beltran, Pascal Hecker, Jesus Favela, Joseph Rafferty, Ian Cleland, Hussein Lopez, Bert Arnrich, and Ian McChesney. 2019. Prototypical system to detect anxiety manifestations by acoustic patterns in patients with dementia. *EAI Endorsed Transactions on Pervasive Health and Technology* 5, 19 (2019), e5–e5.

[13] Netzahualcoyotl Hernandez-Cruz, Matias Garcia-Constantino, Jessica Beltran-Marquez, Dagoberto Cruz-Sandoval, Irvin Hussein Lopez-Nava, Ian Cleland, Jesús Favela, C Nugent, Andrew Ennis, Joseph Rafferty, et al. 2019. Study Design of an Environmental Smart Microphone System to Detect Anxiety in Patients with Dementia. In *Proceedings of the 13th EAI International Conference on Pervasive Computing Technologies for Healthcare*. 383–388.

[14] Muhammad Nazrul Islam and Harry Bouwman. 2016. Towards user–intuitive web interface sign design and evaluation: A semiotic framework. *International Journal of Human-Computer Studies* 86 (2016), 121–137.

[15] Muhammad Nazrul Islam, Md Mahboob Karim, Toki Tahmid Inan, and A. K. M. Najmul Islam. 2020. Investigating usability of mobile health applications in Bangladesh. *BMC Medical Informatics and Decision Making* 20, 1 (2020).

[16] Sapna Juneja, Gaurav Dhiman, Sandeep Kautish, Wattana Viriyasitavat, Kusum Yadav, et al. 2021. A perspective roadmap for IoMT-based early detection and care of the neural disorder, dementia. *Journal of Healthcare Engineering* 2021 (2021).

[17] Paul-Ariel Kenigsberg, Jean-Pierre Aquino, Alain Berard, Fabrice Gzil, Sandrine Andrieu, Sube Banerjee, François Brémond, Luc Buee, Jiska Cohen-Mansfield, Francesca Mangialasche, et al. 2016. Dementia beyond 2025: Knowledge and uncertainties. *Dementia* 15, 1 (2016), 6–21.

[18] Frank R Lin and Marilyn Albert. 2014. Hearing loss and dementia–who is listening? , 671–673 pages.

[19] J Lindeboom, B Schmand, L Tulner, G Walstra, and C Jonker. 2002. Visual association test to detect early dementia of the Alzheimer type. *Journal of Neurology, Neurosurgery & Psychiatry* 73, 2 (2002), 126–133.

[20] Inna Lisko, Jenni Kulmala, Martin Annetorp, Tiia Ngandu, Francesca Mangialasche, and Miia Kivipelto. 2021. How can dementia and disability be prevented in older adults: where are we today and where are we going? *Journal of internal medicine* 289, 6 (2021), 807–830.

[21] Kejun Liu, Yi Yao, Zhejun Liu, and Reika Sato. 2019. Design Concepts of Electronic Medical Tools for Dementia Early Detection and Assessment. In *2019 IEEE 1st Global Conference on Life Sciences and Technologies (LifeTech)*. IEEE, 31–33.

[22] Juan Pedro López, Francisco Moreno, Mirela Popa, Gustavo Hernández-Peñaloza, and Federico Álvarez. 2019. Data analysis from cognitive games interaction in Smart TV applications for patients with Parkinson's, Alzheimer's, and other types of dementia. *AI EDAM* 33, 4 (2019), 442–457.

[23] Kenneth Maiese. 2019. Impacting dementia and cognitive loss with innovative strategies: mechanistic target of rapamycin, clock genes, circular non-coding ribonucleic acids, and Rho/Rock. *Neural regeneration research* 14, 5 (2019), 773.

[24] Bahman Mirheidari, Daniel Blackburn, Ronan O'Malley, Traci Walker, Annalena Venneri, Markus Reuber, and Heidi Christensen. 2019. Computational cognitive assessment: Investigating the use of an intelligent virtual agent for the detection of early signs of dementia. In *ICASSP 2019-2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*. IEEE, 2732–2736.

[25] Kazi Md. Munim, Iyolita Islam, Mahmuda Khatun, Md Mahboob Karim, and Muhammad Nazrul Islam. 2017. Towards developing a tool for UX evaluation using facial expression. In *2017 3rd International Conference on Electrical Information and Communication Technology (EICT)*. IEEE, 1–6. https://doi.org/10.1109/EICT.2017.8275227

[26] Kazi Md Munim, Iyolita Islam, Md Mahbubar Rahman, and Muhammad Nazrul Islam. 2020. Adopting HCI and Usability for Developing Industry 4.0 Applications: A case study. In *2020 2nd International Conference on Sustainable Technologies for Industry 4.0 (STI)*. IEEE, 1–6.

[27] Chris D Nugent and Rose-Marie Driies. 2010. Review of ICT-Based Services for Identified Unmet Needs in People with Dementia. *Supporting People with Dementia Using Pervasive Health Technologies* (2010), 37.

[28] Hessel Oosterbeek, Randolph Sloof, and Gijs Van De Kuilen. 2004. Cultural differences in ultimatum game experiments: Evidence from a meta-analysis. *Experimental economics* 7 (2004), 171–188.

[29] World Health Organization et al. 2017. Global action plan on the public health response to dementia 2017–2025. (2017).

[30] World Health Organization et al. 2019. Adopting a healthy lifestyle helps reduce the risk of dementia. *World Health Organization* (2019).

[31] Peter Osvath, Attila Kovacs, Adrienn Boda-Jorg, Tamas Tenyi, Sandor Fekete, and Viktor Voros. 2018. The use of information and communication technology in elderly and patients with dementia. *J Gerontol Geriatr Res* 7, 03 (2018).

[32] Moisés R Pacheco-Lorenzo, Sonia Valladares-Rodríguez, Luis Anido-Rifón, and Manuel J Fernández-Iglesias. 2022. A Conceptual Framework Based on Conversational Agents for the Early Detection of Cognitive Impairment. In *Proceedings of 2nd International Conference on Artificial Intelligence: Advances and Applications: ICAIAA 2021*. Springer, 801–813.

[33] Moisés R Pacheco-Lorenzo, Sonia M Valladares-Rodríguez, Luis E Anido-Rifón, and Manuel J Fernández-Iglesias. 2021. Smart conversational agents for the detection of neuropsychiatric disorders: A systematic review. *Journal of Biomedical Informatics* 113 (2021), 103632.

[34] Stephanie Perin, Rachel F Buckley, Matthew P Pase, Nawaf Yassi, Alexandra Lavale, Peter H Wilson, Adrian Schembri, Paul Maruff, and Yen Ying Lim. 2020. Unsupervised assessment of cognition in the Healthy Brain Project: Implications for web-based registries of individuals at risk for Alzheimer's disease. *Alzheimer's & Dementia: Translational Research & Clinical Interventions* 6, 1 (2020), e12043.

[35] Antoine Piau, Katherine Wild, Nora Mattek, and Jeffrey Kaye. 2019. Current state of digital biomarker technologies for real-life, home-based monitoring of cognitive function for mild cognitive impairment to mild Alzheimer disease and implications for clinical care: systematic review. *Journal of medical Internet research* 21, 8 (2019), e12785.

[36] Brenna Posner, Megan Sutter, Paul B Perrin, Guillermo Ramirez Hoyos, Jacqueline Arabia Buraye, and Juan Carlos Arango-Lasprilla. 2015. Comparing dementia caregivers and healthy controls in mental health and health related quality of life in Cali, Colombia. *Psicología desde el Caribe* 32, 1 (2015), 1–26.

[37] Martin Prince, Renata Bryce, Emiliano Albanese, Anders Wimo, Wagner Ribeiro, and Cleusa P Ferri. 2013. The global prevalence of dementia: a systematic review and metaanalysis. *Alzheimer's & dementia* 9, 1 (2013), 63–75.

[38] H Rubiani, E Samsoleh, and S Fitri. 2021. Activity recognition (AR) to detect dementia using wi-fi based wireless sensor network with receive signal srength indicator (RSSI) method. In *IOP Conference Series: Materials Science and Engineering*, Vol. 1115. IOP Publishing, 012079.

[39] Utkarsh Sarawgi, Wazeer Zulfikar, Nouran Soliman, and Pattie Maes. 2020. Multimodal inductive transfer learning for detection of Alzheimer's dementia and its severity. *arXiv preprint arXiv:2009.00700* (2020).

[40] Joon-Ho Shin. 2022. Dementia epidemiology fact sheet 2022. *Annals of Rehabilitation Medicine* 46, 2 (2022), 53.

[41] Alzheimer's Society. 2021. The progression, signs and stages of dementia. https://www.alzheimers.org.uk/about-dementia/symptoms-and-diagnosis/how-dementia-progresses/progression-stages-dementia.

[42] Marjanne D Van Der Hoek, Arie Nieuwenhuizen, Jaap Keijer, and J Wesson Ashford. 2019. The MemTrax test compared to the Montreal Cognitive Assessment estimation of mild cognitive impairment. *Journal of Alzheimer's Disease* 67, 3 (2019), 1045–1054.

[43] Julian Wangler and Michael Jansky. 2021. Factors influencing general practitioners' perception of and attitude towards dementia diagnostics and care—results of a survey among primary care physicians in Germany. *Wiener Medizinische Wochenschrift (1946)* 171, 7 (2021), 165.

[44] Adrienne Withall, Brian Draper, Katrin Seeher, and Henry Brodaty. 2014. The prevalence and causes of younger onset dementia in Eastern Sydney, Australia. *International psychogeriatrics* 26, 12 (2014), 1955–1965.

[45] Kristina Yordanova, Philipp Koldrack, Christina Heine, Ron Henkel, Mike Martin, Stefan Teipel, and Thomas Kirste. 2017. Situation model for situation-aware assistance of dementia patients in outdoor mobility. *Journal of Alzheimer's Disease* 60, 4 (2017), 1461–1476.

[46] IV Zhirova, IV Spichak, and Yu E Kharchenko. 2022. Analyses of epidemiological indicators of dementia globally and in russian federation. In *Innovations in life sciences*. 233–234.