COMPANIAN FOR ELDERLY: CHATBOT AND MINI-GAMES FOR ALZHEIMER'S PREDICTION

By

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ABSTRACT

In recent years, many elderly people who are living alone have faced lots of difficulties, such as a lack of companionship, difficulty managing daily tasks, and unawareness of health issues like Alzheimer's disease. Although there are a few mobile applications available to help solve these issues, they often lack a comprehensive, all-in-one solution tailored specifically for the elderly. This project aims to study the development of a mobile application designed to help elderly people by combining multiple features into a single platform. The proposed application addresses limitations found in existing mobile applications such as CogniFit, Replika, and MyTheraphy which they do not contain the features cognitive assessment, companionship feature, and tools to assist in daily lives in a single platform. Thus, the proposed application will provide an integrated solution to assist the elderly in their daily lives. It includes a chatbot that serves as a virtual companion to engage users in meaningful conversations and a minigame-based cognitive assessment tool which reference from Mini-Mental State Examination (MMSE) test to help monitor cognitive health. The polynomial regression model with average MAE score of 0.639, average RMSE score of 0.915, and average R^2 score of 0.595 is integrated as predictive model for Alzheimer's disease. The application is developed using Android Studio, Unity Game Engine with C#, and Android SDK with Kotlin and JavaScript, and is designed to be compatible with Android smartphones. Besides, users can use the utility tools built in the application such as the contact and the reminder to support in their daily activities.

Area of Study (Minimum 1 and Maximum 2): Artificial Intelligence, Mobile Application Development

Keywords (Minimum 5 and Maximum 10): Alzheimer Test, Monitoring Applications, Chatbot, Minigames, Utility Tools

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LIST OF ABBREVIATIONS

AI	Artificial Intelligent
AD	Alzheimer's Disease
MMSE	Mini-Mental State Examination
AUC	Area Under Curve
MCI	Mild Cognitive Impairment
NLP	Natural Language Processing
CASE	Computer Aided Software Engineering
SDLC	Software Development Life Cycle
IDE	Integrated Development Environment
API	Application Programming Interface
MAE	Mean Absolute Error
RMSE	Root Mean Square Error

CHAPTER 1 INTRODUCTION

1.1 Problem Statement and Motivation

Nowadays, the number of elderly people choosing to live alone is increasing, because they have the desire to maintain independence even though living alone can be challenging for them [1]. They will be lacking companionship and support, meanwhile they will also face difficulties in completing daily tasks, especially for those with cognitive impairments such as Alzheimer's disease. Many elderly people are unaware of cognitive decline, as traditional clinical screening methods can be stressful for them.

Although there are mobile applications like CogniFit allow users to assess their cognitive abilities [9], they are primarily focused on evaluation and do not offer support for daily living or companionship. Similarly, Replika which have Artificial Intelligent (AI) Chatbot have provide companionship but lack features to assist with daily tasks or cognitive monitoring [10]. On the other hand, applications like MyTherapy only assist with daily task management but do not address companionship or cognitive evaluation [11]. These had highlighted that there is no single platform currently can provide an integrated approach for cognitive assessment, companionship, and daily living support.

The motivation for this project is to enhance the quality of life for elderly people who are living independently. By developing a comprehensive mobile application that combines cognitive evaluation through engaging minigames, a chatbot for meaningful companionship, and tools assisting their daily tasks, this project aims to maintain users' independence meanwhile provide monitoring for cognitive health and reducing the feelings of isolation. Besides, by offering cognitive assessments in a more interesting way which is minigame format will attract the elderly people compared to the traditional clinical methods such as Mini-Mental State Examination (MMSE) [5] which is a questionnaire which consists of eleven questions used by doctors and other health professionals to check for cognitive impairment.

1.2 Objectives

The mobile application developed for elderly support must achieve the following objectives to effectively meet the needs of users:

- To develop a minigame based cognitive assessment reference from MMSE for the user to keep track on their cognitive performance.
- To develop a predictive model for determining the likelihood of Alzheimer's disease in user based on their performance scores from a series of cognitive minigames.
- To implement an integrated AI-powered chatbot that offers companionship and emotional support.
- To provide tools for managing daily routines, including setting and receiving reminders for medications, appointments, and other important tasks.
- To provide a user-friendly interface to ease the communication between the user and the application.

1.3 Project Scope and Direction

The primary users of this mobile application are the elderly people who living alone and may face the challenges such as the lack of companionship, difficulties in completing their daily routine, and may have the risk of getting cognitive problem such as Alzheimer’s disease.

The core function of this mobile application is having an engaging minigames to determine user cognitive functions including orientation, memory, attention, language, and visual and spatial skills which reference from the Mini-Mental State Examination (MMSE). The games are designed to be simple and attractive for purpose so that it will be suitable for the elderly people to play.

While the users able to keep track on their performance after playing the minigames but it does not serve as a diagnostic tool for Alzheimer’s disease instead it may indicate the early signs of cognitive impairment. The prediction of cognitive problem is based on the user performance in the minigames and raise their awareness to the cognitive issues. A real

diagnosis still requires the medical experts to conduct. The user may show the performance of the minigames to medical experts for further diagnosis.

This mobile application is developed using Android Studio and integrated with Unity inside for the minigames together with the Firebase for the authentication and the database to store the data. The programming languages used are Kotlin with JavaScript for Android Studio and C# for the Unity side. This mobile application designed for Android mobile phone as it is used by majority people to ensure the accessibility.

1.4 Contributions

The main contribution of this project is to develop a single mobile application which contain the minigame based cognitive assessment which can be used as Alzheimer diseases prediction, AI chatbot, and tools for managing daily lives. The core of this mobile application is having a minigame base cognitive assessment which is much more interesting compared to the traditional clinical method such as Mini-Mental State Examination (MMSE) which is used to check for cognitive impairment by doctors and other health professionals. It is expected that the users are more interested in playing the games compared to have a cognitive test. Users can keep track on their cognitive performance through the application and able to know whether their performance is improving, maintaining, or decreasing as Alzheimer diseases prediction. This mobile application with user friendly interface will be helpful especially for those elderly people who are living alone.

1.5 Report Organization

The details of this research are shown in the following chapters. In Chapter 2, the effectiveness of Mini-Mental State Examination (MMSE) was studied, some existing mobile application for the elderly people such as CogniFit, Replika and MyTheraphy are selected to be reviewed. The critical analysis will be investigated to compare the strengths and weaknesses among these applications. Chapter 3 will discuss system design with system architecture diagram, use case diagram and description. Chapter 4 will include the methodology for this project. Chapter 5 is on system implementation while Chapter 6 will discuss system evaluation. Lastly, Chapter 7 will report on the conclusion for this project.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Previous works have highlighted the potential of digital health applications in supporting the cognitive and emotional well-being of elderly individuals. Among these applications, systems designed to detect Alzheimer's disease, chatbots for companionship, and tools to assist with daily life have shown significant promise. This chapter explores the integration of the Mini-Mental State Examination (MMSE) to evaluate cognitive health for Alzheimer patients with minimal time commitment. Additionally, this chapter will focus on reviewing existing similar applications that assist elderly patients with or without Alzheimer's to identify their functionalities and limitations.

2.2 Evaluation of Mini-Mental State Examination (MMSE)

Mini-Mental State Examination (MMSE) [5] is a questionnaire which consists of eleven questions used by doctors and other health professionals to check for cognitive impairment. The MMSE checks six areas of mental ability, including location, attention and concentration, short-term memory (recall), language skills, visual and spatial relationships between objects, and the ability to understand and follow instructions. Each of this section will contributes to the overall score with a maximum 30 points, where lower scores indicate higher levels of cognitive impairment. During the test, the patient will be asked to do a set of tasks such as trying to remember a few objects and then repeat the list back, copying a drawing, write a short sentence with correct grammar and so on. The test usually takes about 5 to 10 minutes for each patient [5]. Through this, MMSE is used to detect whether a patient has Alzheimer disease or otherwise and its severity. According to the total score of 30 points, the patient with MMSE score 21–26 is said to have mild Alzheimer's disease, MMSE score 10–20 is said to have moderate Alzheimer's disease, MMSE score 10–14 is said to have moderately severe Alzheimer's disease, and lastly, the patient who has a MMSE score below 10 is said to have severe Alzheimer's disease [6].

The reliability and validity of the Mini-Mental State Examination (MMSE) have been tested in different cultural contexts, including Turkish [7] and Korean [8] populations. The Turkish version of the MMSE, known as MMSE-I, was evaluated by Yildiz et al. [7] in a study

focusing on illiterate patients diagnosed with Alzheimer's Disease (AD). With an Area Under Curve (AUC) of 1.0, the results showed that the MMSE-I's excellent level of validity and reliability in this population, with a sensitivity of 99-100% and a specificity of 97-98.5%. Internal consistency was also strong, with a Cronbach's alpha of 0.70, supporting its use in distinguishing AD patients from healthy controls. The study concluded that the MMSE-I is a useful tool for evaluating cognitive impairment in illiterate population, a demographic that often faces challenges with traditional cognitive screening tools.

Similarly, Baek et al. [8] conducted a study on the MMSE-2, testing its reliability and validity for detecting Mild Cognitive Impairment (MCI) and Alzheimer's disease in a Korean population. The MMSE-2 was shown to have excellent internal consistency, test-retest reliability, and interrater reliability, with good concurrent validity when compared to other neuropsychological tests. Although the MMSE-2 performed well overall, it was noted that the tool was less sensitive in distinguishing between MCI and normal cognitive aging, which may be an area for improvement in future studies. However, the MMSE-2 was found to be a valid and reliable cognitive screening instrument for identifying more severe forms of cognitive impairment.

Despite the high reliability and validity demonstrated in both studies, certain challenges were noted. In the Turkish study, MMSE-I was tailored to accommodate the unique needs of illiterate patients, which may limit its generalizability to other populations. Additionally, the Korean study highlighted the limitations of the MMSE-2 in detecting early-stage cognitive decline, particularly MCI, suggesting that further refinement of the tool may be necessary for early diagnosis.

Overall, these findings highlight the importance of adapting cognitive assessment tools like the MMSE to fit the cultural and educational context of the population being tested. Both studies support the use of these modified MMSE versions in their respective populations, with strong evidence for their validity and reliability in identifying cognitive impairments associated with Alzheimer's disease.

Even though MMSE is widely used as a cognitive screening tool, but it has several limitations that should be considered. MMSE alone cannot provide a definitive diagnosis of cognitive impairment of Alzheimer like any cognitive test. A low score does not mean the patient is having Alzheimer's disease. It could be caused by other factors such as physical problems, education level, cultural differences, and so on. Meanwhile, a high score does not

mean the patient has normal mental ability. For example, an educated Alzheimer patient might perform well in the MMSE test. This is likely to happen in the early stages of Alzheimer's disease [5].

2.3 Evaluation of Existing Similar System

2.3.1 CogniFit

CogniFit [9] is a popular cognitive assessment and training platform designed to evaluate and improve cognitive skills such as memory, processing speed, attention, problem-solving, etc. Users, especially the elderly, can use CogniFit via mobile application or through their website. The application provides different training and assessments to the users to test their cognitive performance, and the performance will be visualized in a score and graph. Besides, the application also offers a range of games with the purpose of helping the user maintain their cognitive performance while playing the games. The application also provides meditation courses to help the users relax their minds.

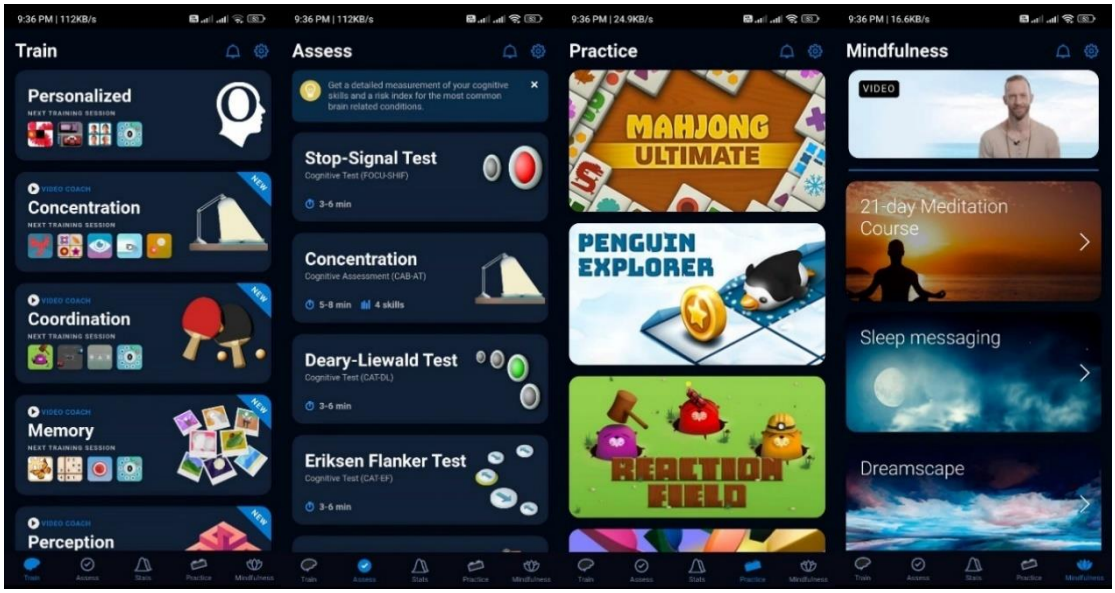

Figure 2.1 Different features provided in CogniFit

According to Figure 2.1, there are four main features provided in CogniFit to assist the users to improve their cognitive performance. These features include guided training, assessment to test the cognitive performance, games related to cognitive skills, and guided meditations. However, not all the features are available in the free versions. Majority training and guided meditations are not available in the free versions. Users are only able to play the game for a limited time in the free version. Subscription of membership is required for users to

enjoy all the features provided in CogniFit. Each main feature consists of more subcategories designed according to different user needs. Users can explore and find the one that is suitable for them in each feature.

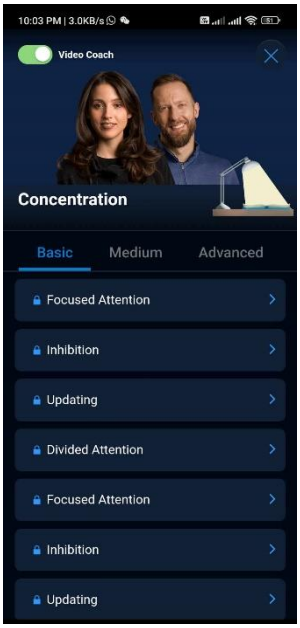

Figure 2.2 Training Feature in CogniFit

One of the main features in CogniFit is the training feature. The main purpose of this feature is to help the user improve their cognitive skills. This training feature is very user-friendly, as it allows the user to choose the training and the difficulty they prefer. According to Figure 2.2, users can choose the level of training feature provided in CogniFit. For example, the user can choose whether to have a basic, medium, or advanced level of training. There are also different subcategories provided inside a category of training feature. For example, focused attention, inhibition, divided attention, etc are inside the concentration training. All these trainings are guided by a coach through the video.

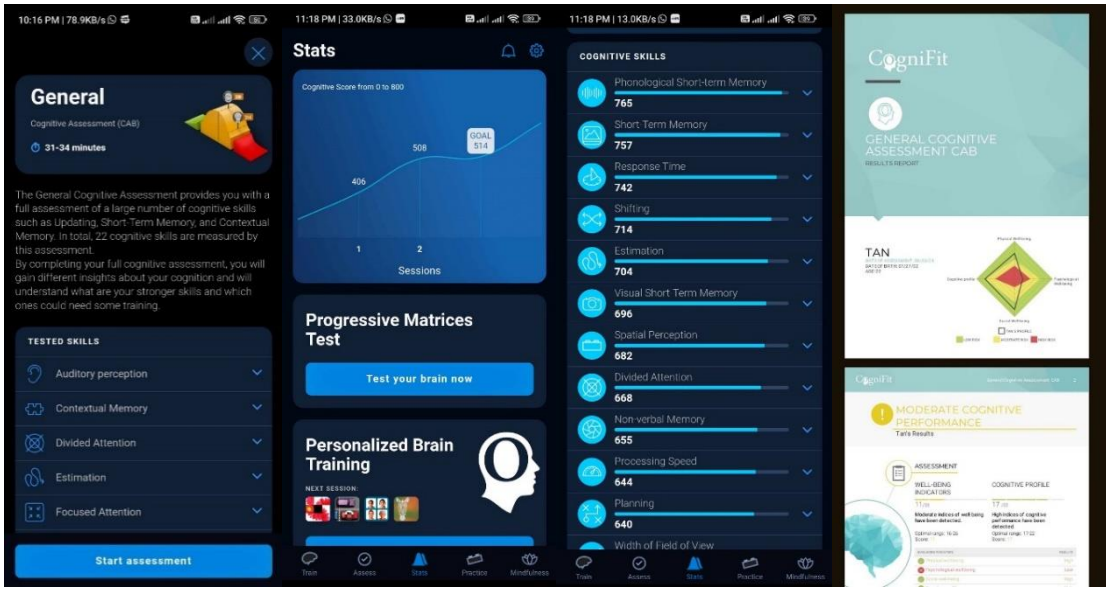

Figure 2.3 Assessment Feature in CogniFit

Another main feature of CogniFit is the assessment feature. The main purpose of this feature is to help the user test their cognitive performance through a series of tests. This training feature is user-friendly too, as it will show the total time needed and the tutorial before the user conducts the test. After the users complete the assessment, their cognitive performance will be visualized in a graph, and the score for each test is shown. Users are also able to download the report regarding their performance after completing the assessment. The report includes the detailed performance of each test and an overall summarization of the user performance. According to Figure 2.3, the time needed to complete a general assessment is within 31-34 minute, and the cognitive performance of the user is shown after completion of the assessment.

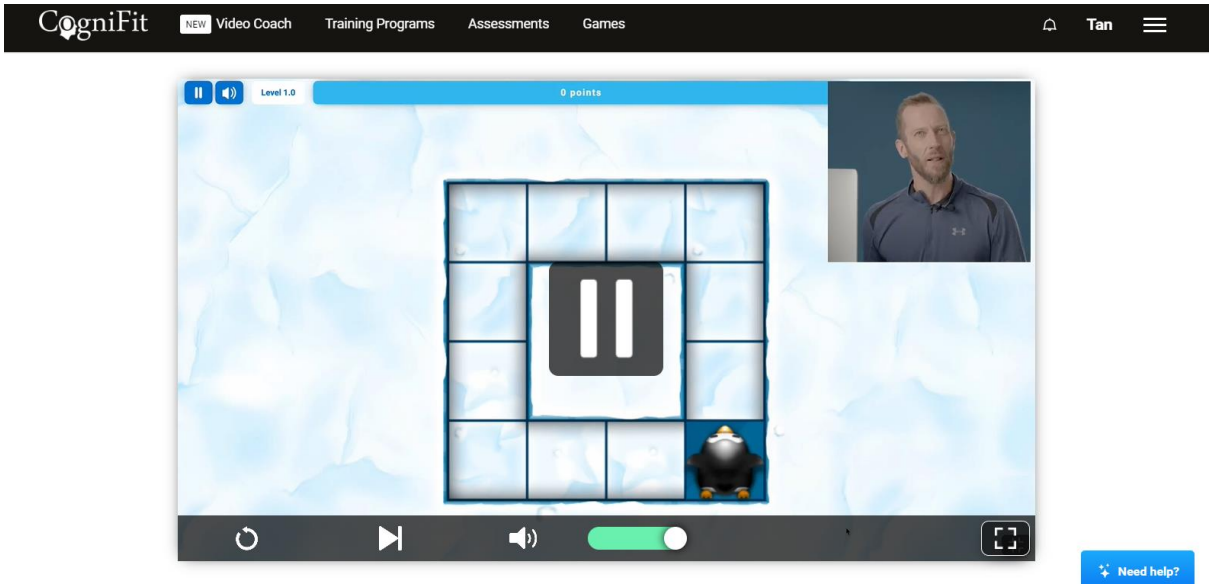

Figure 2.4 Tutorial Video for Game Feature in CogniFit

Another feature of CogniFit is games related to cognitive training. Users can play a series of games as time killers while maintaining their cognitive performance. The tutorial video will be shown as a guideline before the user plays the game. The user can proceed to play the game after watching the tutorial video. The performance and score of the game will be shown after the user completes the game. According to Figure 2.4, the video tutorial of the game "Penguin Explorer", which is related to the cognitive skill processing speed, is shown before the user starts to play the game. Users are able to know the purpose of this game and follow the instructions after watching the tutorial video.

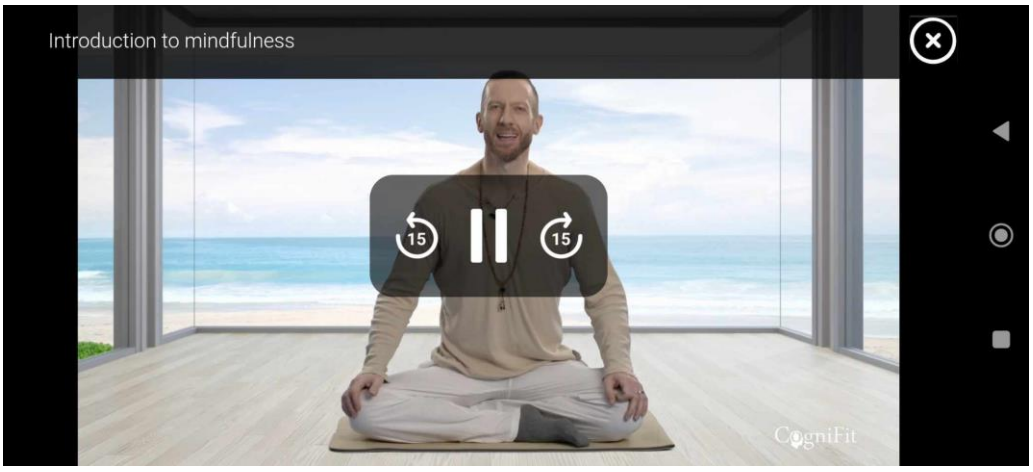

Figure 2.5 Tutorial Video for Mindfulness Meditation Feature in CogniFit

The last feature of CogniFit is meditation. Different types of meditation, such as sound meditation, mindfulness, etc., are offered in this feature. Users can choose the type of meditation that they prefer in this section to relax their mind. All these meditations are guided by the coach through the video. For example, according to Figure 2.5, users can follow the tutorial video of mindfulness meditation and do meditation to release their stress and relax their mind.

2.3.2 Replika

Replika [10] is an AI chatbot that is designed with the main purpose of providing emotional support and regular interaction as a companion. It uses Natural Language Processing (NLP) to simulate conversations and create a virtual friend that learns from interactions with its user. Users can customize the Replika according to their preference. According to the Figure 2.6 below, the main page is always displayed with the customized avatar created by the users. The key features of Replika are emotional support, personalization, and skill building.

Figure 2.6 Main Page of Replika

Figure 2.7 Chat Conversation between Replika

As shown in figure 2.7 above, users can interact with the Replika they created through chatting. Users can talk with the avatar about their feelings, daily routine, etc. This will serve as emotional support for them, thus reducing the feeling of loneliness, especially for the elderly since they might not have much companionship from their family members. Beside chatting, the user is also able to have a call with the avatar. This feature will ease the users who have problems with typing, especially the elderly people. The chatbot will improve the elderly quality of life and make them more active to fight their sense of loneliness [4].

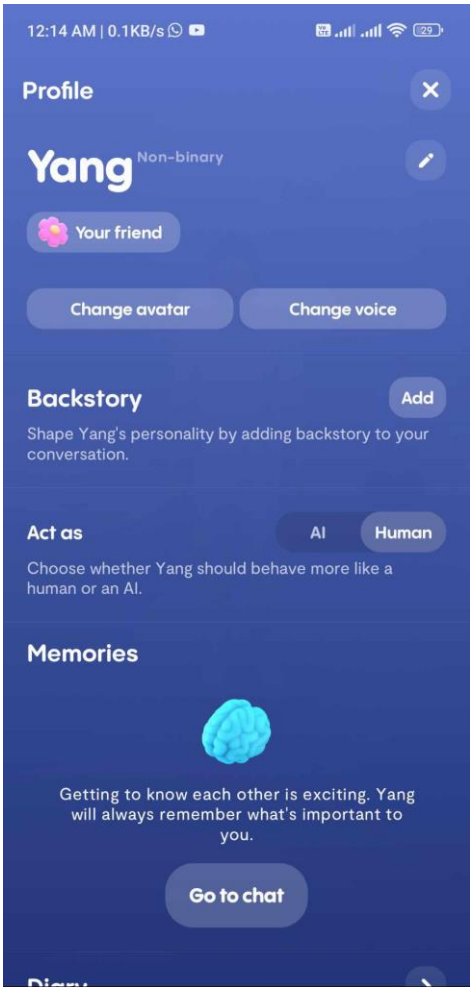

Figure 2.8 Profile of the Replika

According to Figure 2.8, the users can customize their Replika by changing their appearance or voice. Besides, users can also add a backstory to the Replika and set it to act as artificial intelligence (AI) or human. The Replika can also learn from the conversation, adapting to the user's personality and preferences to provide more personalized interactions. This personalization feature will allow the user to have more interactive and personalized interactions between the Replika. Furthermore, users can build skills while having the interaction with the Replika. Users can learn new skills or languages and manage their stress through the conversation between the Replika. Replika will also be able to memorize and learn during the conversation with the user. This will provide a better interaction with the user.

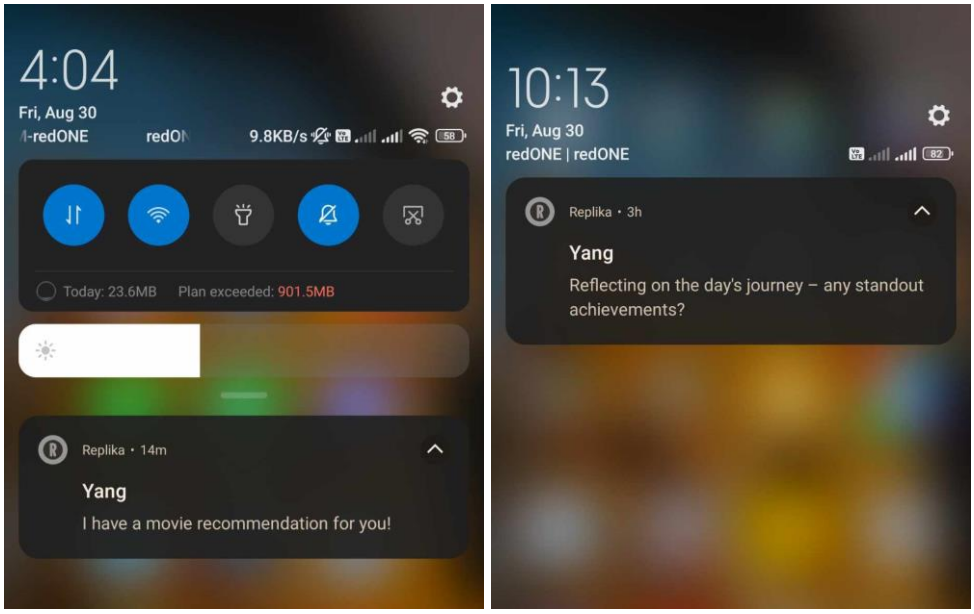

Figure 2.9 Notification from Replika

According to Figure 2.9, users will receive notifications from their Replika, encouraging them to participate in conversation or activities. These notifications are designed to initiate interaction by suggesting various topics or actions. For example, Replika may suggest a movie for the user to watch or inquire about their day's experiences, such as asking about specific events, emotions, or plans. These personalized notifications not only serve as a reminder for the user to interact with them but also create a sense of companionship and engagement. By regularly reaching out, Replika aims to reduce feelings of loneliness and encourage meaningful interactions, eventually encouraging a closer relationship between the user and the virtual companion. This approach makes use of AI's ability to simulate companionship and maintain user interest, offering both emotional support and a feeling of presence, even in the absence of human interaction.

2.3.3 MyTheraphy

MyTheraphy [11] is a medication reminder and health management application designed to help users, especially the elderly adhere to their prescribed medication schedule and manage their overall health. The application is primarily focused on supporting medication adherence, tracking health metrics, and managing chronic conditions. The key features of MyTheraphy include medication reminders, health tracking, reports and data sharing, and team and community support.

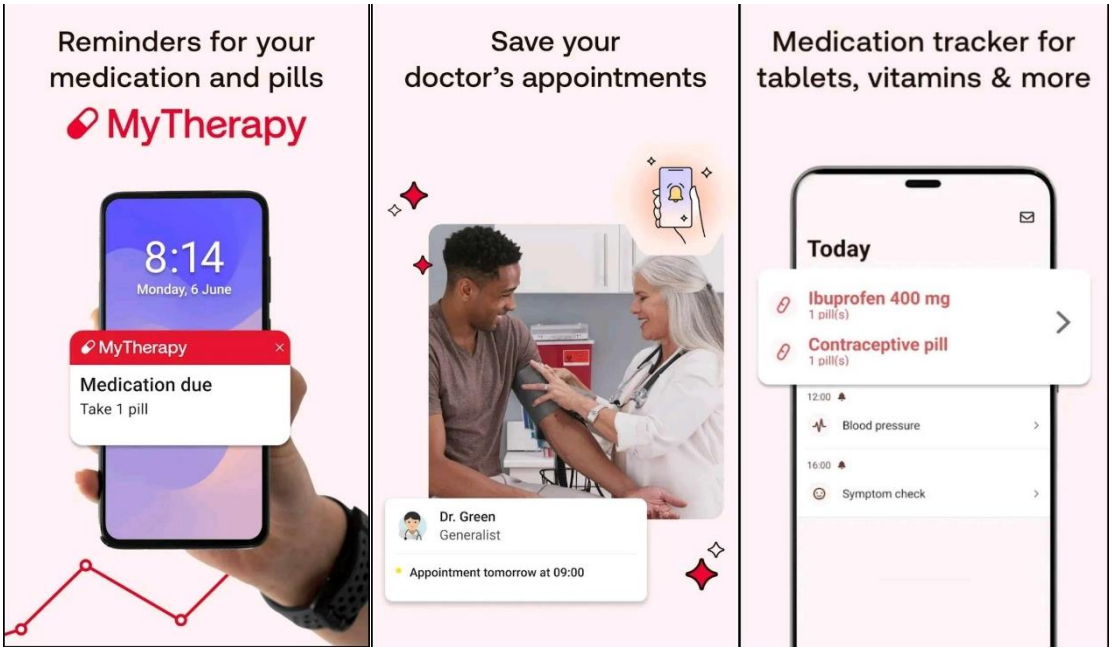

Figure 2.10 Medication Reminder of MyTheraphy

One of the main features of MyTheraphy is the medication reminder system, which is essential for elderly people who may have difficulty remembering their medication schedules. According to Figure 2.10, the user can easily set up the medication reminder in order to remind them to take the pills or visit the doctor. When it is time for a reminder, a notification will pop up on the lock screen of their mobile phone, ensuring the user is notified even if the application is not open. This feature is particularly useful for elderly users who live alone, as it helps them adhere to their prescribed medication regimen without relying on others. With this feature, elderly people can live independently without worrying about burdening their family members or outsiders [1].

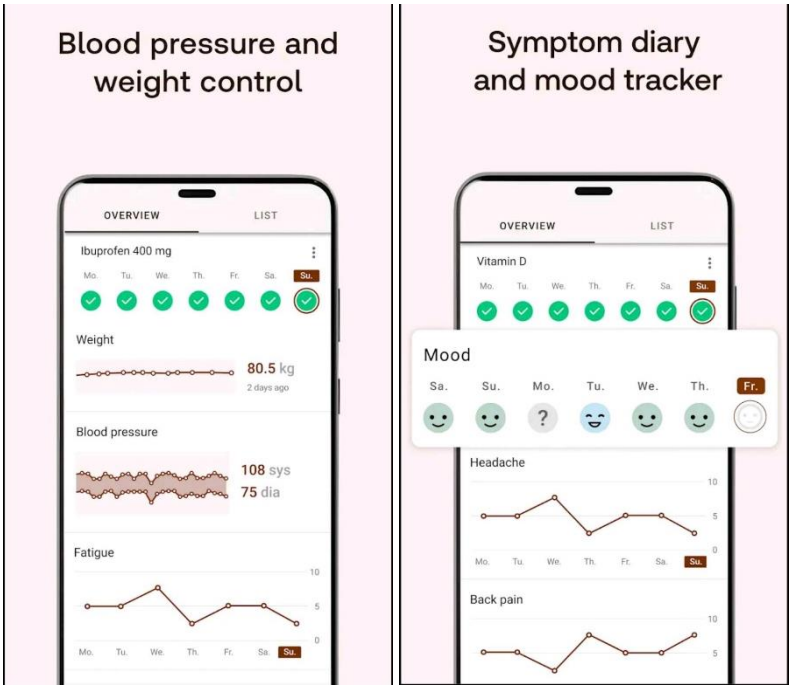

Figure 2.11 Health Tracking of MyTheraphy

Another valuable feature of MyTheraphy is its comprehensive health tracking system, which allows users to monitor various aspects of their health daily. According to Figure 2.11, users can easily track their health metrics, such as the change of their blood pressure, weight, and the rate of fatigue every day, enabling them to observe changes over time and gain insights into their overall health status. Besides, users can log their daily symptoms, such as headaches and backpain, and even track their mood, providing a holistic view of their physical and emotional well-being. This feature is particularly beneficial for elderly users, who may face multiple health challenges and need to keep track of their health. Through the app, family members can remotely access the health data of their parents, allowing them to stay informed about their health status. If any concerning patterns are detected, family members can immediately act and provide support or arrangements for medical assistance.

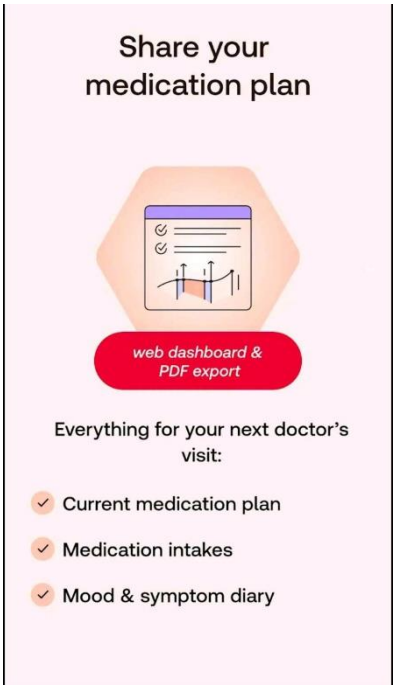

Figure 2.12 Medication Report of MyTheraphy

The last feature of MyTheraphy is its ability to generate the medication reports. Through the application, users can create detailed reports that include their medication plans, records of medication intake, mood diaries, and symptoms tracking. According to Figure 2.12, these reports can be easily exported to a web dashboard or downloaded as PDF documents, allowing the flexibility in sharing health information. The detailed and clearly organized medication report can save time for both the patient and the doctor, as it provides a snapshot of the patient's current health status. This will allow the doctor to make more informed decisions, adjust the medication plans promptly, and address the concerns of the patient.

2.4 Critical Analysis

This section will discuss the critical analysis of the mobile application, namely CogniFit [9], Replika [10], and MyTheraphy [11], which are reviewed in Section 2.3. It will focus on the three main features, which are cognitive tests for Alzheimer's disease prediction, companionship and assisting the elderly in daily life.

2.4.1 CogniFit

As referred to in Table 2.1, this application offers numerous cognitive assessments that allow the elderly users to test their cognitive performance. The performance will be visualized in a graph for easier understanding. Furthermore, users are able to know their cognitive performance more detailed in the generated report after completing the assessment. This report will show the severity of their cognitive profile, and through this profile, the user can use it as a reference whether they have Alzheimer's disease. Besides, it also offers detailed cognitive training to the users to improve their cognitive performance. Moreover, there are minigames related to cognitive in this application. Additionally, this application offers a variety of mindfulness meditation features to the user to relax their mind and release their stress. However, this application does not provide any assistance or companion for the elderly in their daily lives, while the majority of features of this application required a membership for full access, which required the user to pay for it.

Advantages	Disadvantages
- Wide variety of cognitive training and testing assessments. - Visualize of cognitive performance. - Alzheimer's prediction inside report. - Minigame as time killers - Meditation features to release stress and relax the mind.	- Does not provide any assistance to elderly in daily life. - Does not provide any companion to the elderly. - Required membership for full access of application

Table 2.1 Advantages and Disadvantages of CogniFit

2.4.2 Replika

As referred to in Table 2.2, this application has the AI chatbot, which allows the elderly users to interact with it as a companion. The users who are unable to type can interact with the chatbot via video or voice call. The chatbot has a memory system to improve the interaction with the user. Moreover, the notification regarding the willingness of Replika to interact with the user will pop out several times in a day to encourage the conversation between the user and the Replika. The drawback of this application is that it does not provide any cognitive tests for Alzheimer's disease prediction. Besides, this application does not provide any assistance for the elderly in their daily lives, while the majority of features of this application required a membership for full access, which required the user to pay for it.

Advantages	Disadvantages
- Allow to interact with chatbot as a companionship. - Video call/ voice call to ease the people having typing problems. - Memory system to improve interaction. - Notifications pop out to encourage the interactions.	- Does not have provided cognitive test for Alzheimer's disease prediction. - Does not provide any assistance to elderly in daily life. - Required membership for full access of application.

Table 2.2 Advantages and Disadvantages of Replika

2.4.3 MyTheraphy

As referred to in Table 2.3, this application has the advantage of allowing the users to setup for medication reminders. Users can customize their medication intake and frequency through this application. The alarm and notification will be triggered when it is time for the reminder. Besides, users are also able to track their health performance to know their current health status when using this application. Next, the users can generate their medication report, which will ease the visits for the doctor or share with their family members to take care of them. Users are able to access all the features of this application without purchasing a membership. However, this application does not provide any cognitive tests for Alzheimer's disease prediction and companion for the elderly.

Advantages	Disadvantages
- Notifications will pop out as medication reminders - Health Tracking System - Generate medication report - No membership required	- Does not have provided cognitive test for Alzheimer's disease prediction. - Does not provide any companion to the elderly.

Table 2.3 Advantages and Disadvantages of MyTheraphy

This Table 2.4 showed the availability of the three main features for the three applications analysed and the proposed application.

Application / **Feature**	**CogniFit**	**Replika**	**MyTheraphy**	**Proposed Application**
Alzheimer' disease Prediction	✓	χ	χ	✓
Companionship	χ	✓	χ	✓
Assistant in Daily Life	χ	χ	✓	✓

Table 2.4 Overall Performance for CogniFit, Replika, MyTheraphy, and Proposed Application

CHAPTER 3 SYSTEM DESIGN

3.1 Overview

This chapter will explain the flow for the proposed application. The system is illustrated through a series of diagrams such as system architecture diagram, use case diagram, and activity diagram. The use case description to outline how a task is performed by the users.

3.2 System Architecture

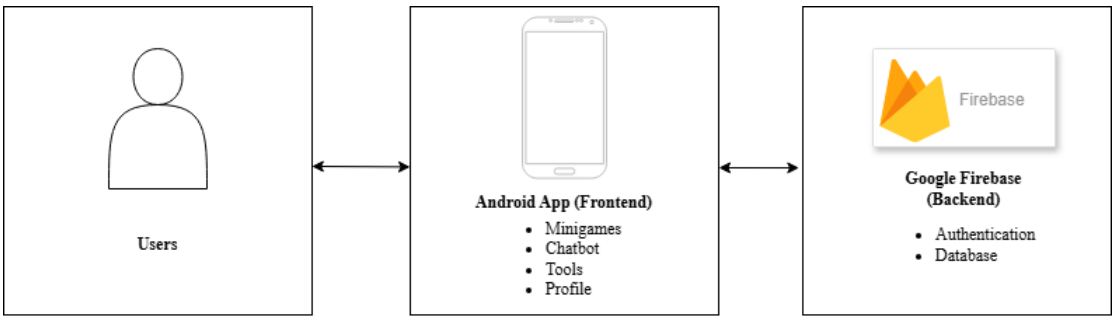

Figure 3.1 System Architecture Diagram of proposed mobile application

Figure 3.1 shows the system architecture diagram of the proposed mobile application. The Android Application is used as the frontend, which serves as the primary interface for users. It has the features such as cognitive assessment with minigames based, chatbot for companionship, tools for daily lives assistance, and a profile section for managing their data.

The Android application communicates with the Google Firebase which acts as the backend for our mobile application. It has the services such as Authentication and Database. Firebase Authentication is used for the user to register and login to the application meanwhile the Firebase Database is used to store the user data such as profile details and the scores of the minigames so the user able to keep track on it.

3.3 Use Case Diagram

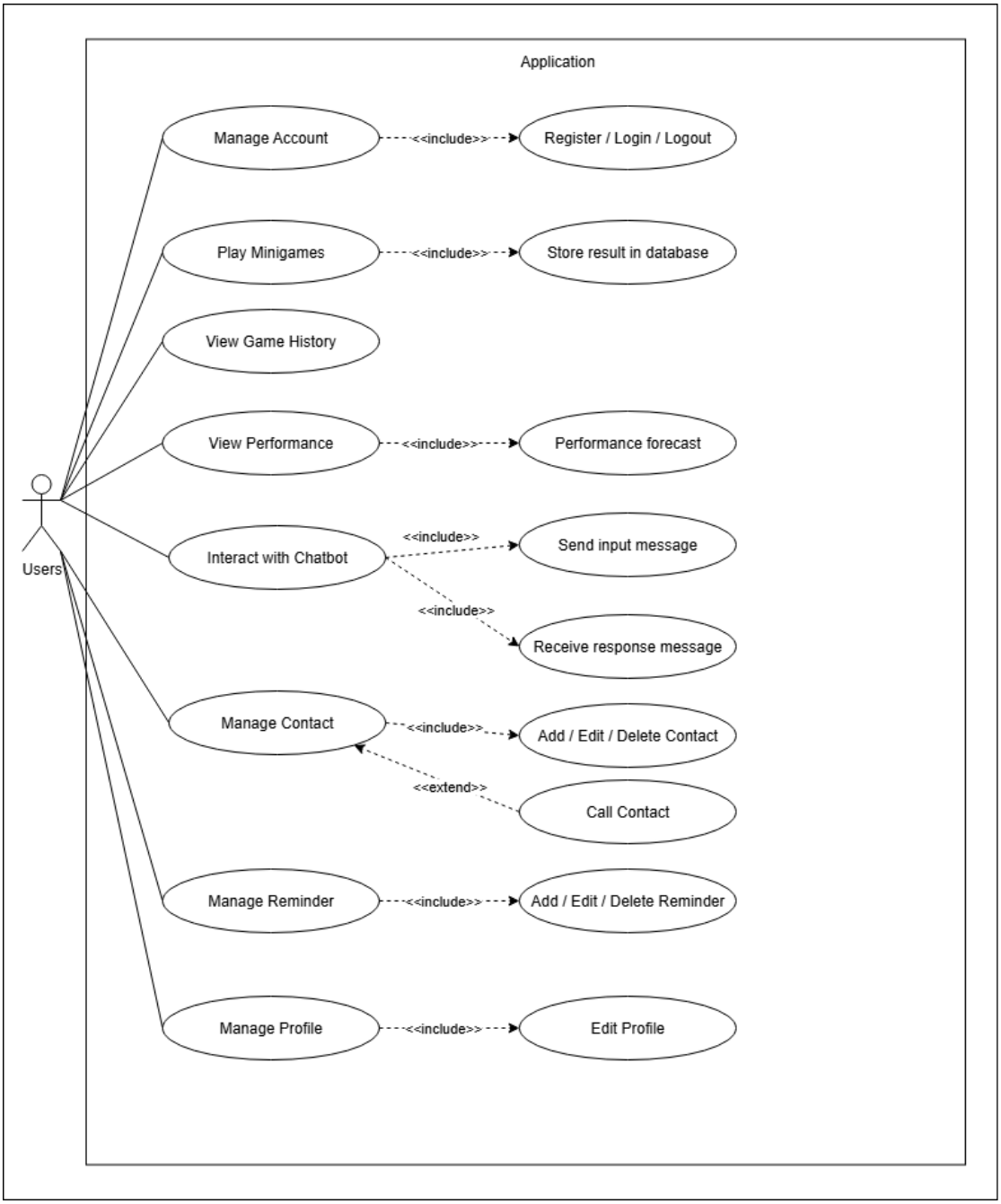

Figure 3.2 Use Case Diagram of proposed mobile application

3.4 Use Case Description

Use Case ID	UC0001	**Use Case Name**	Manage Account
Primary Actor	User		
Brief Description	This use case describes how a user manages their account, such as register a new account, login into the application and logout from the application.		
Trigger	The user selects the "Register," "Login," or "Logout" option in the application.		
Precondition	Login/logout: the user must have account first and verify email.		
Scenario Name	**Step**	**Action**	
Main Flow - (Login)	1	User proceeds to Login page.	
	2	User enters email and password.	
	3	System verifies the email and password.	
	4	System proceeds to main page if valid.	
Sub Flow - (Register)	1a.1	User selects “Register” in Login page.	
	1a.2	System displays the registration form.	
	1a.3	User fills in the required details.	
	1a.4	System validates the details and sends the verification email.	
	1a.5	System back to the Login page.	
Sub Flow - (Logout)	4a.1	User proceeds to the Profile page.	
	4a.2	User selects “Logout”	
	4a.3	System redirects the user back to the Login page.	
Exceptions	Step 3	If wrong email and password, system prompts a message ask user to fill in again.	
	Step 3	If user has not verified their email, system prompts a message ask user to verify their email first.	

Table 3.1 Use Case Description for “Manage Account” Use Case

Use Case ID	UC0002	**Use Case Name**	Play Minigames
Primary Actor	User		
Brief Description	This use case describes how a user starts the minigames in the application. The system stores the result in the database after completion of minigames.		
Trigger	The user selects to play minigames.		
Precondition	The user is logged in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Minigames page.	
	2	User selects “Start Game” in the page.	
	3	System launches unity games in the application.	
	4	User play the minigames.	
	5	System stores the result into database after the user finish the minigames.	
Sub Flow – (Exit Game)	4a.1	User selects “Exit” in when playing the minigames.	
	4a.2	System closes the games and back to Minigames page.	

Table 3.2 Use Case Description for “Play Minigames” Use Case

Use Case ID	UC0003	**Use Case Name**	View Game History
Primary Actor	User		
Brief Description	This use case describes how a user can view their game history.		
Trigger	The user selects the "Game History" in the Minigames Page.		
Precondition	The user is logged in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Minigames page.	
	2	User selects “Game History” in the page.	
	3	System retrieves the data from the database.	
	4	System displays a window showing the game history.	
Sub Flow - (Details for Game History)	4a.1	User selects any game session in the window.	
	4a.2	System displays the game details on that session.	

Table 3.3 Use Case Description for “View Game History” Use Case

Use Case ID	UC0004	**Use Case Name**	View Performance
Primary Actor	User		
Brief Description	This use case describes how a user track on their performance.		
Trigger	The user proceeds to the Minigames Page.		
Precondition	The user is logged in and played at least two sessions of minigames.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Minigames page.	
	2	System retrieves the data from the database.	
	3	System forecasts the user’ future performance with model.	
	4	System displays user current and future performance in graph.	

Table 3.4 Use Case Description for “View Performance” Use Case

Use Case ID	UC0005	**Use Case Name**	Interact with Chatbot
Primary Actor	User		
Brief Description	This use case describes how a user can have the interaction with the AI chatbot in the application. Through interaction, the user can reduce the feeling of loneliness.		
Trigger	The user proceeds to the Chatbot Page.		
Precondition	The user is logged in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Chatbot page.	
	2	User sends the input messages.	
	3	System processes the input message.	
	4	System generates and displays the chatbot's reply.	

Table 3.5 Use Case Description for "Interact with Chatbot" Use Case

Use Case ID	UC0006	**Use Case Name**	Manage Contact
Primary Actor	User		
Brief Description	This use case describes how a user manages their contact, such as add, edit and delete or even call the contact with the application.		
Trigger	The user selects the "Contact" in the Tools page.		
Precondition	The user is logged in. For Call Contact: user need to have at least one contact.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Tools page.	
	2	User selects "Contact" in the page.	
	3	User selects "Edit Contact" option.	
	4	User add, updates or deletes the contact.	
	5	System perform update in the database.	
Sub Flow – (Call Contact)	2a.1	User selects "Call Contact" in the page.	
	2a.2	User selects a person to call.	
	2a.3	System exits and proceeds to the contact in the mobile phone filled with the contact number selected.	

Table 3.6 Use Case Description for "Manage Contact" Use Case

Use Case ID	UC0007	**Use Case Name**	Manage Reminder
Primary Actor	User		
Brief Description	This use case describes how a user manages their reminder such as add, edit and delete the reminder with the application		
Trigger	The user selects the "Reminder" in the Tools page.		
Precondition	The user is logged in.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User proceeds to Tools page.	
	2	User selects “Reminder” in the page.	
	3	User add, updates or deletes the reminders.	
	4	System perform update in the database.	
Alternative Flow– (Send Reminder)	1	System sends the reminder to users when the time is reached.	
	2	User receives the reminder from the application.	
	3	System deletes the reminder data stored in database.	

Table 3.7 Use Case Description for “Manage Reminder” Use Case

Use Case ID	UC0008	**Use Case Name**	Manage Profile
Primary Actor	User		
Brief Description	This use case describes how a user manages their profile, editing on their profile and system performs update in database.		
Trigger	The user selects the "Edit “in the Profile page.		
Precondition	The user is logged in.		
Scenario Name	**Step**	**Action**	
Main Flow - (Login)	1	User proceeds to Profile page.	
	2	User selects “Edit” in the page.	
	3	User updates the details on their profiles.	
	4	System updates the profile data in the database.	

Table 3.8 Use Case Description for “Manage Profile” Use Case

3.3.3 Activity Diagram

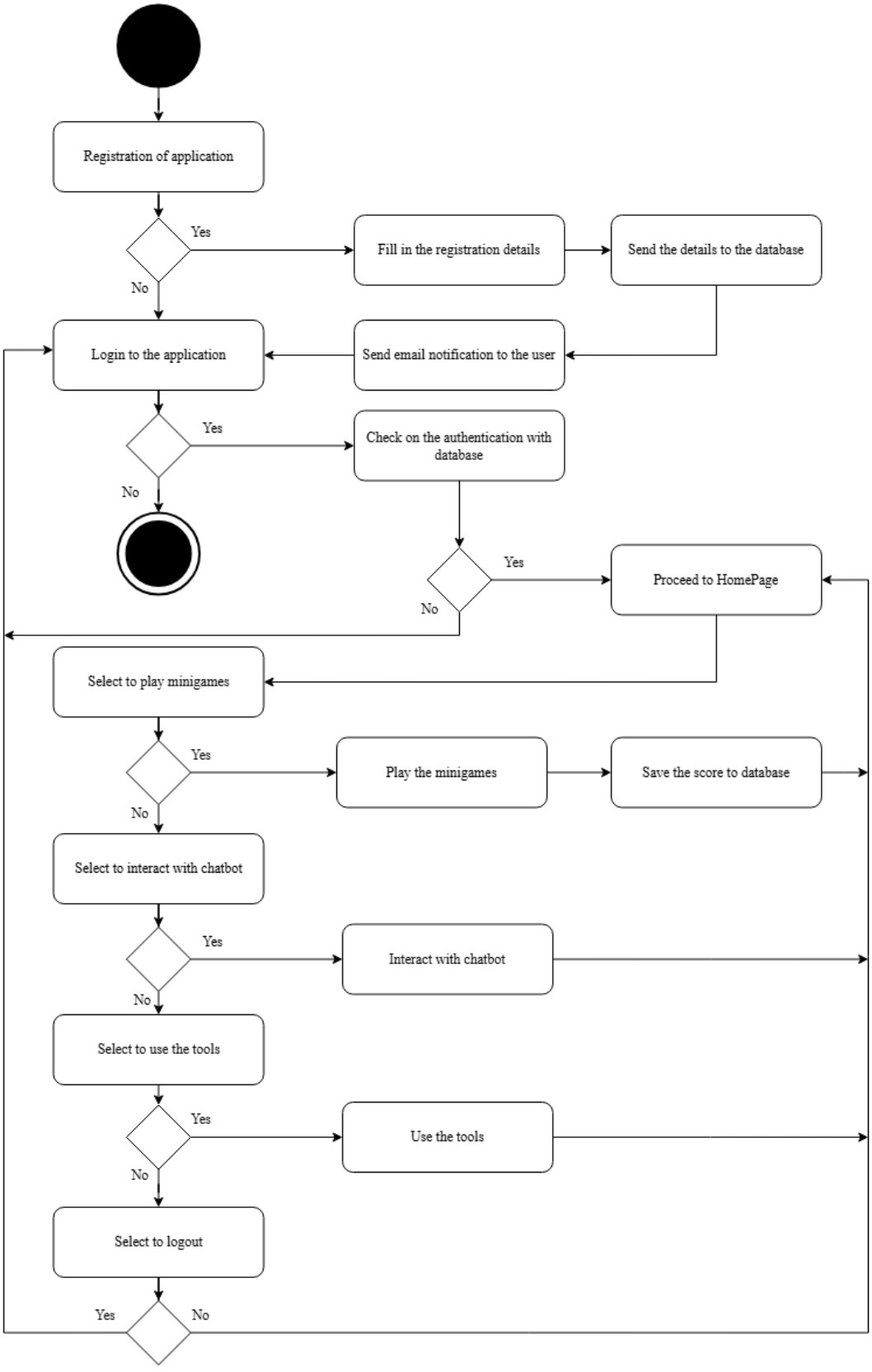

Figure 3.3 Activity Diagram of proposed mobile application

Figure 3.3 shows the activity diagram of the proposed mobile application. The user will need to register before they able to login to the application. The user needs to fill in their details in the registration page and their details will be sent to the Firebase Database. An email notification will be sent to the user after the registration. The user is then able to login to the system with their email and password after the registration. The system will check on the authentication of the user with the Firebase Database. It will only proceed to the Home Page of the application upon successful of the login else it will back to the login interface.

The user is allowed to select whether to play the minigames, interact with the chatbot, use the tools such as reminder or contact manager for daily lives assistance, and logout from the application on the profile page. The unity game will be launched from the application if the user selects to play the minigames. The score of the minigame will be saved to the Firebase Database after finish playing the minigames. The user can then view their performance in the minigames page and there will be a machine learning model analyse and forecast their future performance. The user can use respective features based on their choice on the interface. The user can also manage their profile on the profile page or choose to logout from the application. It will proceed to the login page if the users choose to logout from the application.

CHAPTER 4 SYSTEM METHODOLOGY/ APPROACH

4.1 Proposed Method/ Approach

Computer Aided Software Engineering (CASE) tools controlled and rigorous software development processes, and codified quality, assurance, analysis, and design approaches make up traditional software engineering. This was seen to be the best way to produce better software other than careful project planning. Apart from that, the focus of this software engineering approach was mostly on large-scale system development. However, applying the traditional waterfall method to small and medium-sized systems can introduce significant overhead, slowing down the software development process [13]. Therefore, the proposed application will be developed using agile methodologies. In agile methodology, program specification, design, and implementation are interrelated, guaranteeing that regular delivery of the latest versions for continuous evaluation [13].

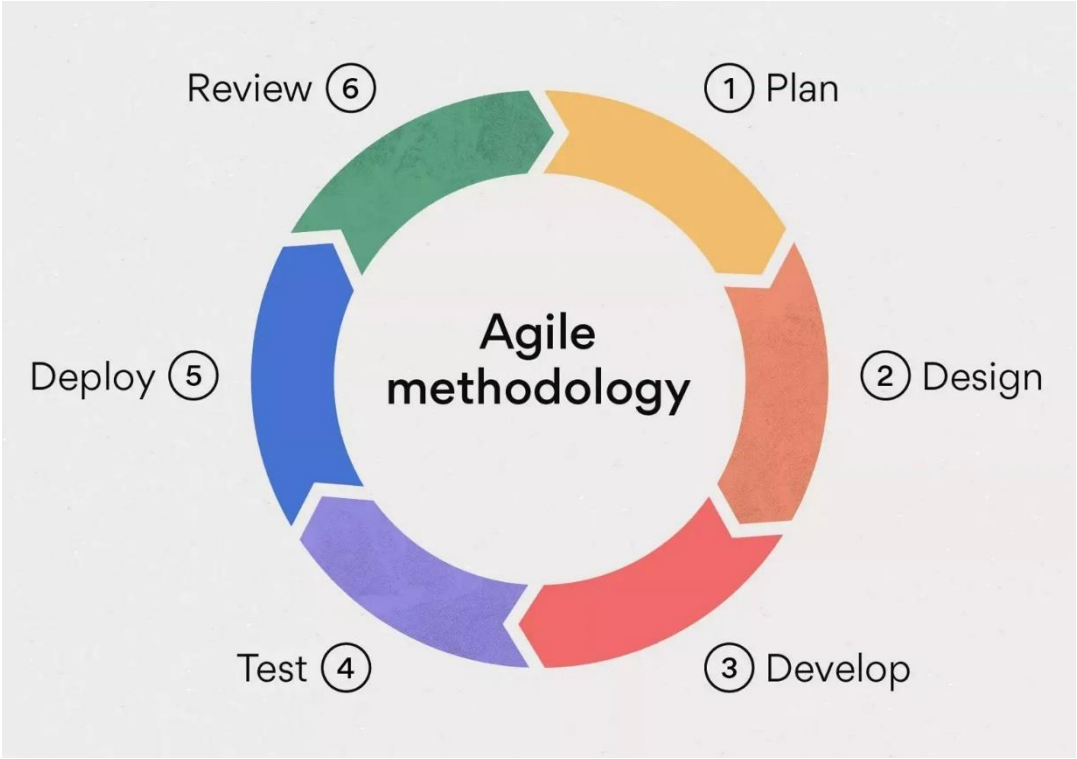

Figure 4.1 Agile Methodology in System Development [13]

The agile methodology is well-suited for the development of the proposed application due to its adaptability, early delivery, and flexible life cycle, as shown in Figure 4.1. Agile practices involve iterative cycles of development that allow for regular updates, user feedback, and adaptability to evolving requirements [14]. This approach is ideal for integrating both a

chatbot and a system that can evolve based on user interactions and feedback. Agile methodologies provide several benefits, such as improved communication, higher quality through frequent iterations, efficient risk management through early issue detection and resolution, and lower costs through continuous integration and testing.

The development process for the proposed application will be developed in smaller, more manageable modules that will include stages like analysis, design, implementation, and testing. Each phase will be supported by integrated documentation and quality assurance measures to maintain high standards throughout the development. Agile development's iterative process will make it possible to regularly prototype to test the chatbot, tools assisting daily lives, and minigame features to make sure they align with user expectations. As explained in [14], the agile Software Development Life Cycle (SDLC) prioritizes rapid delivery and flexibility by breaking down the project into smaller increments, each delivering a functional component. During the design phase, the sequence of features will be determined, then select the appropriate technologies and thus create initial prototypes. During the development phase, the proposed application will be delivered in iterative sprints, and real-time user feedback will be used to refine the minigame elements, chatbot interactions, and tools assisting daily lives. This approach ensures that the final product is both functional and user-friendly.

By leveraging agile methodologies, the development of the "Companion for Elderly: Chatbot and Mini-Games for Alzheimer's Prediction" application will be dynamic and responsive, ensuring that both the chatbot and minigame components are effectively integrated and optimized to support elderly users in managing and predicting Alzheimer's disease.

4.2 System Requirement

4.2.1 Hardware Requirements

The hardware involved in this project is laptop and android mobile device. The laptop is used for the development meanwhile the mobile device is used for testing.

Description	Specifications
Model	TUF Gaming F15 FX506LH_FX506LH
Processor	Intel(R) Core (TM) i5-10300H CPU @ 2.50GHz 2.50 GHz
Operating System	Windows 11 64-bit
Graphic	NVIDIA GeForce GTX 1650
Memory	16.0 GB RAM
Storage	1TB SSD

Table 4.1 Specifications of laptop

Description	Specifications
Model	M2101K7BG
CPU	Octa-core Max 2.05GHz
Operating System	Android 13.0.13; MIUI Global
Display Resolution	2400 * 1080 Pixels
Memory	8.0 GB RAM
Storage	128 GB

Table 4.2 Smartphone Specification

4.2.2 Software Requirements

Software	Explanation
Android Studio	A popular Integrated Development Environment (IDE) used for building Android applications. It offers various tools and plugins to facilitate coding, testing, and debugging mobile apps.
Android SDK	A collection of software development tools and libraries required for building, testing, and deploying Android applications. It includes emulators, debuggers, and an Application Programming Interface (API) to interact with Android system services.
Unity Engine	A cross-platform game engine developed by Unity Technologies. It supports a variety of desktops, mobile, console, augmented reality and virtual reality game development. It is popular for iOS and Android mobile game development.
Google Firebase	A Backend-as-a-Service (Baas) platform developed by Google and offer a variety of tools and services such as Authentication, Database, Cloud Function etc.

Table 4.3 Software Tools to Use

4.3 Timeline

4.3.1 Timeline of the FYP1

ID	Activity	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Planning for the games design														
2	Develop the minigames using Unity														
3	Develop the android application														
4	Set up the Google Firebase for Database on Unity Side														
5	Set up the Google Firebase for Authentication and Database on Android Side														
6	Integrate Unity Game into Android Application														
7	Enhancement of User Interface														
8	System Testing														
9	Report Writing														
10	Complete and submit the final report														
11	Presentation														

Figure 4.2 Timeline of the FYP1

The first activity planned in the FYP1 timeline is to plan for game design using Unity. After that, the development of the minigames started using Unity Engine. Meanwhile, the basic function of android application such as simple interface, and navigation to each interface are developed using Android Studio. The next activity is to set up the Google Firebase for the Database on the Unity side. After completing on the Unity side, the Google Firebase for Authentication and Database is set up on the Android side. After both Google Firebase are set up, the unity game is integrated into the android application. Next, the simple enhancement of the user interface is done on the minigames and android application. Later, the system is exported to a mobile device and has a testing on it. Then, the report writing is proceeded and submitted on Week 12. Finally, the proposed mobile application's presentation and demonstration are conducted on Week 13.

4.3.2 Timeline of the FYP2

ID	Activity	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Develop the model to predict alzheimer diseases														
2	Develop the chatbot feature														
3	Develop the tools to assist in daily lives														
4	Enhancement of User Interface														
5	Enhancement of Application performance														
5	Finalize all the features in the application														
6	System Testing														
7	Deployment of the application														
8	Report Writing														
9	Complete and submit the final report														
10	Presentation														

Figure 4.3 Timeline of the FYP2

The main tasks to be completed in the starting timeline of FYP2 include the development of remaining features such as model for Alzheimer disease prediction, chatbot feature, tools to assist in daily lives. After completing the development, the enhancement of user interface and application performance is conducted. Then, all the features are finalized in the application and proceed to the system testing. If there is no problem with the application, the deployment of the application will be conducted and continue with the report writing. Lastly, the report will be submitted in Week 12 and the FYP2 presentation and demonstration will be conducted in Week 14.

CHAPTER 5 SYSTEM IMPLEMENTATION

5.1 Developing Minigames with Unity

Unity Game Engine with version (2022.3.59f1) together with the required installation such as Android support is used to develop minigame based cognitive assessment. There are 5 different types of minigames developed which are Orientation, Memory, Attention, Language, Visual and Spatial Game which same as the MMSE cognitive function assessment.

5.1.1 Orientation Game

The first game developed is Orientation Game. This game consists of 10 questions related to the Orientation to Time and Place. One point will be allocated for each correct answer. According to Figure 5.1, the game will start by showing the instruction of the game which require the user to choose the correct answer. After the "Start Game" button is clicked, the game will start by selecting 10 questions from the question bank, asking the user to answer and given 3 choices for each question.

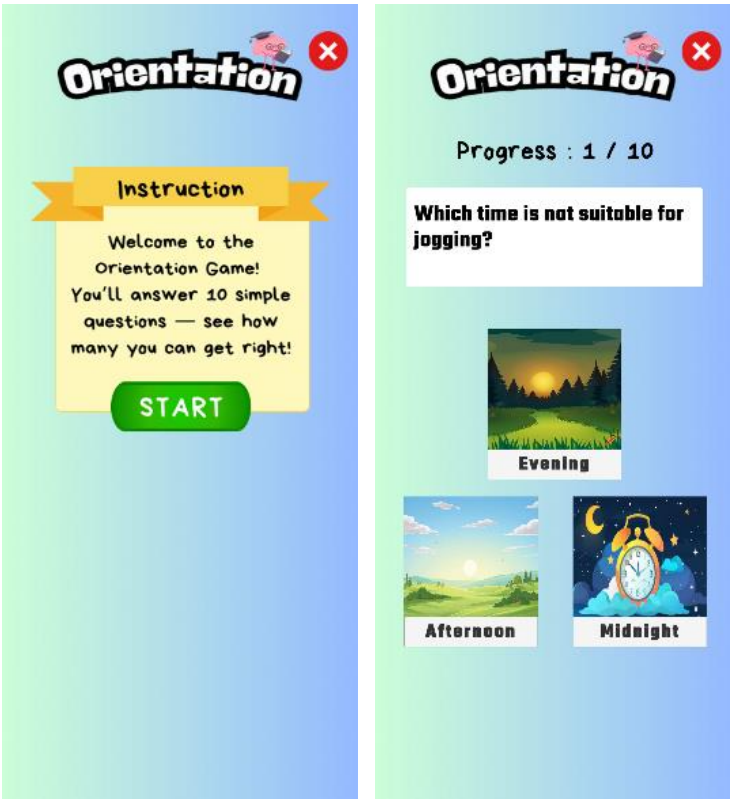

Figure 5.1 Screenshots of Orientation Game (1)

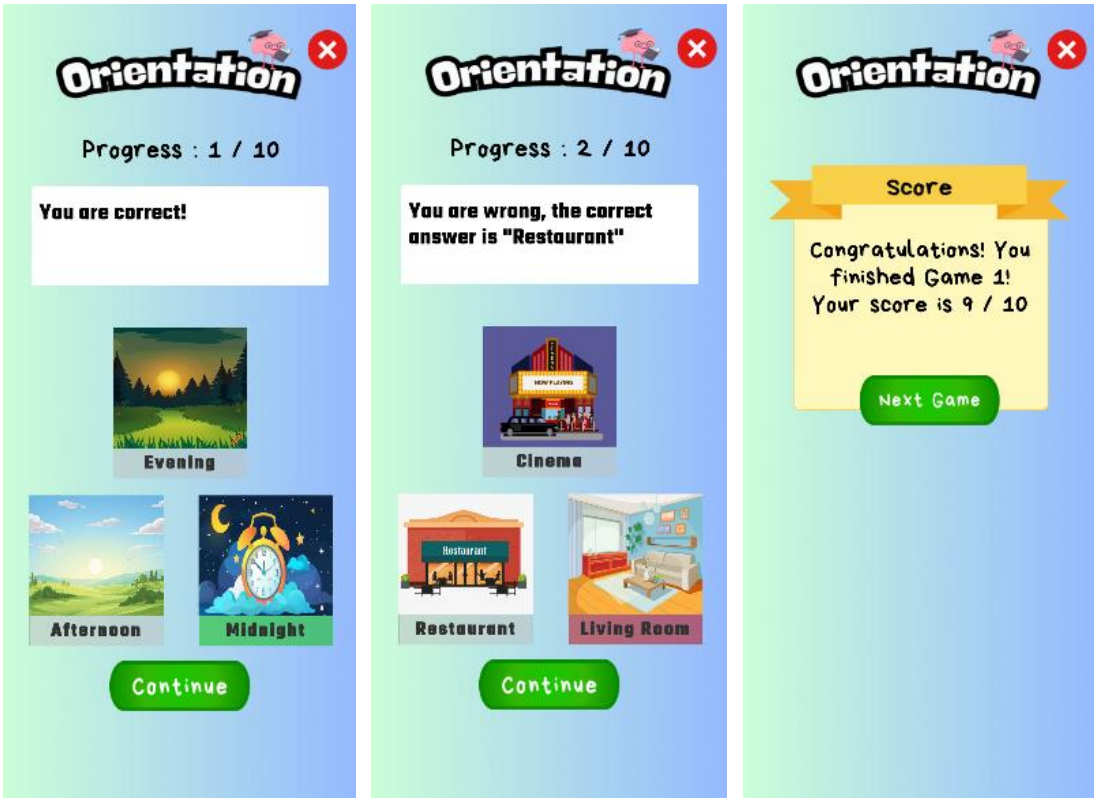

Figure 5.2 Screenshots of Orientation Game (2)

Referring to Figure 5.2, the correct choice will display green, and the score will be allocated if the user chooses the correct answer else it will display red colour on the options user selected and revealing the correct answer if the user chooses the wrong option. Lastly, after completed all the 10 questions, the total scores will be displayed and user able to proceed to the next game after they clicked “Next Game” button.

5.1.2 Memory Game

The second game developed is Memory Game. According to Figure 5.3, the game will start by showing the instruction of the game which require the user to memorize the sequence the animal enlarge and tap them according to the sequence. After the “Start Game” button is clicked, the game will start by enlarging the animal step by step. The number of animals enlarge will increased each time for a level based on levels and there got a total 6 levels in this game.

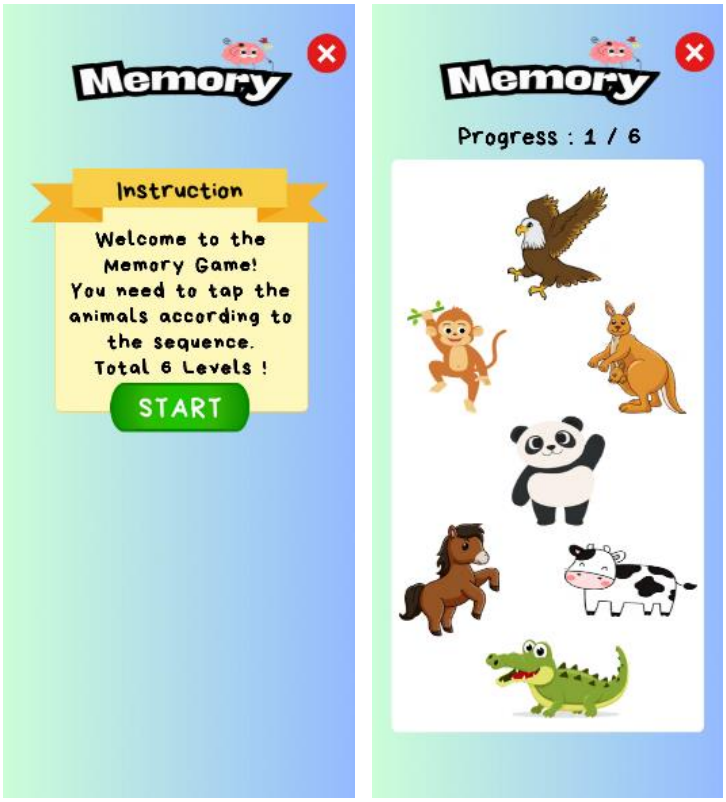

Figure 5.3 Screenshots of Memory Game (1)

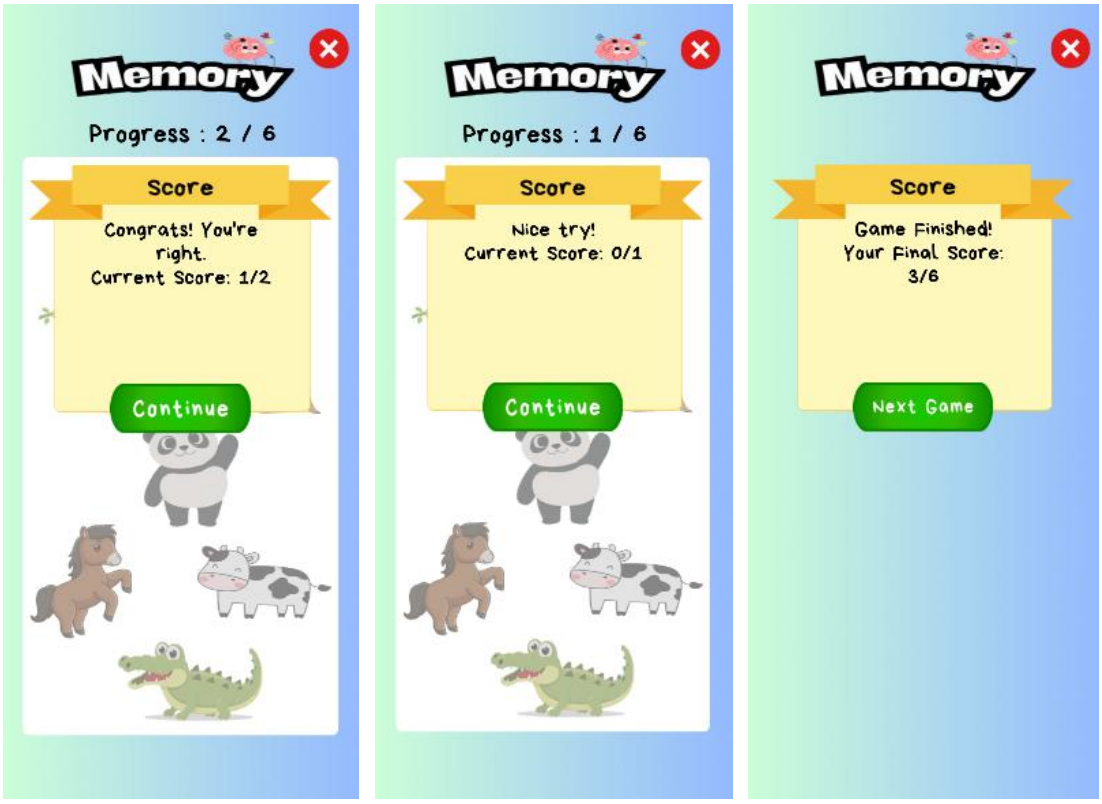

Figure 5.4 Screenshots of Memory Game (2)

Figure 5.4 showed the scoreboard of both situations which the user taps on the correct sequence and the wrong sequence. Lastly, after completed all the 6 levels, the total scores will be displayed and user able to proceed to the next game after they clicked “Next Game” button.

5.1.3 Attention Game

The third game is Attention Game. According to Figure 5.5, the game will start by showing the instruction of the game which require the user to select the cup that contains the coin after the cup swapping. After the “Start Game” button is clicked, the game will start by revealing the cup that has the coin and swapping between them. There are a total 5 different levels on the game, and the speed and times of cup swapping will be increased by level.

Figure 5.5 Screenshots of Attention Game (1)

Figure 5.6 Screenshots of Attention Game (2)

Figure 5.6 showed the scoreboard of both situations which the user chooses the correct and the wrong cup. Lastly, after completed all the 5 levels, the total scores will be displayed and user able to proceed to the next game after they clicked “Next Game” button.

5.1.4 Language Game

The fourth game developed is Language Game. According to Figure 5.7, the game will start by showing the instruction of the game which require the user to select the correct object based on the audio or images with total 6 stages. After the “Start Game” button is clicked, the game will start from the audio part then will only proceed to the image part. The user can replay the audio by clicking on the audio image.

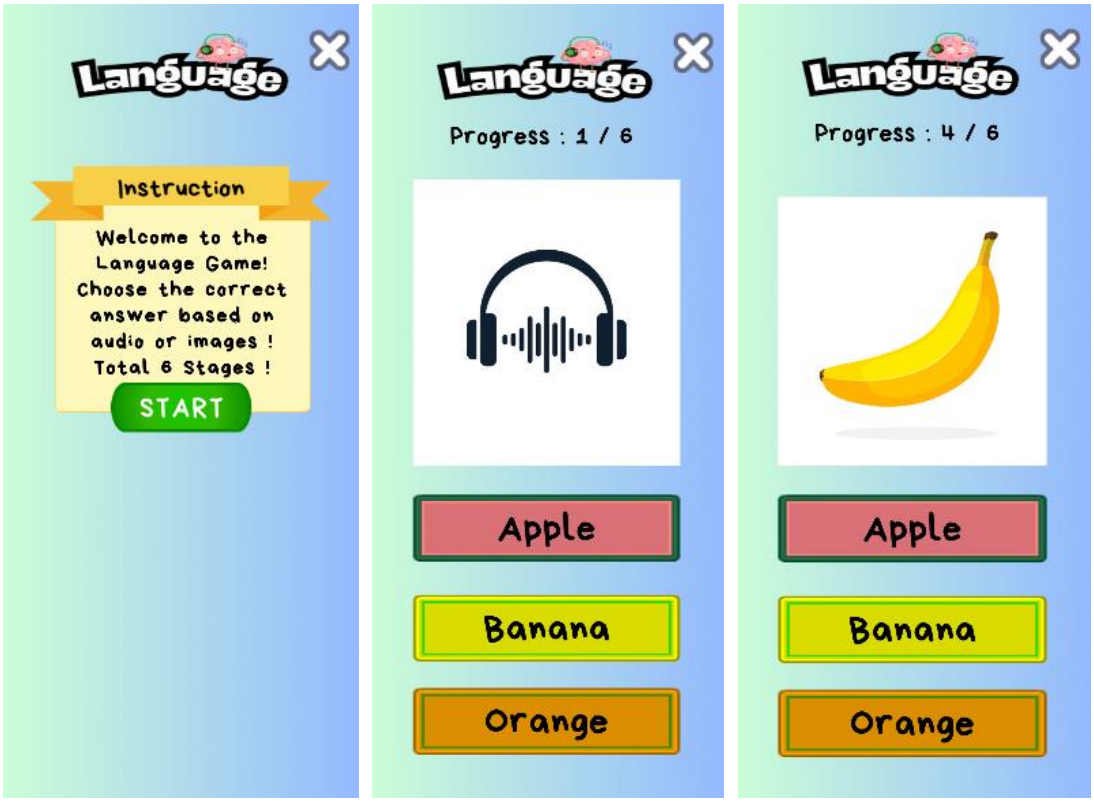

Figure 5.7 Screenshots of Language Game (1)

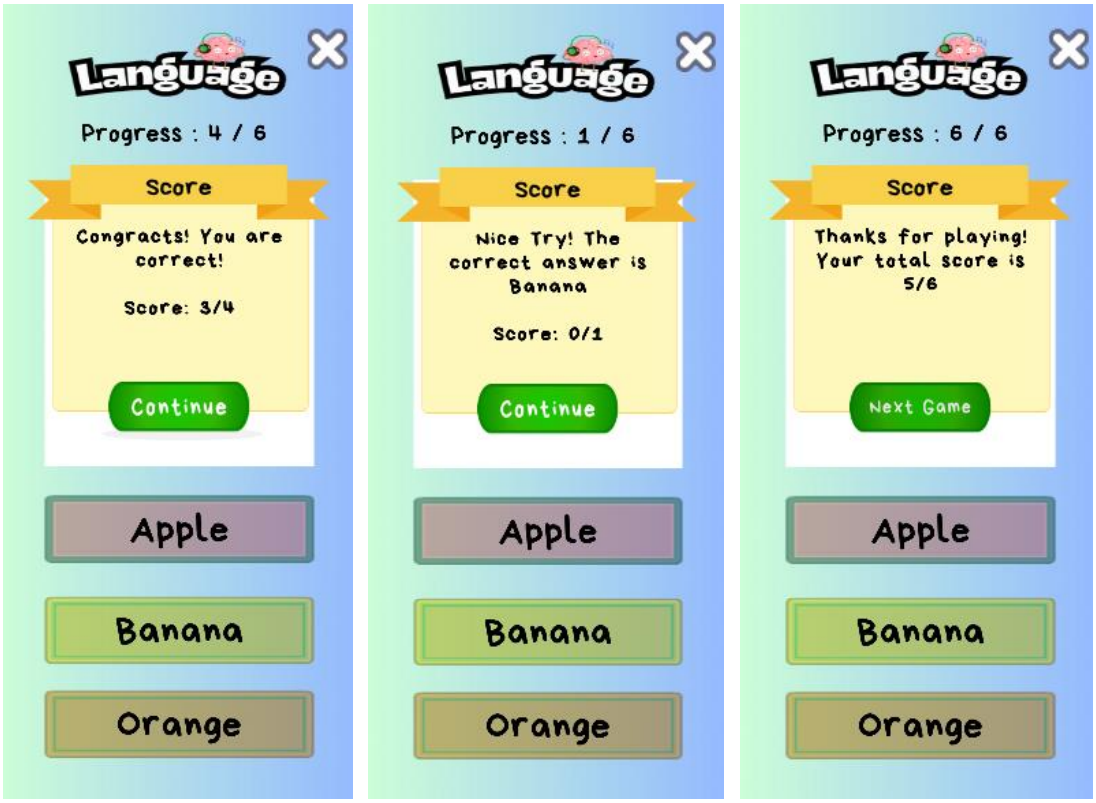

Figure 5.8 Screenshots of Language Game (2)

Figure 5.8 showed the scoreboard of both situations which the user chooses the correct and the wrong option. Lastly, after completed all the 6 stages, the total scores will be displayed and user able to proceed to the next game after they clicked “Next Game” button.

5.1.5 Visual and Spatial Game

The last game developed is Visual and Spatial Game. According to Figure 5.9, the game will start by showing the instruction of the game which require the user to copy and draw the shape showed. After the “Start Game” button is clicked, the game will start by showing the shape to copy at upper side. There is total 3 different stages on this game. The shape drawn by the user is determined by the pre-trained shape detection model which can detect the shape of Triangle, Square and Circle with very high accuracy. The model is based on InceptionV3, a deep convolutional neural network that has been trained on a dataset of hand-drawn geometric figures. The user can click on “Clear” button to clear the drawing and click “submit” to submit the drawing.

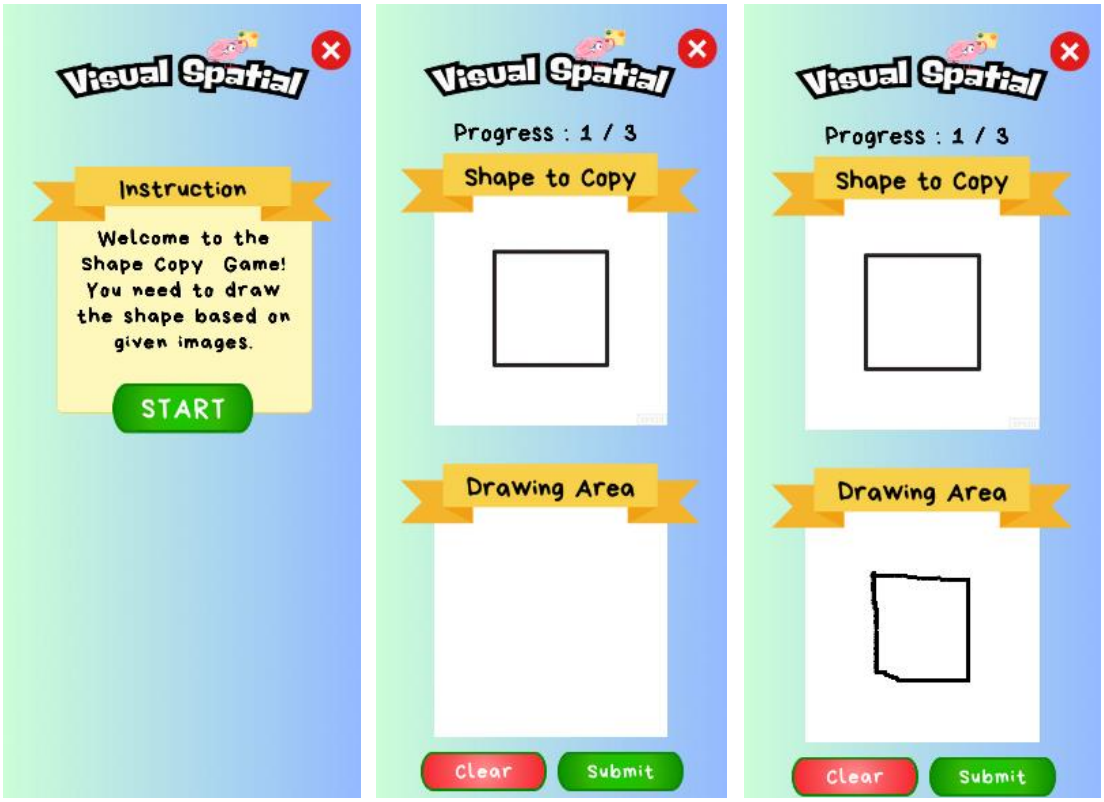

Figure 5.9 Screenshots of Visual and Spatial Game (1)

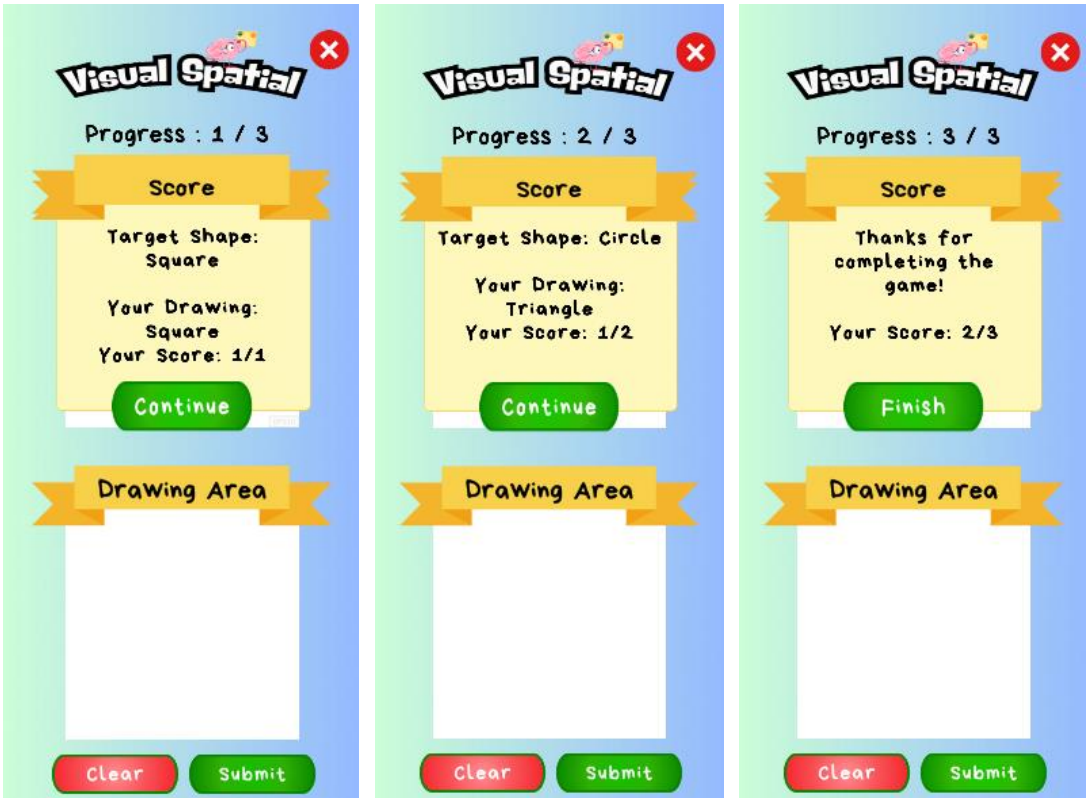

Figure 5.10 Screenshots of Visual and Spatial Game (2)

Figure 5.10 showed the scoreboard of both situations which the user draws the correct and the wrong shape. Lastly, after completed all the 3 stages, a thank you message will pop out and the total score will be displayed. The user can proceed after clicking the “Finish” button.

5.1.6 Store the score to Database

Firebase Realtime Database is used to store the user score on the database. The summary score panel will be displayed after the user completed all the games. The user can store their game performance to the database by clicking on the “Save Score” button. This button will trigger the function to pass the score for each game to the database and saved accordingly to the userID. Figure 5.12 showed that the game score of the user for each category is stored into the database.

Figure 5.11 Screenshot of Summary Score

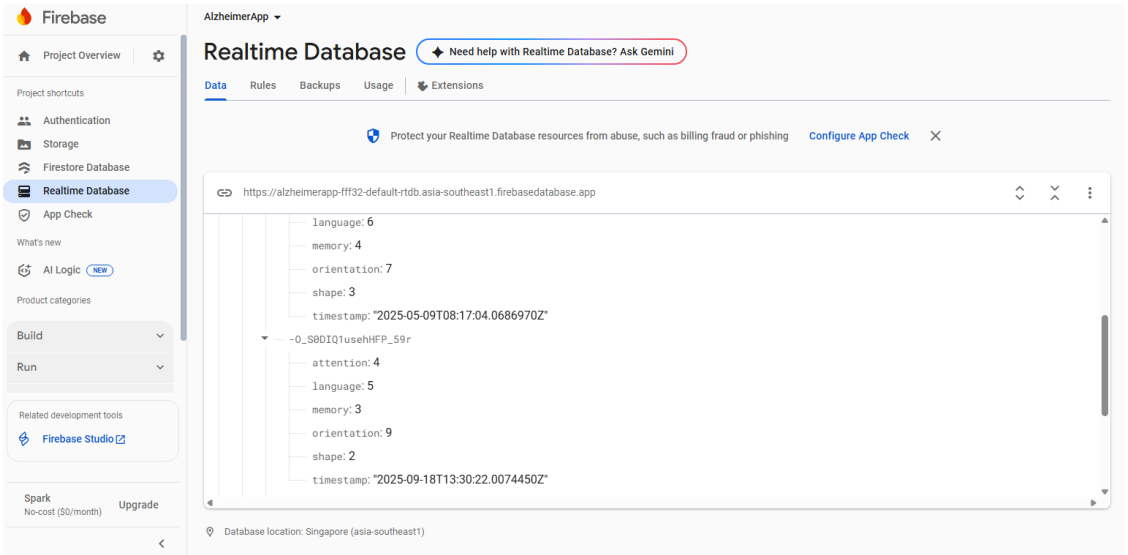

Figure 5.12 Score Collection in Firebase Realtime Database

5.2 Developing Android Application

The proposed mobile application is developed with Android Studio with programming language JavaScript.

5.2.1 Authentication and Registration

The Firebase Authentication and Firebase Realtime Database is used for the user to login, register and store their profile information.

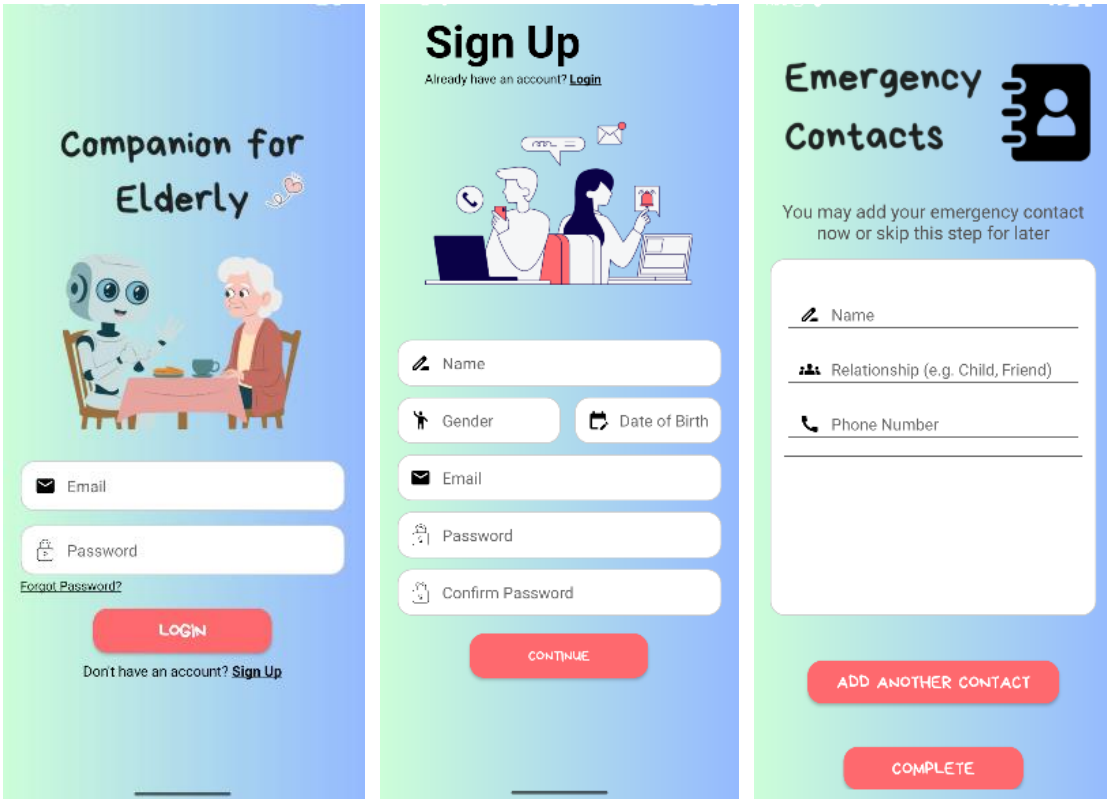

Figure 5.13 Login and Registration User Interface

The user needs to have an account first before they able to login to the application as illustrated in Figure 5.13. There is a “Sign Up” text hyperlink which enables user to proceed to the registration page when user click on it. The user can register an account by filling up their details such as name, gender, date of birth, email and password. Then the system will proceed to the emergency contact page where the user can choose to add the contact information into the system.

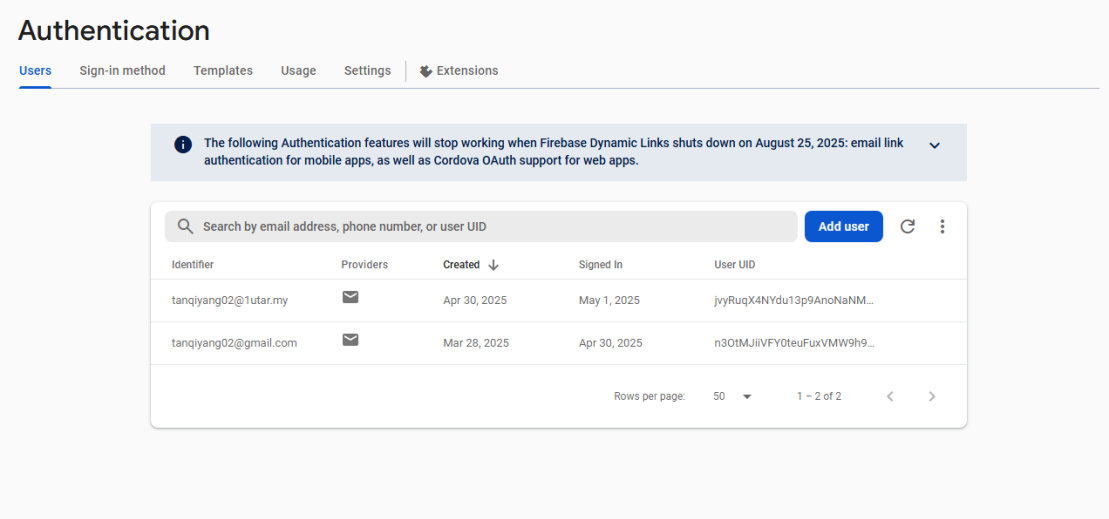

Figure 5.14 Firebase Authentication for users

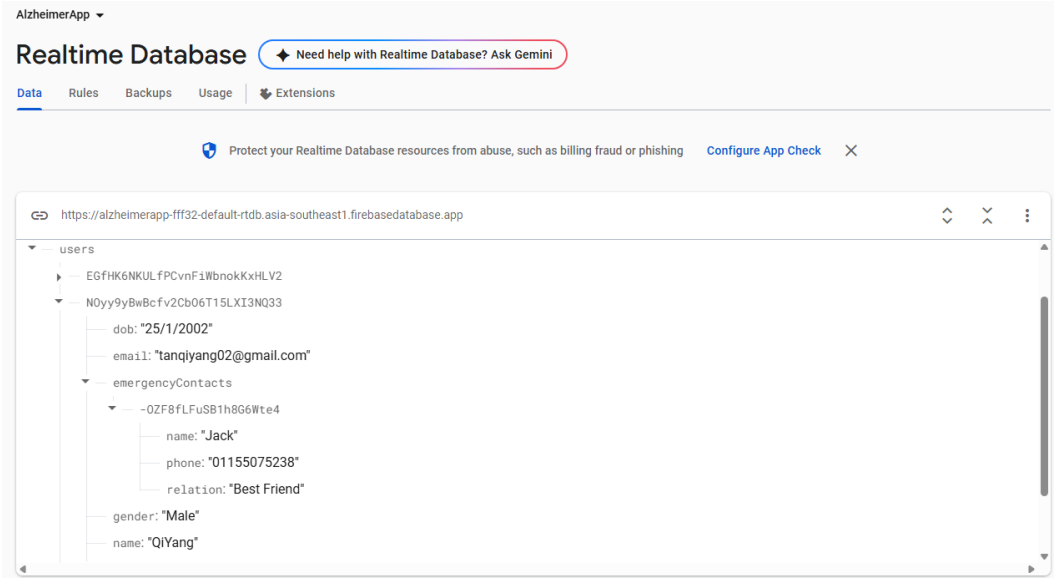

Figure 5.15 Firebase Realtime Database for user information

The user personal information and such as name, id, email and etc which used for the login feature and profile management will be sent to the Firebase Authentication and Firebase Realtime Database after the successful of registration. The Figure 5.14 and Figure 5.15 showed that the user information had been sent to the Firebase Authentication and Realtime Database.

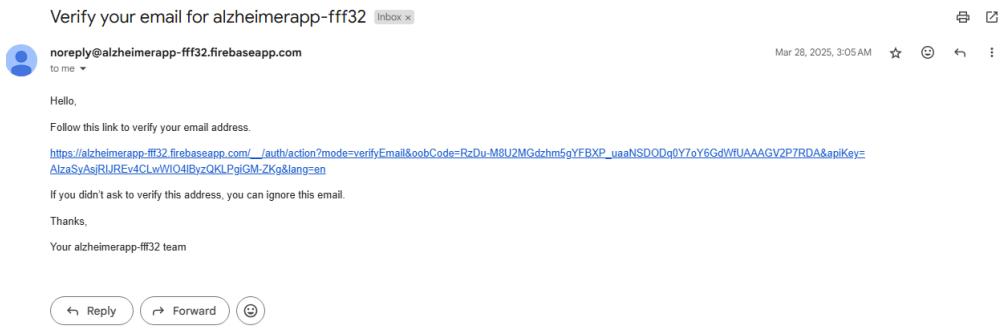

Figure 5.16 Verification Email

An email will be sent to the user email after the user is registered as shown in Figure 5.16 above. The user had to verify their account before they login to the application. The user can click on the hyperlink on the email to verify their email address. Once verified, the user can login to the application using their email and the password they registered for.

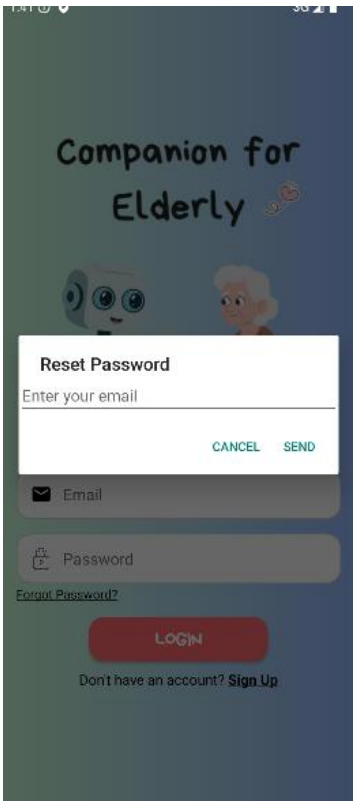

Figure 5.17 Reset Password

The user can reset their password by clicking on the “Forgot Password?” on the Login interface as shown in Figure 5.17 above, and the user are able to reset their password by filling their email address.

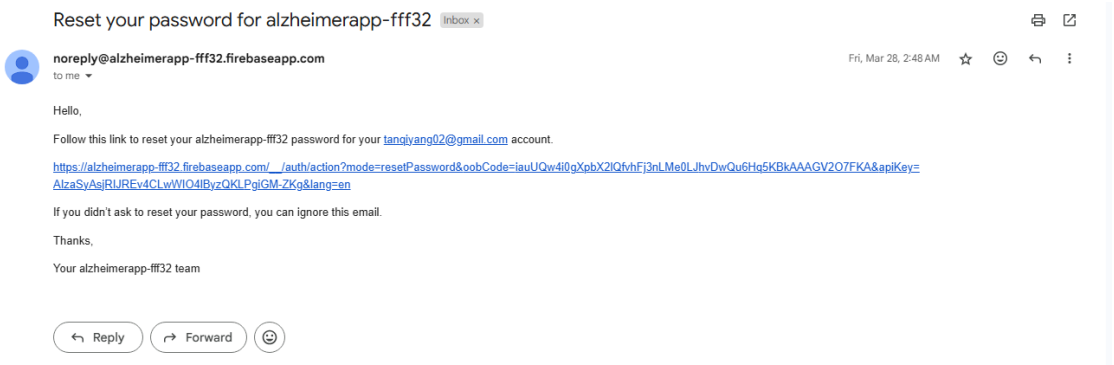

Figure 5.18 Reset Password Email

An email will be sent to the user email if the user requested to reset their password as shown in Figure 5.18 above. The user can reset their password by clicking on the hyperlink inside the email and then they able to login to the application with the new password they set for just now.

5.2.2 Navigation to Different User Interface

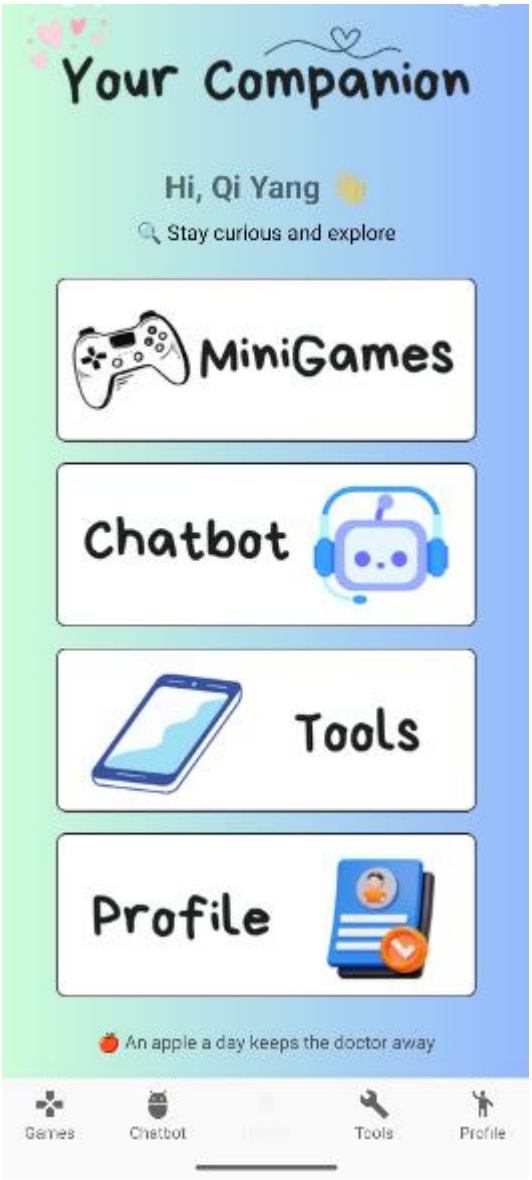

Figure 5.19 Main Page of the application

The user will proceed to the Main Page as illustrated in Figure 5.19 after successful login and able to proceed to different features by clicking on the button on the main page or the button at the bottom navigation bar.

5.2.3 Minigames Feature

A Minigames Page is developed in this application. This page includes several key functions such as viewing the game history, reviewing past performance with a forecasting model – polynomial regression model to predict future outcomes, and a reminder to notify users if they have not played the game yet. The interface of the Minigames Page is shown in Figure 5.20 below.

Figure 5.20 Minigame Page of the application

The system will check on the database to verify whether the user has played the game every day. If the user has not played the game, the application will automatically send a notification to remind them to play the game, as shown in the figure 5.21 below.

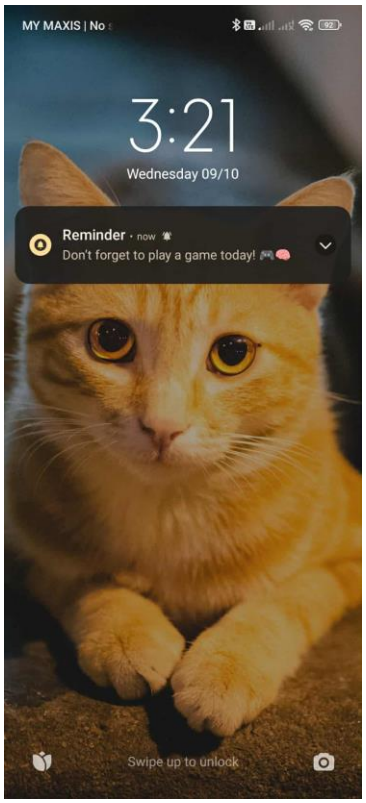

Figure 5.21 Reminder Notification to play minigames

Lastly, there is a chart developed in this minigames page to show the performance of user playing the minigames, as shown in Figure 5.22 below where the blue line represents the actual results from the games, while the grey dashed line represents the forecasted performance. The users are required to play at least two games to unlock the forecasting function to ensure the meaningful prediction. The forecasting model used in this system is polynomial regression model. The further explanations on forecasting are given in Chapter 6.

This forecasting feature can serve as the reference for detecting potential cognitive impairment. If users observe that both of their actual and forecasted performance are consistently decreasing, they may seek for the help from professional consultation for early diagnosis of conditions such as Alzheimer's disease. Besides, there is a comment section at the bottom part of the page. These comments will be difference based on the user performance.

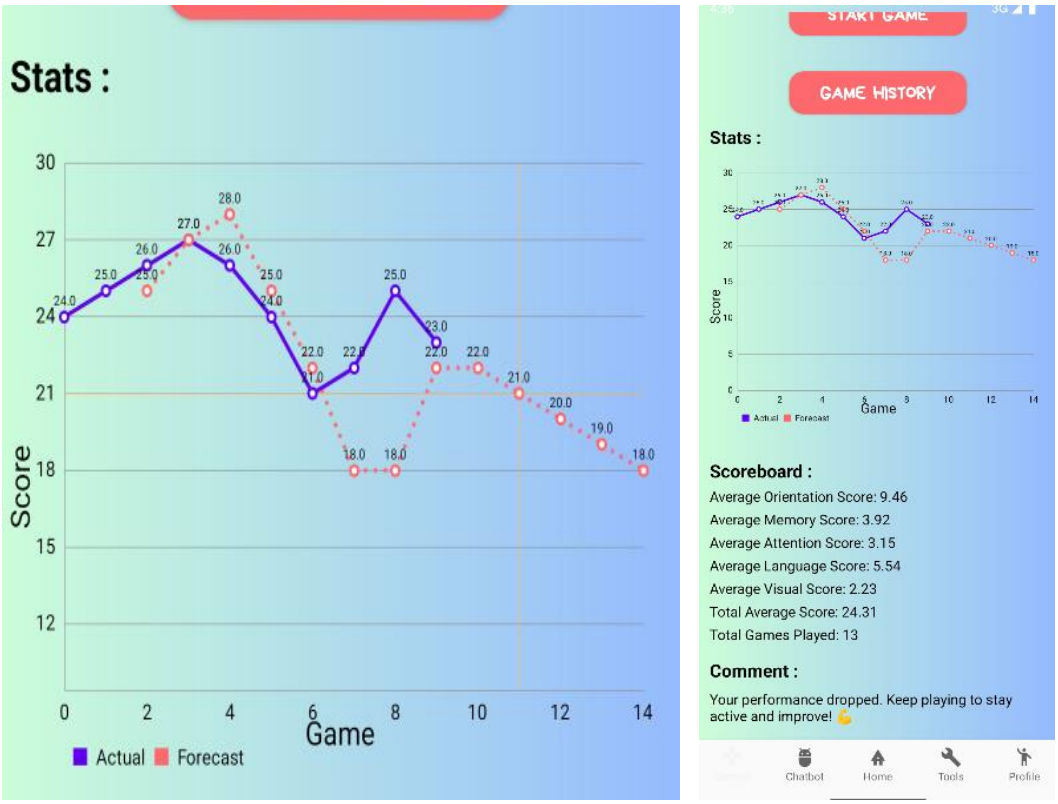

Figure 5.22 User's Minigames Performance

5.2.4 Integrating the Chatbot – Mistral AI

The chatbot feature is one of the key features of this application, with the purpose to provide companionship to the elderly users to reduce the feeling of loneliness through the communication with the chatbot.

The chatbot is developed using Mistral Small 3.2 (24B), a free and updated 24B parameter model from Mistral. An API key with unlimited token is created in the OpenRouter platform as shown in Figure 5.23 below. Then this API key is integrated into the application which configured within the backend. This API secure the communication between the application and the Mistral AI model.

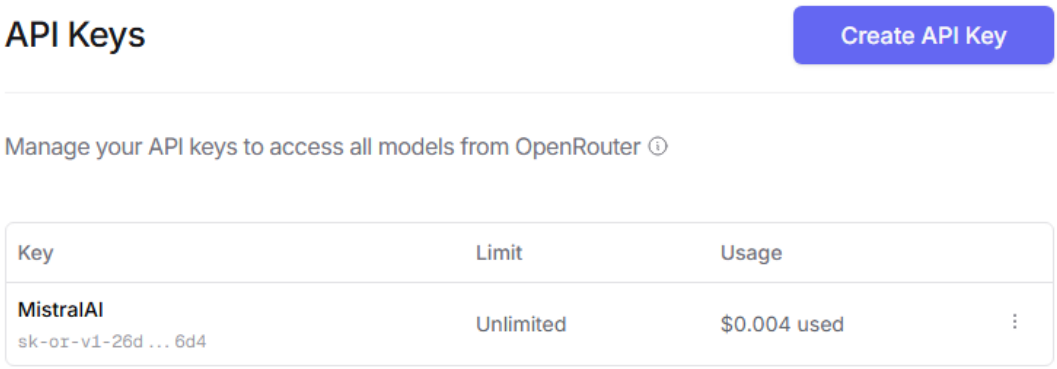

Figure 5.23 API Keys for Mistral AI in OpenRouter

There is a chatbot page developed in this application which allowed the users to have the interaction with the chatbot through texting. Every query is sent to the Mistral AI model through the API with the parameters such as message, temperature (0.2), and maximum tokens (200). These configurations ensure that the chatbot provides shorter and controlled response that suitable for the elderly users. The chatbot page is designed with the Android Studio where the users can send and receive the messages as shown in the Figure 5.24 below. By integrating this Mistral AI chatbot, the system can provide the companionship and emotional support for those elderly people who are living alone.

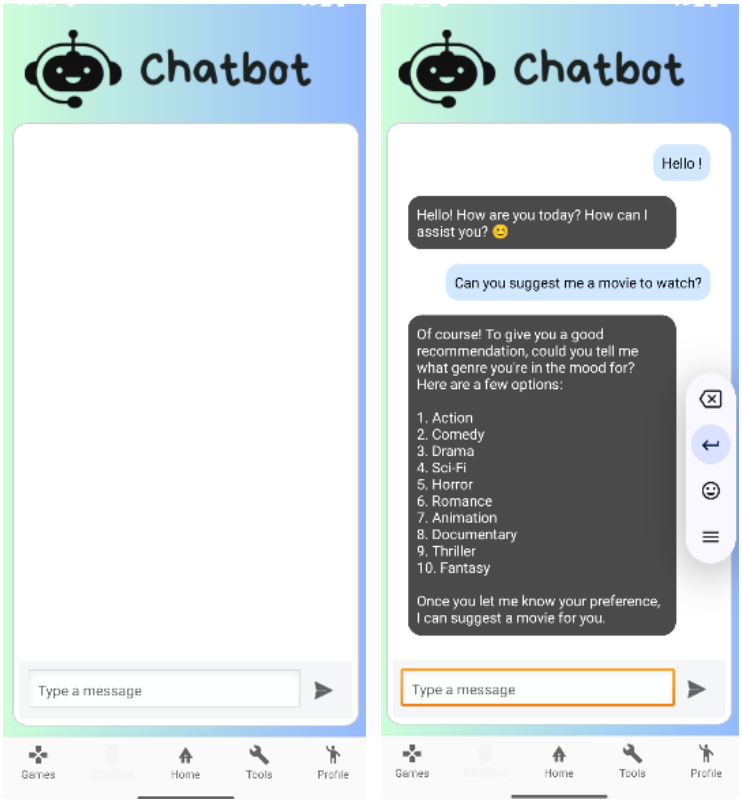

Figure 5.24 Demonstration of Chatbot Feature

5.2.5 Tools Feature Implementation

A Tools Page is developed in this application, providing two utility tools: Contact Management and Reminder Management. Users can access either tool by clicking the corresponding button, as illustrated in Figure 5.25 below.

Figure 5.25 Tools Page of the application

For the Contact Management tool, users can choose either “Call Contact” or “Edit Contact” after pressing the Contact button. In the edit option, users are able to add, update, or delete contact information within the application, and the system will automatically update the changes in the database. If the user selects the “Call Contact” option, the system will redirect to the device’s phone dialer with the selected contact’s number pre-filled, as shown in Figure 5.26 below.

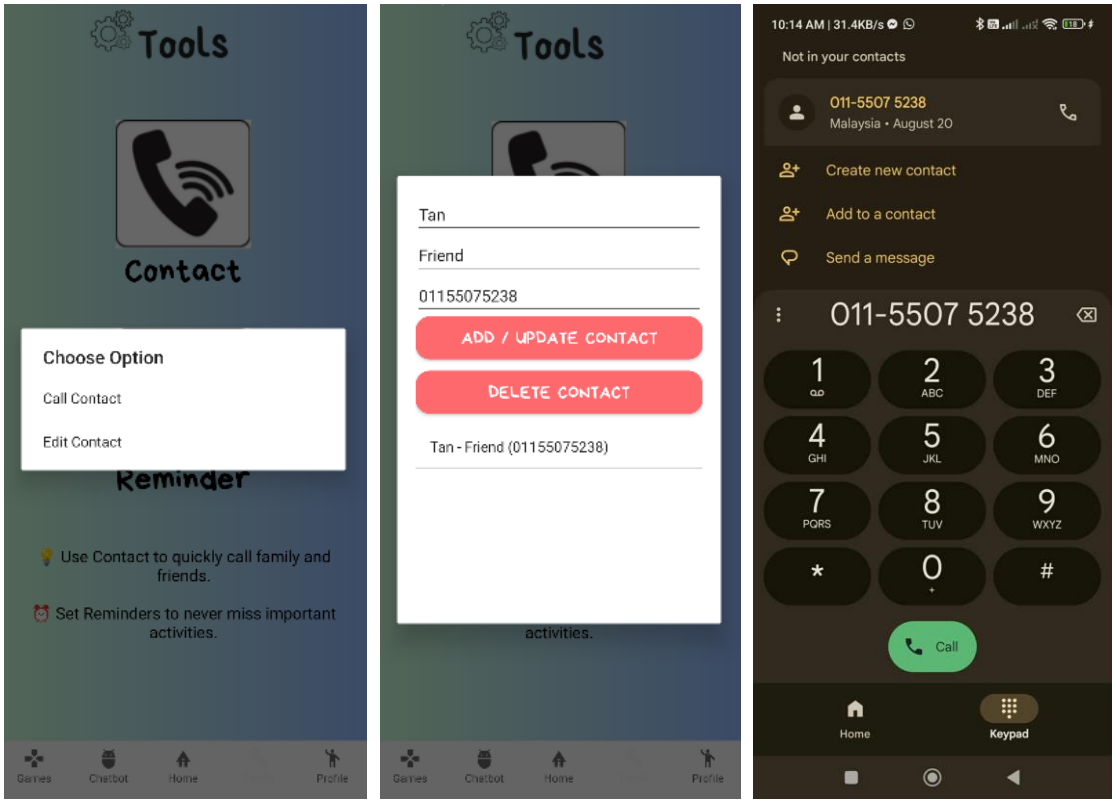

Figure 5.26 Screenshots of Contact Management Feature

For the Reminder Management tool, users can add, edit, or delete reminders according to their needs. The system will update these changes in the database accordingly. When the reminder time is reached, the system will trigger a notification to alert the user about the scheduled task, as shown in Figure 5.27 below. After the reminder is completed, the system will automatically remove it from the database.

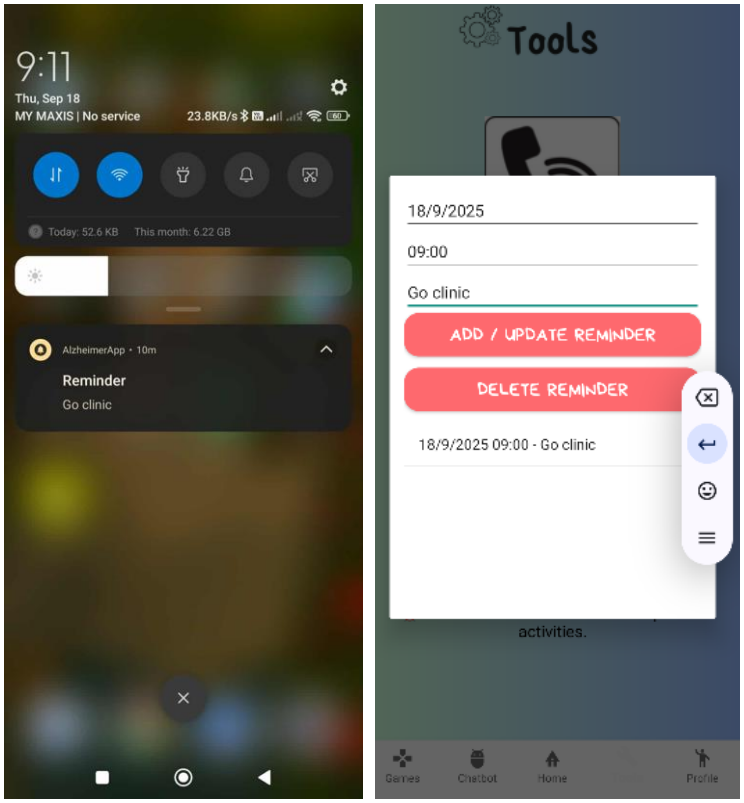

Figure 5.27 Screenshots of Reminder Management Feature

5.2.6 Profile Page Implementation

There is a profile page developed in this application as shown in Figure 5.28 below. The design of this page allows the users to view and edit their personal details in a structured layout.

Users are provided with an edit button. When it is clicked, the users can update their personal information such as name, email, gender, and so on. Once the modifications are saved, the updated information will be stored in the Realtime Database. The system will then retrieve the latest data and display it on the profile page. Besides, there is also a logout button in the profile page, which allows the users to logout from the application.

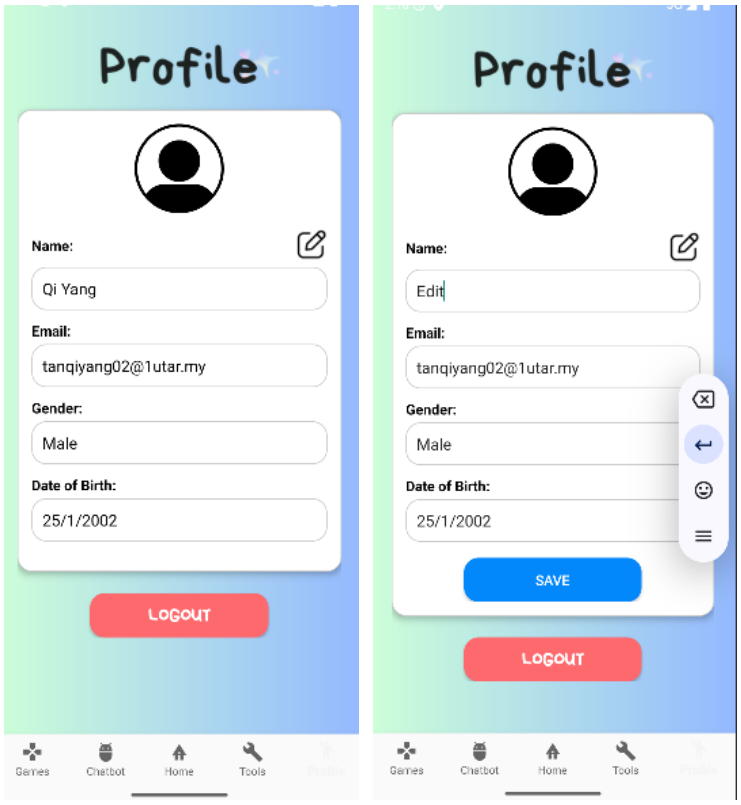

Figure 5.28 Profile Page of the application

5.3 Integration of Unity Game and Android Application

The unity game is exported as a folder instead of an application to integrate with the Android Application. The game is then exported as a folder called unityLibrary and placed inside the folder together with our Android Application as shown in Figure 5.29 below. Then, the Android Studio will automatically sync the gradle file.

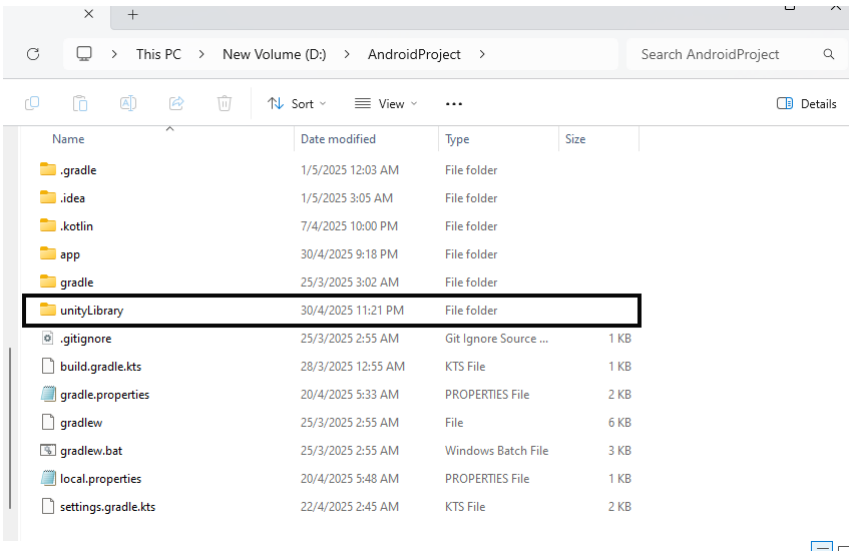

Figure 5.29 unityLibrary folder

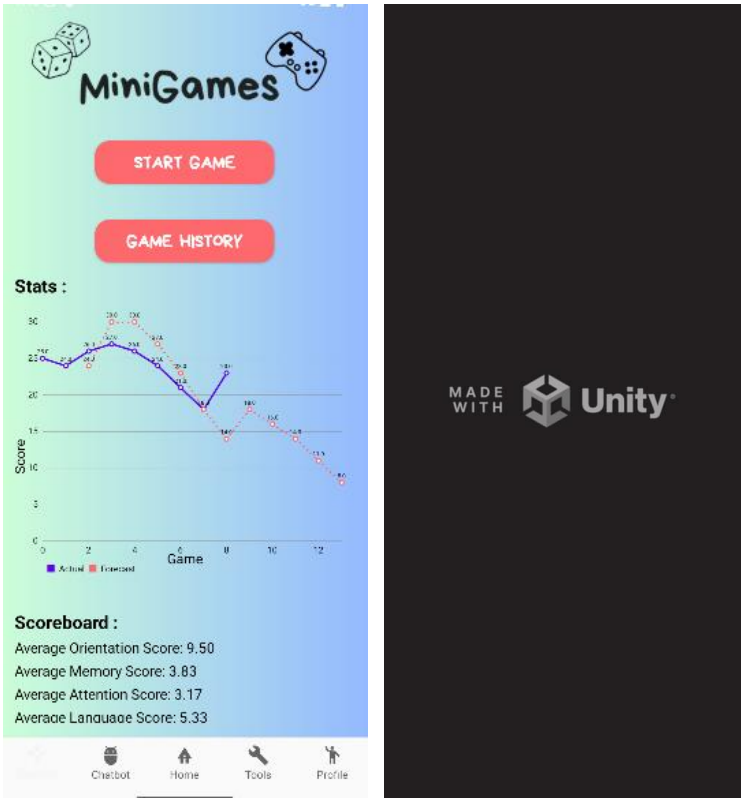

Figure 5.30 Game Interface and Unity Game

Then, a button is created on the Minigames Page to launch the Unity Game from the android application as illustrated in Figure 5.30 above. The unity game which consists of those minigames will be launched after the user click on the “START GAME” button.

CHAPTER 6 SYSTEM EVALUATION AND DISCUSSION

6.1 Evaluation Setup

To evaluate the forecasting capability for the minigames, five scenarios were simulated to represent the possible user performance:

1. Consistently Improving – performance improves steadily over the time.
2. Consistently Downgrading – performance downgrading steadily over the time.
3. Consistent Performance – performance remains stable within a small range over the time.
4. Improving then Downgrading – performance improve initially followed by downgrading over the time.
5. Downgrading then Improving – performance downgrading initially followed by increasing over the time.

The datasets were generated for these five scenarios for testing and evaluating. Each dataset consists of a total of 100 days of performance scores with the maximum of 30 points and small fluctuations to simulate the real performance.

Two forecasting models were implemented and compared:

- Linear Regression Model [15]

  $$y = mx + c$$

  where y is the predicted value (forecast score), x is the input (average score for the day), m is the slope and c is the intercept.

- Polynomial Regression Model [16]

  $$y = w_0 + w_1 x + w_2 x^2 + +w_3 x^3 + \cdots + w_n x^n + €$$

  where y is the predicted value (forecast score), x is the input (average score for the day), w_0 , w_1 , …, w_n are the coefficient, and € is the error term.

Both models were evaluated with Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the Coefficient of Determination (R^2). If the model has lower MAE and RMSE values means that such model has better prediction performance. If the value of R^2 is closer to 1 means that such model has stronger ability to explain the variance in the data and better in prediction.

6.2 Results and Analysis

(a) Consistently Improving

- Both models successfully predicted the upward trend.
- Through the observation from the figure 6.1 below, the results forecasted by the linear regression model closely aligned with the actual performance scores.
- Through the observation from the figure 6.2 below, the polynomial regression model also produced accurate forecast, but it is slightly less precise compared to the linear regression model.
- Linear Regression model work better in this situation because the data is almost a linear trend. This model finds the best fit line that minimize the error, making it more suitable for this situation [15]. However, polynomial regression model introduced the curvature for the prediction, which is not necessary for a near-linear trend, causing it less precise as compared to the linear regression model.

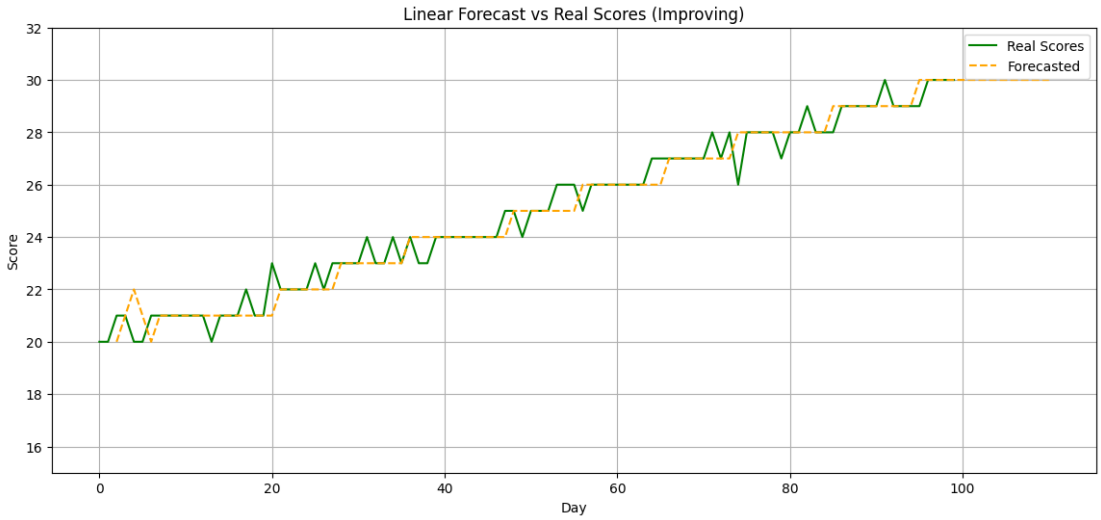

Figure 6.1 Linear Regression Model in Consistently Improving Scenario

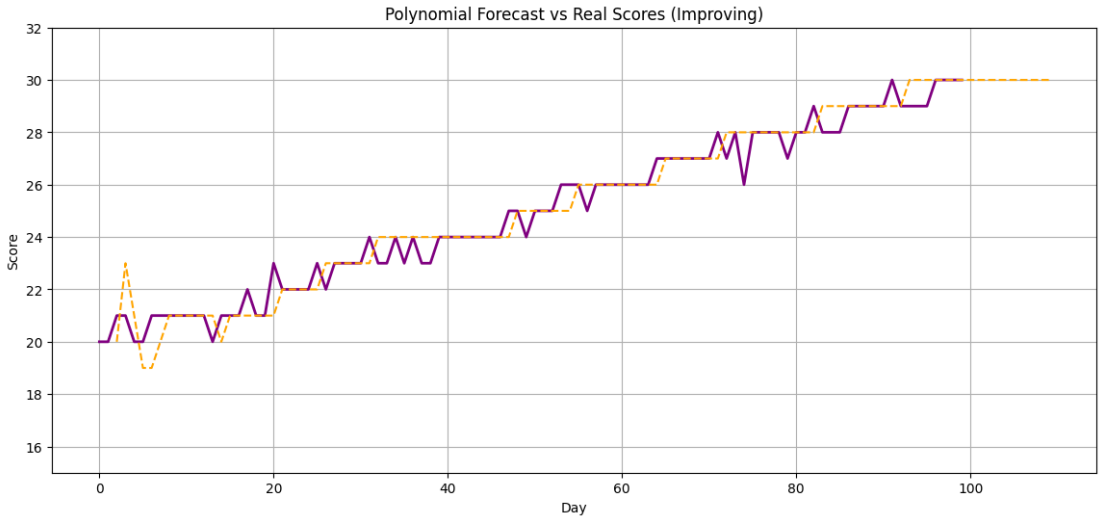

Figure 6.2 Polynomial Regression Model in Consistently Improving Scenario

(b) Consistently Downgrading

- Both models successfully predicted the downward trend.
- Through the observation from the figure 6.3 below, the linear regression model performing well in forecasting the future score.
- Through the observation from the figure 6.4 below, the polynomial regression model also achieved a good forecast result, but still linear regression model is slightly better a bit than polynomial regression model.
- Similar to the consistently improving situation, the linear regression model performed better because this scenario followed a linear decreasing pattern.

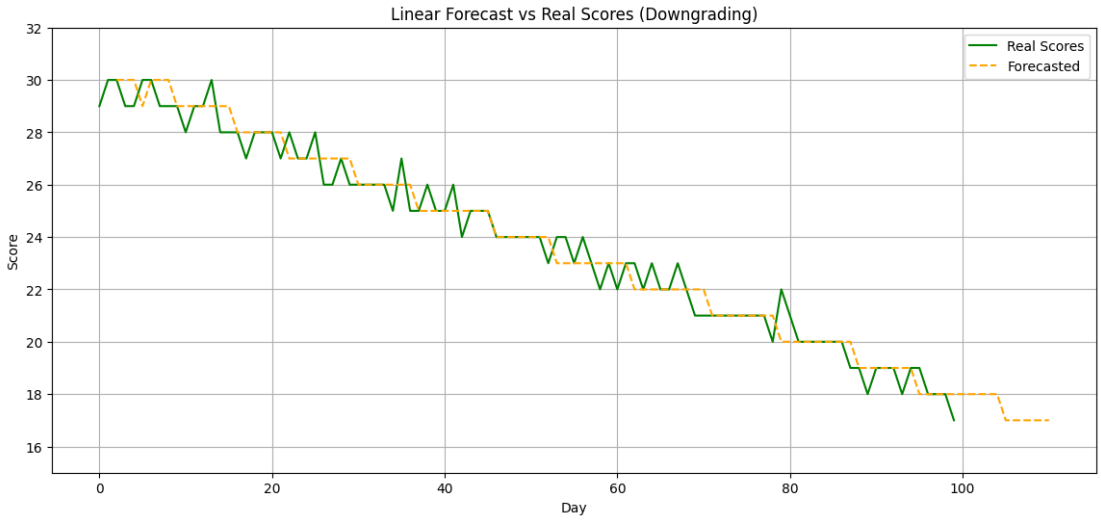

Figure 6.3 Linear Regression Model in Consistently Downgrading Scenario

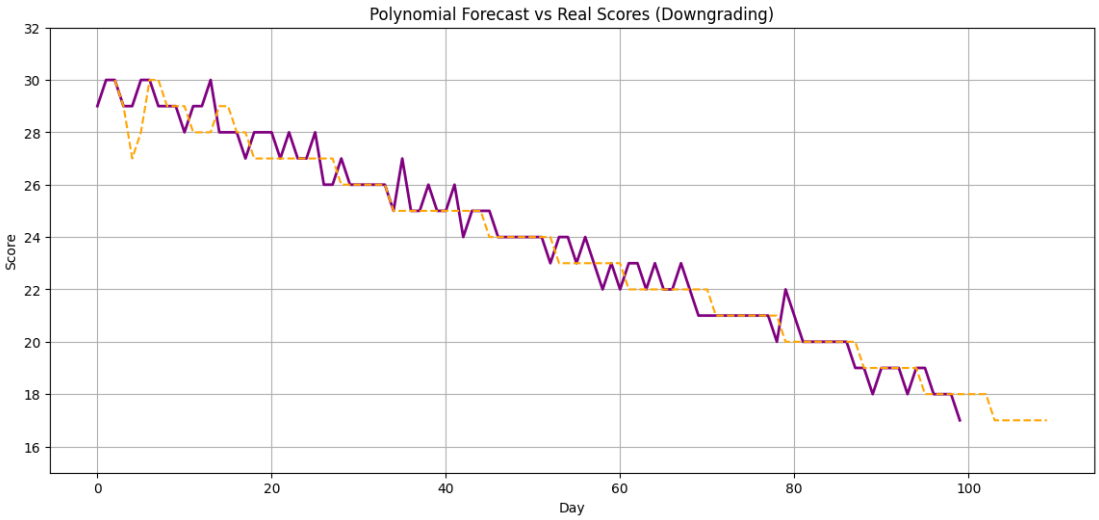

Figure 6.4 Polynomial Regression Model in Consistently Downgrading Scenario

(c) Consistent Performance

- Both models able to predict that future performance is consistent even the scores fluctuated within a small range.
- Through the observation from the figure 6.5, linear regression model showed a stable forecasting score after day 20 indicating that user has consistent performance. This is because the model successfully identified the best fit line that reflected the same score across the trend.
- Through the observation from the figure 6.6, polynomial regression model also predicted consistent performance with slightly floating on it. This is because the polynomial regression model is trying to capture the small fluctuations in the data, resulting a small variance for the predicted score.

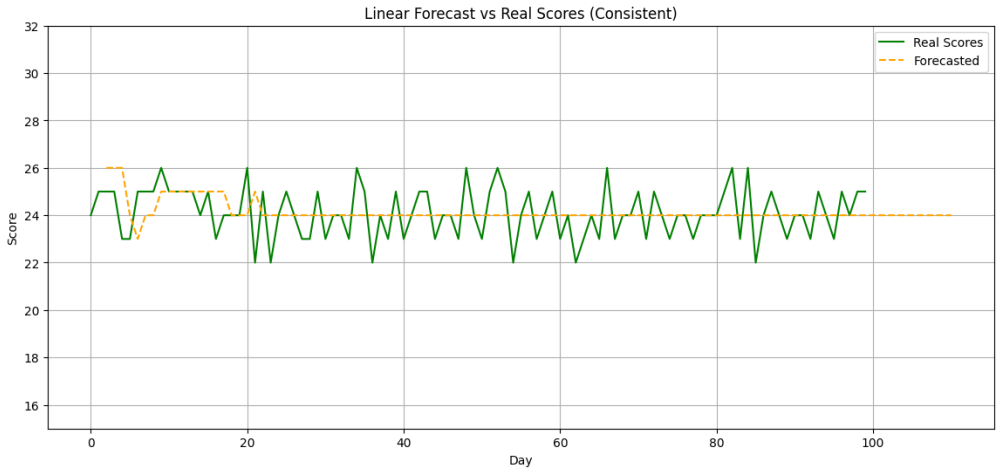

Figure 6.5 Linear Regression Model in Consistent Performance Scenario

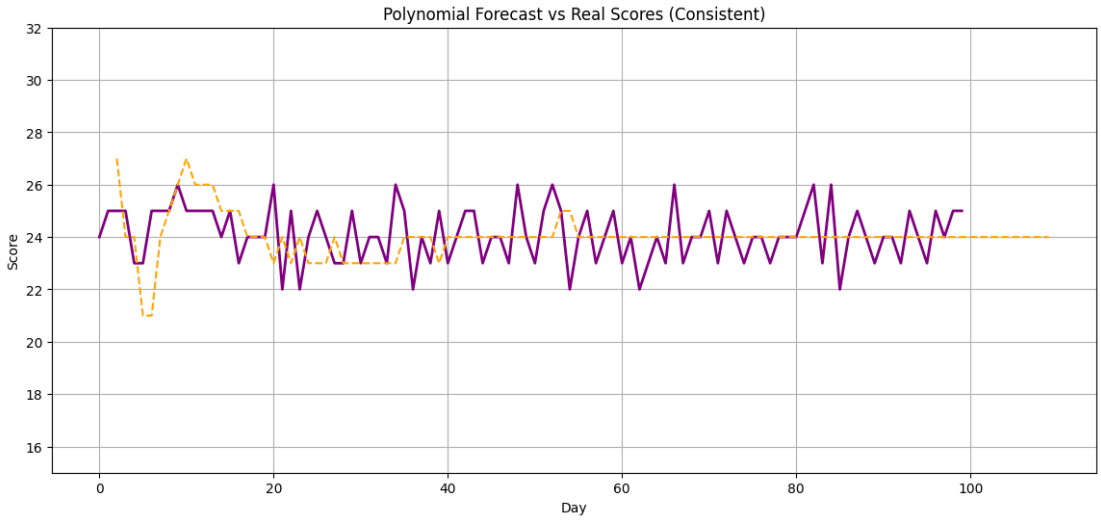

Figure 6.6 Polynomial Regression Model in Consistent Performance Scenario

(d) Improving then Downgrading

- Both models able to predict the future performance even the actual scores change from improving to downgrading.
- Through the observation from the figure 6.7, linear regression did not perform very well in this scenario, it able to capture uptrend wells but not good when the trend shifted downward. This is because the formula for drawing of best fit line from linear regression model with estimations will be the similar as the straight-line formula, but with hat notation [15].
- Through the observation from the figure 6.8, polynomial regression performed better, successfully capturing both uptrend and downtrend of the performance. This is because the polynomial regression model introduces curvature by adding higher degree terms, making it more flexible, more suitable in this nonlinear pattern situation [16].

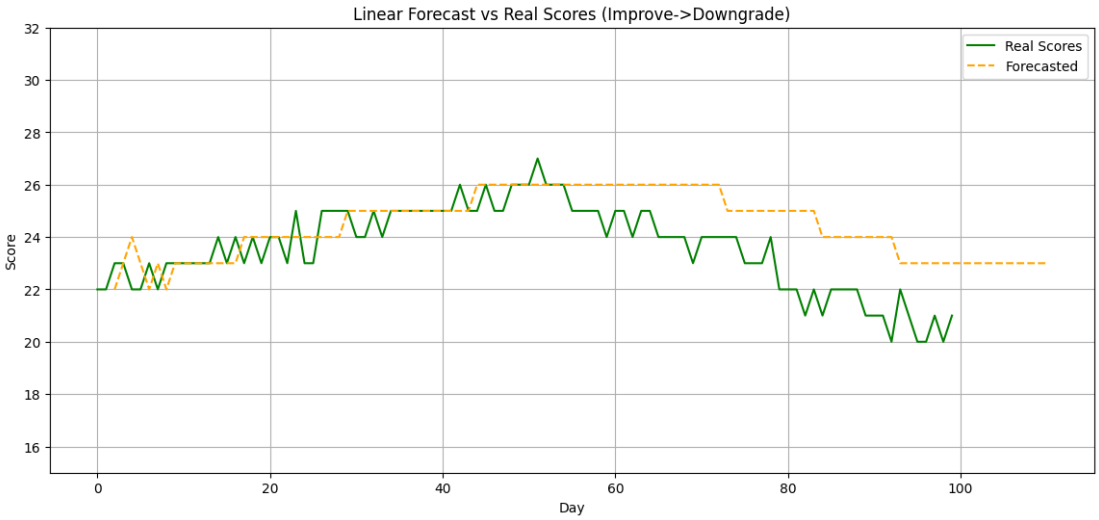

Figure 6.7 Linear Regression Model in Improving then Downgrading Scenario

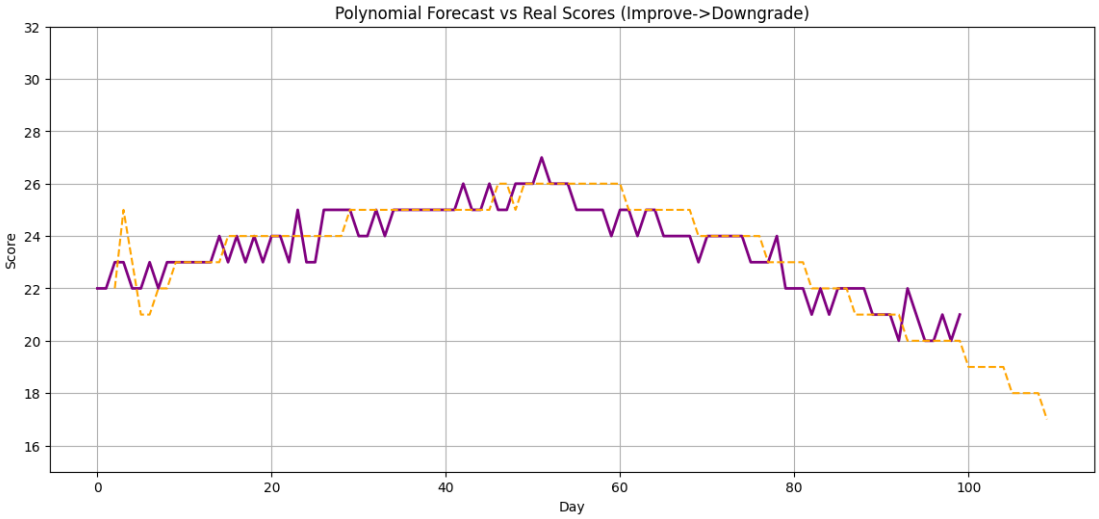

Figure 6.8 Polynomial Regression Model in Improving then Downgrading Scenario

(e) Downgrading then Improving

- Similar to the previous scenario, polynomial regression model performed better than linear regression model.
- Through the observation from the figure 6.9 and figure 6.10, linear regression model delayed the forecasting score when the trend swap from upward to downward meanwhile polynomial regression model performing well in this scenario.
- This result is consistent with the scenario for improving then downgrading. The linear regression model fits well when the trend is linear with the best fit line, but it is not

efficient to capture the turning point. However, the polynomial regression model was able to capture the fluctuations in data because of the introduction of curvature.

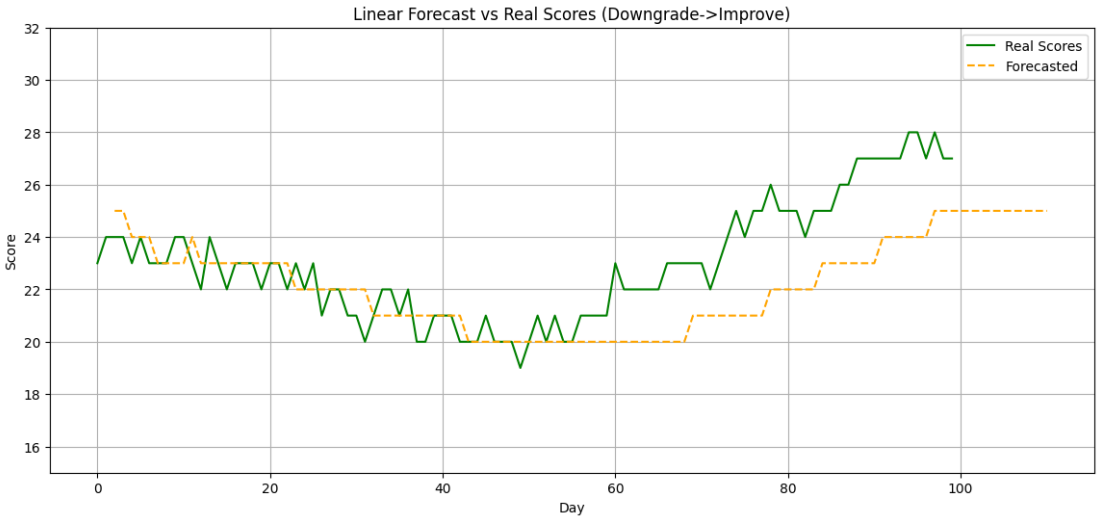

Figure 6.9 Linear Regression Model in Downgrading then Improving Scenario

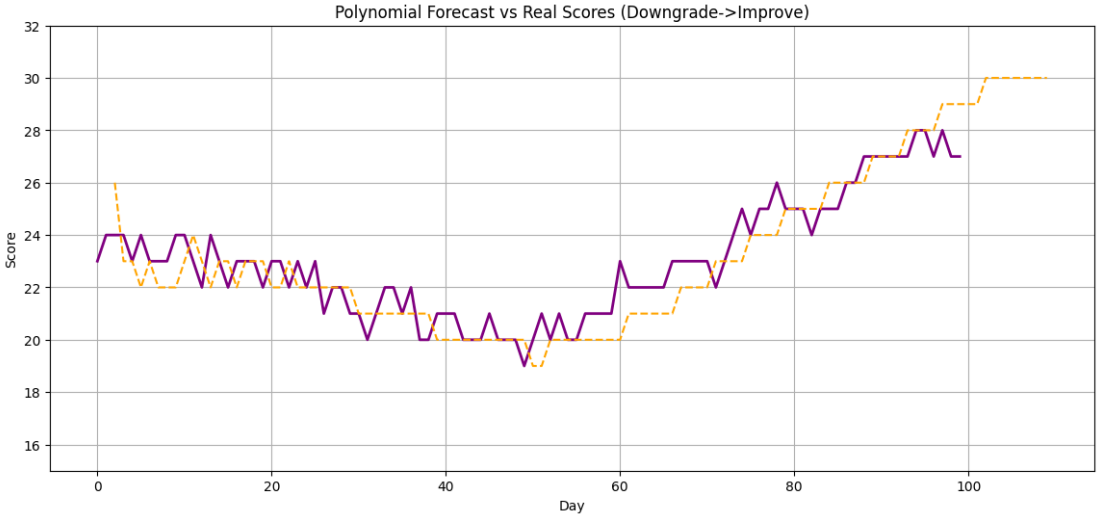

Figure 6.10 Polynomial Regression Model in Downgrading then Improving Scenario

6.3 Quantitative Evaluation

The quantitative analysis was conducted with Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the Coefficient of Determination (R^2). The results across the five simulated scenarios are summarized in Table 6.1.

Scenario	Linear MAE	Linear RMSE	Linear R^2	Polynomial MAE	Polynomial RMSE	Polynomial R^2
Improving	0.327	0.623	0.955	0.408	0.700	0.943
Downgrading	0.429	0.670	0.963	0.490	0.769	0.952
Consistent	0.837	1.116	-0.128	0.939	1.270	-0.461
Improve to Downgrade	1.224	1.616	-0.003	0.582	0.814	0.745
Downgrade to Improve	1.500	1.982	0.230	0.776	1.020	0.796
Overall Average	0.863	1.201	0.403	0.639	0.915	0.595

Table 6.1 Results for Five Simulated Scenario

Through the observation of the from the table above, linear regression model achieved better performance when the actual scores are having a consistent trend, such as consistently improving, downgrading or remain stable. In these scenarios, the linear regression model produced lower MAE and RMSE values, with R^2 values closer to 1. This is because the "best fit line" drawn by linear regression model will be the same as the straight-line formula, but with hat notation [15]. Thus, linear regression model showed better performance in the consistent trends.

However, the polynomial regression model showed a good performance in scenarios where the trend changed direction, such as Improve to Downgrade and Downgrade to Improve. In these scenarios, the polynomial regression model adapted to the non-linear patterns. This is because the polynomial regression model introduced higher degree terms that added the curvature, allowing it to capture non-linear pattern more effectively [16]. Thus, polynomial regression showed better performance in these non-linear patterns as linear regression model is limited to the straight-line fit.

For the overall averages, the polynomial regression model performed better compared to the linear regression model, with lower MAE value (0.639 vs 0.863) and RMSE value (0.915 vs 1.201). Besides, the polynomial regression model has a higher average of R^2 value (0.595)

which closer to 1 compared to the linear regression model (0.403). These values showed that among these two models, polynomial regression model is better.

6.4 Discussion

The evaluation results indicate that the polynomial regression model is better than linear regression model in forecasting user's score performance. Even linear regression model achieved a good result in consistent trends, but it does not perform well when the trend shifted direction. In contrast, polynomial regression model able to capture these fluctuations more effectively. The forecast scores were closer to the actual scores in these scenarios because the introduction of curvature able to capture these fluctuations more effectively. This finding is useful because fluctuating performance are closer to the real-world user cognitive performance, where they might involve the phase of recovery, improvement and so on. Therefore, the polynomial regression model is chosen as our model to forecast the user future performance in the cognitive based minigames.

6.5 Challenges Faced

During the evaluation and the development for these predictive models, several challenges are encountered. Firstly, there is no real performance data for the minigames from the Alzheimer's patients, so the dummy datasets were generated for testing and evaluating. While this approach allowed for the testing across different scenarios such as downgrading process, recovering process, but the generated data does not fully represent the real behaviour from the Alzheimer's patients. As a result, the reliability of the predictive model will be limited. Besides, both linear regression and polynomial regression model have their pros and cons. Linear regression model is effective to capture the consistent trend while the polynomial regression model performed better in the non-linear patterns. Therefore, evaluating these two models and determining which is more suitable for our system is a challenging process.

CHAPTER 7 CONCLUSION AND RECOMMENDATION

7.1 Conclusion and Novelty

This project has successfully achieved its development objectives by integrating a comprehensive set of features into the proposed application, designed to help elderly users in monitoring cognitive performance as well as forecasting, providing companionship and assisting them in their daily routine. The key features of the application are summarized as shown below:

1. Cognitive Assessment Minigames: A series of minigames inspired by the Mini-Mental State Examination (MMSE) were developed using unity engine and integrated into android application. Users can play the minigames, tracking and evaluate their cognitive performance. This feature allows the user to keep their mind active by playing the game and can keep tracking on their performance.

2. Predictive Model for Alzheimer's Diseases: A forecasting model was implemented to analyse users' minigame performance and predict the user's future performance. The polynomial regression model with average MAE score of 0.639, average RMSE score of 0.915, and average R^2 score of 0.595 which showed a better result as compared to the linear regression model is used, especially in fluctuating scenarios. With this model, the user can gain insights with their future performance patterns, which may serve as an early indicator of potential cognitive impairment and seek for help at an earlier stage.

3. AI-Powered Chatbot Companion: The chatbot with Mistral AI model was included in this application to provide companionship and emotional support to the users. This feature allows the users to reduce the feeling of isolation and loneliness by having the interaction with the chatbot.

4. Utility Tools for daily routine: The application provides several tools such as contact and reminder management. These tools provide conveniences by enabling the users to make quick call within the application and set the reminders for important tasks, appointments, or medications.

5. User-Friendly Interface: A simple and intuitive cartoon-style interface was designed for the minigames and applications. This design enhances the accessibility, especially for the elderly users with Alzheimer's disease, by providing a playful interface. This

friendly user interface help to reduce the confusion and create a more engaging experience when using the application.

In summary, the proposed application is designed to provide users with a comprehensive set of features for monitoring their cognitive performance, reducing the feeling of loneliness and assisting them in their daily lives. The key feature, cognitive based minigames referenced from Mini-Mental State Examination (MMSE) integrated with polynomial regression model allowed the users to monitoring their cognitive performance as well as their future performance also.

7.2 Recommendation

There are several recommendations that could further enhance the functionality, user experience, and effectiveness of this application. Firstly, integrating a speech-to-text feature into the chatbot would make it more user friendly, especially for those elderly users or patients with limited typing ability. Besides, there is still significant improvement for current user interface. Enhancing the visual layout, and navigation flow would make the application more user-friendly. Furthermore, regarding the predictive model for Alzheimer's diseases, the current implementation only fits the user's minigame score into the regression models without full training, as there is no real dataset available during the development. To improve accuracy, it is recommended that Alzheimer's patients use the application to play the minigames, collecting their performance data. This real data can then be used to train the model, providing more reliable predictions for Alzheimer's diseases. In addition, the application could be enhanced to generate detailed professional reports based on users' minigame performance as currently it is just with a short comment only. These reports will be automatically shared with family members or healthcare providers so that they able to notice if the users are abnormal. Lastly, adding more utility tools to the application, such as location tracking. This feature would allow family members to track the user's location in real time, especially since Alzheimer's patient are likely getting lost outside. These recommendations would strengthen the application's role as a comprehensive digital assistant for elderly users.

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APPENDIX A

POSTER