

**COGNITIVE REHABILITATION BASED
PERSONALIZED SOLUTION FOR DEMENTIA
PATIENTS USING REINFORCEMENT LEARNING**

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Dissertation submitted in partial fulfillment of the requirements for the Bachelor of
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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. Also, I hereby grant to Sri Lanka Institute of Information Technology the non-exclusive right to reproduce and distribute my dissertation in whole or part in print, electronic or other medium. I retain the right to use this content in whole or part in future work (such as article or books).

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Date:

Signature of co-supervisor:

Date:

DEDICATION

I devote my thesis to my family and numerous companions. An extraordinary sentiment of appreciation to my caring parents who have been my source of motivation and gave me the strength when I thought of surrendering, who consistently give their ethical, spiritual, enthusiastic and financial help.

To sister and brother who shared their expressions of advice and encouragement to complete this investigation.

This research thesis is dedicated to my supervisor, co-supervisor and external supervisor, who always supported me giving every guidance to this research.

ABSTRACT

Sri Lanka has one of the world's quickest maturing populations [1]. As indicated by the ongoing forecasts, 20% of Sri Lankans will become more than 60 years in 2020 [1]. In this way, diseases like Dementia will turn out to be increasingly prevalent in the network. The current medication can't fix this Disease [2]. Be that as it may, during the beginning times like mild or moderate in Dementia, there are a few different ways to help those patients to keep their mind dynamic by easing back the indications of one phase to the following stage for somewhat more. Dementia is a general term for illnesses and conditions described by a decrease in memory, language, critical thinking and other reasoning aptitudes that influence an individual's capacity to perform regular activities. Because of the successful utilization of brilliant devices at present, the usage of new application including games and exercises for expanding the memory intensity of Dementia patients will be useful. Among the core mental functions of dementia, this research component study and focus on executive functions. There are number of mind preparing versatile applications on the planet that could be valuable to develop executive functions skills however there isn't appropriate portable application for Sri Lankan culture in light of the fact that the greater part of the dementia patients in Sri Lanka are senior residents and they are not capability with the English language and the accessible current applications are not free and the clients must pay an expense for utilizing those applications. The execution of the research part will incorporate a brain game dependent on reinforcement learning and algorithms along with the supervision and suggestion from a Consultant Psychiatrist in Sri Lanka.

Key Words : Dementia, Cognitive Rehabilitation, Reinforcement Learning,

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Table of Contents

DECLARATION	III
ABSTRACT	V
ACKNOWLEDGEMENT	VI
1.INTRODUCTION	1
1.1 BACKGROUND	1
1.2 LITERATURE REVIEW	2
1.2.1 Dementia	2
1.2.2 Mobile Applications for Dementia Patients	3
1.2.3 Reinforcement Learning.....	3
1.2.3.1 Different techniques of Reinforcement Learning.....	5
1.2.3.2 Q Learning	6
1.2.3.3 Q Learning in Games.....	7
1.3 RESEARCH GAP.....	7
1.4 RESEARCH PROBLEM.....	9
1.5 RESEARCH OBJECTIVES.....	10
1.5.1 Main Objective.....	10
1.5.2 Specific Objective.....	11
2. METHODOLOGY	13
2.1 SYSTEM OVERVIEW	13
2.2 METHODOLOGY	14
2.3 IMPLEMENTATION AND TESTING	15
2.3.1 Implementation.....	15
2.3.1.1 Implementation of the Game	16
2.3.1.2 Data Management	17
2.3.1.3 Sending Email to Doctor.....	18
2.3.2 Testing	23
2.4 COMMERCIALIZATION.....	28
3. RESULTS AND DISCUSSION.....	30
3.1 RESULTS.....	30
3.2 RESEARCH FINDINGS	31
3.3 DISCUSSION.....	32
4. CONCLUSION	34
5. REFERENCES	35
8. GLOSSARY	37
7. APPENDICES.....	38

LIST OF TABLES

Table 1: Comparison between existing applications and proposed application	8
Table 2: The patient selects an answer for a mathematical problem	25
Table 3: Test case for checking the timer for changing number sets.	27

LIST OF FIGURES

Figure 1: Reinforcement Learning Illustration	4
Figure 2: System Architecture of the Component	13
Figure 3: Technologies used to the research	14
Figure 4: Appearing numbers randomly and formatting answers for the calculation.....	16
Figure 5: Checking Answers.....	17
Figure 6: Sample data in PlayFab.....	18
Figure 7: Implementation of progress chart	19
Figure 8: Sending Email to Doctor	19
Figure 9: Update Score.....	20
Figure 10: Unlocking the steps and levels	21
Figure 11: Work Breakdown Structure	22
Figure 12: Gantt Chart	22
Figure 13: Test Class for checking score	23
Figure 14: Test Class for calculating math problem	24
Figure 15: Test cases are running on Unity Test Runner	25
Figure 16: Selecting a correct answer	26
Figure 17: Selecting a wrong answer	26
Figure 18: Progress chart	30
Figure 19: Interface of the game	30
Figure 20: Sample test of sending progress report to doctor.	31

LIST OF ABBREVIATIONS

RL: Reinforcement Learning.....	1
AD: Alzheimer's Disease	4
SARSA: State Action Reward State Action.....	5
DQN: Deep Q Network.....	5
DDPG: Deep Deterministic Policy Gradient	5
AD: Alzheimer's Disease	12
SDLC: Software Development Life Cycle.....	13
MMSE: Mini-Mental State Examination	22
UTF: Unity Test Framework.....	28

1.Introduction

1.1 Background

Dementia is a condition, typically of a ceaseless or dynamic nature, wherein there is disintegration in psychological capacity past what may be normal from ordinary maturing. It influences memory, thinking, direction, understanding, computation, learning limit, language, and judgment. The debilitation in intellectual capacity is regularly went with, and once in a while went before, by decay in emotional control, social conduct, or inspiration. Around the globe, around 50 million people have dementia, and there are around 10 million new cases every year. Dementia is one of the huge explanations behind insufficiency and dependence among progressively settled people far and wide [3].

Dementia has a physical, mental, social, and money related impact, on people with dementia, yet also on their considerations, families, and society free to move around at will. Dementia impacts each person in another way, dependent upon the impact of the sickness and the person's character before becoming ill. The signs and indications connected to dementia can be perceived in three phases.

1. Early stage
2. Middle stage
3. Late stage

There is no treatment beginning at now open to fix dementia or to adjust its dynamic course. Diverse new solutions are being analyzed in different times of clinical groundworks. Notwithstanding, much can be offered to help and improve the lives of individuals with dementia and their contemplations and families.

In spite of the fact that age is the most grounded realized danger factor for dementia, it's anything but an unavoidable result of maturing. Studies show that individuals can diminish their danger of dementia by getting normal exercise, not smoking, dodging destructive utilization of liquor, controlling their weight, eating a healthy diet, and keeping

up solid pulse, cholesterol and glucose levels, Additional danger factors incorporate misery, low instructive fulfillment, social seclusion, and psychological idleness [3].

Considered by numerous applications, Lumosity is utilized by more than 85 million individuals over the globe. The application comprises of over 50 glowing and fun minigames intended to prepare five intellectual capacities: speed, memory, consideration, adaptability, and critical thinking. Lumosity is an application that could without much of a stretch design to the two youngsters and grown-ups. Lumosity is allowed to download on Android and iOS yet can't gain access to full form in any case the client needs to pay a cost. Fit Brains is a formation of Rosetta Stone, and it has been made to assist practice with keying psychological capacities, including focus, memory, speed of reasoning, and critical thinking. In view of the consequences of each game played, the client is furnished with a score out of 200 for each psychological zone. The application likewise contrasts singular outcomes and those of different clients [4].

The wide assortment of available applications for an overall group got together with the confined openness of uses expressly created for people with dementia shows that cautious idea is needed to pick usable applications for people with dementia. The use of the application will incorporate brain game for executive functions subject to reinforcement learning.

1.2 Literature Review

1.2.1 Dementia

Dementia is one of the most well-known sicknesses in the old, with unrefined commonness rates between 5.9%–9.4% for subjects matured more than 65 in the European Union [5]. In Sri Lanka, the normal future from birth has expanded for men from 62 years in 1963 to 70 years in 1991, and females from 61 years to 74 years (Annual Health Bulletin, 2000). Along these lines, the level of the populace matured more than 60 years right now expected to increment quickly from 8% as of now, to arrive at 13% in 2010, and 21% in 2025. Fundamentally considering lesser accentuation on the

wellbeing of more seasoned grown-ups and lesser assets for wellbeing research contrasted and the industrialized nations, Sri Lanka has not had the option to report solid epidemiological information on maturing related scatters, for example, dementia. Along these lines, the degree of the general wellbeing trouble right now presented by Alzheimer's Disease (AD) and different dementias in Sri Lanka is obscure [6].

1.2.2 Mobile Applications for Dementia Patients

Innovation can help traverse any boundary among patients and staff to improve the individual fulfillment for the emotionally obstructed. Development instruments, for instance, iPods, help animate those with dementia. In a period where Alzheimer's and dementia in more prepared adults are extending, parental considers are looking along with new responses for intervening the crisis. One of these new game plans is the usage of mobile phones to vitalize the view of more settled adults and patients encountering AD. New examination has shown that the use of brain, memory, and dealing with issue games help strengthen the mind and reduce the symptoms of AD. The use of the brain games and other PC based impelling treatment has given new light to medicinal services specialists, guardians, and the patients themselves [7].

1.2.3 Reinforcement Learning

Reinforcement learning will be learning through communication with a situation by taking various activities and encountering numerous disappointments and victories while attempting to augment the gotten rewards. The agent isn't advised which move to make. Reinforcement learning is like regular learning forms where an instructor or a boss isn't accessible and learning process advances with experimentation, unique concerning administered learning, in which an agent should be determined what the right activity is for each position it experiences.

Reinforcement learning is not the same as different parts of machine learning both supervised learning and unsupervised learning. And it is considered as a third model of machine learning, at the edge of unsupervised learning and supervised learning [8].

Reinforcement learning is a field of machine learning strategies and issues dependent on the idea of learning from numerical rewards received by an agent through communicating with a domain. In some random advance, the agent watches a condition of the earth and gets a prize sign. Because of the present state and the agent's conduct work — the approach — the agent picks a move to make. The activity is then sent to the environment which is refreshed and the circle repeats. See Figure 2.1 for an outline of the agent-condition interface [9].

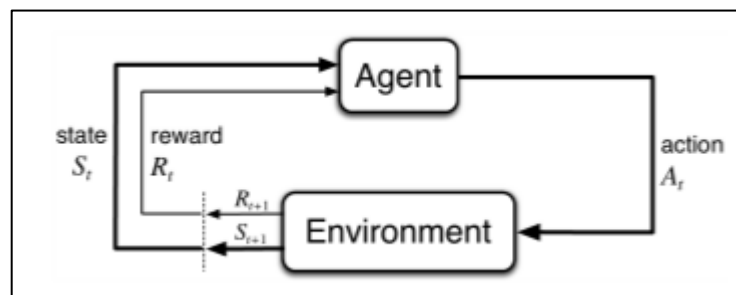


Figure 1: Reinforcement Learning Illustration

Action (A): moves that the agent can possibly take

State (S): current situation that is returned by the environment

Reward (R): immediate feedback returned by the environment in order to evaluate the last state

In RL issues, a specialist picks an activity at each time step dependent on its present state and gets an evaluative criticism and the new state from the earth. The objective of the specialist is to get familiar with an ideal approach that boosts the collected prize it gets after some time. In this manner, operators in RL don't get immediate directions in regard to which move they should make, rather they should realize which activities are the best through experimentation cooperation's with the earth. This versatile shut circle highlight

renders RL unmistakable from customary administered learning strategies for relapse or arrangement, in which a rundown of right marks must be given, or from solo learning ways to deal with dimensionality decrease or thickness estimation, which target finding concealed structures in an assortment of model information. Besides, in correlation with other conventional control-based techniques, RL doesn't require an all-around spoke to a numerical model of the earth yet builds up a control strategy legitimately for a fact to foresee states and prizes during a learning system. Since the plan of RL is letting a specialist controller collaborate with the framework, obscure and time-shifting elements just as changing execution necessities can be normally represented by the controller. Ultimately, RL is particularly fit to frameworks with natural time delays, in which choices are performed without prompt information on adequacy however assessed by a long-haul potential compensation [10].

1.2.3.1 Different techniques of Reinforcement Learning

In games, machine learning can be utilized for different purposes. It very well may be utilized to acquire the greatest scores, win the game at the base time conceivable, get most collectibles, or improve survivability. As we don't think a lot about the games, it is ideal to actualize the reinforcement learning technique as it can take in without anyone else from its surroundings. Reinforcement learning has its choice of systems, for example, Q learning, SARSA, DQN, and DDPG [11].

There are two kinds of algorithm model which are model-based and model-free. In the model-based algorithm, the model will learn the transition probability T . The agent will realize how to enter a particular and activity space develops; the model-based algorithm will turn out to be more impractical. The model-free algorithm refreshes its information by depending on the experimentation technique. In this way, the blend of states and actions shouldn't be put away in another space. Instances of the model-free algorithm are Q-learning and SARSA.

1.2.3.2 Q Learning

Q-learning is a type of model-free reinforcement learning. It works by steadily refreshing the normal estimations of activities in states. For each conceivable state, every conceivable activity is assigned out a worth which is a component of both the immediate reward for making that move and the normal award later dependent on the new express that is the consequence of making that move. This is communicated by the one-advance Q-update condition [12].

$$Q(s, a) = Q(s, a) + \alpha [r + \gamma \max_{a'} Q(s', a') - Q(s, a)]$$

Q – expected value of performing action

s – state vector

a – action vector

r – reward

α – learning rating which controls convergence

γ – discount factor

The discount factor makes rewards earned before more important than those got later. This technique learns the estimations of all things considered, as exposed to simply finding the ideal procedure. This information is costly in terms of the measure of data that must be put away, yet it brings benefits. Q-learning is investigation insensitive; any activity can be completed whenever, and data is picked up from this experience [12].

Q Learning Algorithm

Q-learning is a reinforcement learning technique where the learner assembles steadily a Q-function which attempts to measure the limited potential rewards for taking activity from given states. The output yield of Q-function for the state s furthermore, activity is appeared in equation (1). Q-values are as a rule hidden away investigate the table. Officially a Q-learning can be described as follows:

Algorithm:

```
Initialize  $Q(s, a)$  arbitrarily
Repeat (for each episode)
  Initialize  $s$ 
  Repeat (for each step of episode):
    Choose  $a$  from  $s$  using policy derived from  $Q$ 
    Take action  $a$ , observe  $r, s'$ 
     $Q(s, a) = Q(s, a) + \alpha [r + \gamma \max_{a'} Q(s', a') - Q(s, a)]$ 
     $s \leftarrow s'$  ;
  Until  $s$  is terminal
```

1.2.3.3 Q Learning in Games

As of late, the enthusiasm for reinforcement learning in game playing has been restored. This is proven by the momentous outcomes accomplished by AlphaGo. General Game Playing (GGP) gives a decent testbed to reinforcement learning, right now perhaps the most sweltering field of AI. In GGP, a detail of games rules is given. Q-learning is one of the standard reinforcement learning strategies, which is utilized as pattern on some past work [13].

1.3 Research Gap

Subsequent to dissecting some current versatile game applications identified with dementia condition, there were a few disadvantages and there was no reasonable application for Sri Lankan culture since all the portable game applications, which are as of now accessible in the play store and application store in English language. The majority of the patients in Sri Lanka, just as around the world, have a place with the old age since they are not capable with the English language. In this research, the proposed framework has implemented in Sinhala language.

Lumosity is one of those applications which incorporates a few games for control and hinder the weaknesses of intellectual capacities in dementia. In any case, it isn't reasonable for Sri Lankan old individuals in view of the language and game condition. Furthermore, the client needs to pay a cost to pick up the full gotten to variant.

Table 1: Comparison between existing applications and proposed application

Features	Lumosity	Brain Games	Elevate	Proposed System
Based on the performance of user (learning from user) predict the next levels of game	✗	✗	✗	✓
Games in Sinhala language	✗	✗	✗	✓
View the daily report	✓	✓	✓	✓
View the performance of patient as a history	✓	✗	✓	✓
Patient's doctor also can connect with this system and view the patients progress	✗	✗	✗	✓
User can use the application without paying a payment	✗	✗	✗	✓

1.4 Research Problem

Dementia is one of the most significant problems facing with the increase in the ageing population. The estimated current prevalence of dementia is 47.5 million worldwide [1]. This number will nearly double in every 20 years globally [1]. Just as a similar issue has happened in Sri Lanka. Dementia portrays a gathering of manifestations influencing memory, thinking and social abilities seriously enough to meddle with the everyday life. It isn't a specific disease, yet a few distinct illnesses may cause dementia. Dementia isn't just about memory loss. It can likewise influence the manner in which you talk, think, feel and carry on. It's additionally imperative to recall that dementia is not a characteristic piece of maturing.

Dementia is a disorder which can't be restored by drugs. That is the primary and significant issue accessible over the world. In any case, a few medications can assist with control indications for individuals living with Alzheimer's illness, dementia with Lewy bodies or Parkinson's infection dementia. Shockingly, there are as of now no medications that can improve the psychological manifestations of dementia. Drugs assume a key function in the lives of individuals with dementia, essentially to manage indications. Managing prescriptions is complex for individuals with dementia and their family and can bring about different issues prompting harm. The principle drugs used to treat psychological indications of dementia are called 'cholinesterase inhibitors'. These medications don't work for everybody, and the normal impact is fairly small. However, for the vast majority, they're despite everything great worth difficult. While numerous individuals can take dementia drugs with no issues, some may encounter disagreeable reactions. The most well-known reactions include, headaches, sleep problems, loss of appetite, vomiting, muscle pain, feeling tired, itching, dizziness etc. The impact of dementia drugs on the strength of an individual's heart and veins seems, by all accounts, to be commonly very sure [14].

In any case there are medications that help to slowdown the development of the disorder. There are medications just as mental and behavioral treatments that help. But a patient

could be performed that medications during their treatment sessions only. And, doctors can't get the history of treatments of each patient regularly.

The objectives of progressing treatment for dementia are to keep the individual securely at home for to the extent that this would be possible and to offer help and direction to the caregivers. The individual needs to routine follow-up visit each 3 to a half year [15]. The specialist needs to screen medications and the individual's level of functioning. Sooner or later, the family may need to consider setting the individual in a consideration office that has a dementia.

1.5 Research Objectives

1.5.1 Main Objective

The guideline and the most critical consequence of making Personalized Application for Dementia patients to help those patients by giving recuperation in an intelligent manner using different kinds of games or activities that will be finished right now consistent checking. Our proposed application has the ability to beat those issues. It has games and activities to improve the psychological functionalities for the Temporal lobe and Frontal projection from the Cerebral cortex.

This research study is adjusted in with accomplishing a flexible game to improve the executive functioning limit capacities of dementia patients. There are subcategories in the Executive Functions. Executive functioning includes the capacity to compose, plan and complete a lot of undertakings in a productive way. It additionally incorporates the capacity to self-screen, time management, calculation skills and control practices and various other psychological capacities and to perform objective coordinated conduct. It very well may be depicted as elevated level reasoning aptitudes that control and direct lower levels of cognitive functioning. On a viable level, weaknesses in executive

functioning have been related with debilitations in exercises of everyday living which incorporate getting dressed, the capacity to take care of oneself, wash oneself and more.

This research is divided into four subcomponents. Among those components this section belongs to Executive functioning category. This component has implemented a game for develop executive functioning skill of the Dementia patients. As mentioned earlier, there are sub aspects in the executive functions. This game is mainly focus for develop time management skill, small calculation skill and correct decision-making skill of a patient with dementia.

1.5.2 Specific Objective

The external supervisor (Dr.Chathurie Suraweera, Senior Consultant at National Hospital, Colombo/ Senior Lecturer in Department of Psychiatry, Faculty of Medicine, University of Colombo) of the research explained that there are few things to keep in mind when implementing a game so that patients with Dementia can be cured. The first thing is to create the application in a very simple way without confusing the patient. Therefore, even the game created according to the doctor's requirements should be very simple and clear. Also, the selected images and colors should be the same.

The next thing is that there are some physical treatments that are usually given by the doctor to Dementia patients. The most important objective here is to create the same physical treatment as a game. According to this component, the game should be designed in such a way that there is a tendency for executive functioning skills. As the doctor treats, the game belonging to this component also had to be created with a systematic timeline. Sometimes Dementia patients can be lazy. Therefore, this game should be designed in such a way that they are encouraged to use this application. For that, a scoring procedure has been included for each step. Also, there are 4 levels to increase the complexity of the

game since anyone is lazy to do the same thing. Next, the patient, the caregiver and the doctor must have a way to see if there is any improvement in the patient. That fact can also be called an important objective. This should be a good help to facilitate the patient's daily activities and make the life of the caregiver easier.

2. Methodology

2.1 System Overview

The general result of this research is to execute a flexible application for Dementia patients which fuses different kinds of versatile games or activities using Reinforcement Learning and Speech to text segments to restore those patients in a mental way. The principle result of this exploration segment is actualizing a versatile game to help dementia patients to improve the viability and speed cycle of executive capacities.

The specialist will do the MMSE testing for the patients who meet the specialist (applicable Psychiatrist). According to the MMSE test result, patients will be requested into specific stages. Simply the patients under the mild and moderate stages will be picked to use this application. Through the different examination preliminary of the patient for Dementia, the authority will be picked the game for the patient and endorsed to practice the game.

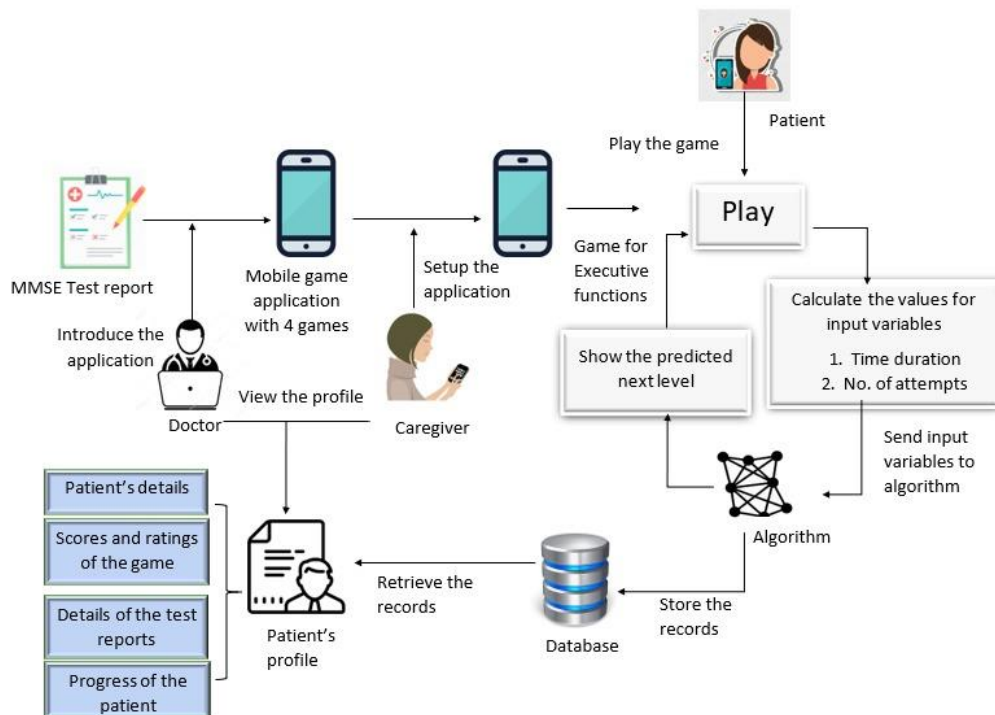


Figure 2: System Architecture of the Component

Register the patient to the application and make a profile for the patient. This undertaking done by a parental figure and he can enter the details of test reports to the patient's profile. It will be served to the specialist on the grounds that the specialist can increase a superior comprehension of the patient whenever. The game of this component is defined with small math calculations. It has 4 levels and patient has to play game levels entire one week one by one. While the patient plays the game, the system identifies the behaviour of the player (patient). Figure and create the scores for the game level of the game and show it to the patient. That would be a solid inspiration for the patient for stepping into the next level of the game. And also, patient can view the weekly progress through this application. Store all the records of each game level in the database. That records in the database can be viewed in the patient's profile. Then every end of the week that the weekly progress of every level of the patient will sent to the doctor's email account via an email.

2.2 Methodology

The system used Unity, product version 2019.2.15f1 and Microsoft Visual Studio, product version 16.4.29613.14



Figure 3: Technologies used to the research

As beginning crossroads of the task, project initiation was performed. Under project initiation stage a few kinds of feasibility studies were directed to find any deserving of the venture. Preceding allot our financial assets, we followed this monetary possibility study to determine cost and advantages which are connected with our task. Our proposed solution is beneficial to individuals who are going through from mellow or moderate Dementia to recoup through training which is result in to decrease Dementia from the general public.

Embrace an operational feasibility, we were centered around regardless of whether our last item would be handily worked at side of end clients. Since our proposed arrangement associates with patient's guardian and specialist yet not just the patient. Because of that point it will push patient to effortlessly work with the application. Secured specialized attainability study to focus on specialized assets available for proposed solution and turned consideration on resources that are obliged to activate, install, or acquire the system to build up a definitive item.

2.3 Implementation and Testing

2.3.1 Implementation

In the implementation segment, first step was the implementing the game which was recommend by the doctor who is positioning as the external supervisor to this research. The game for Executive Functions component is based on simple math calculation process. This game has four levels and it will be more complicated level by level. The game consists with five numbers which are moving, and player has to calculate those numbers from bottom to up according to the math operation. These numbers will change every 30 seconds(It can be changed). In every round user has fixed time duration to play the game. The user has to solve as much as he can within that time duration. There is only one math operation in first level and level by level it will be adding one more math operation (addition, multiplication, subtraction and division) one by one. And there are two timers in this game. One timer for changing numbers appears in here. The user has 30 seconds to solve one number set. After the user clicks an answer a new number set

will appear. The game will stop after second timer became 0. This timer is fixed time duration in every game level.

2.3.1.1 Implementation of the Game

As mentioned earlier, there are five numbers in this game, and they are moving horizontally, and the five numbers are randomly appearing on the screen after fixed time duration or after selecting an answer. Math knowledge of the elderly people might be not in quiet good situation therefore all these five numbers are less than five. Three multiple choices are given to the player and player has to choose the correct answer. Multiple choices are also appearing in random format.

```
if (time <= 0)
{
    time = roundLength;
    randomNums();
    result = numbers[0] + numbers[1] + numbers[2] + numbers[3] + numbers[4];
    displayResults();

    Answers[0] = result;
    Answers[1] = result + Random.Range(1, 6);
    Answers[2] = result - Random.Range(1, 6);
    ShuffleArray(Answers);

    for (int i = 0; i < buttons.Length; i++)
    {
        buttons[i].image.color = Color.white;
    }
}

1 reference
void randomNums()
{
    if (GMS.counterDownDone == true)
    {
        for (int i = 0; i < numbers.Length; i++)
        {
            numbers[i] = Random.Range(0, 5);
            numbersText[i].text = numbers[i].ToString();
        }
    }
}
```

Figure 4: Appearing numbers randomly and formatting answers for the calculation

```

0 references
public void ButtonCheck(int buttonNum)
{
    if (buttons[buttonNum].transform.GetChild(0).GetComponent<Text>().text == result.ToString())
    {
        Debug.Log("Correct !");
        buttons[buttonNum].image.color = Color.green;
        score += 2 * time;
        scoreText.text = score.ToString("0");
        source.PlayOneShot(clips[0]);
    }
    else
    {
        Debug.Log("Wrong !");
        buttons[buttonNum].image.color = Color.red;
        //score -= 15;
        scoreText.text = score.ToString("0");
        source.PlayOneShot(clips[1]);
    }
}

```

Figure 5: Checking Answers

Next step is check whether the answer which is given by the player is correct or wrong. If the answer is correct it will appear in green color otherwise it will be red color. And also, for every correct answer there will be adding a score and it is based on the time.

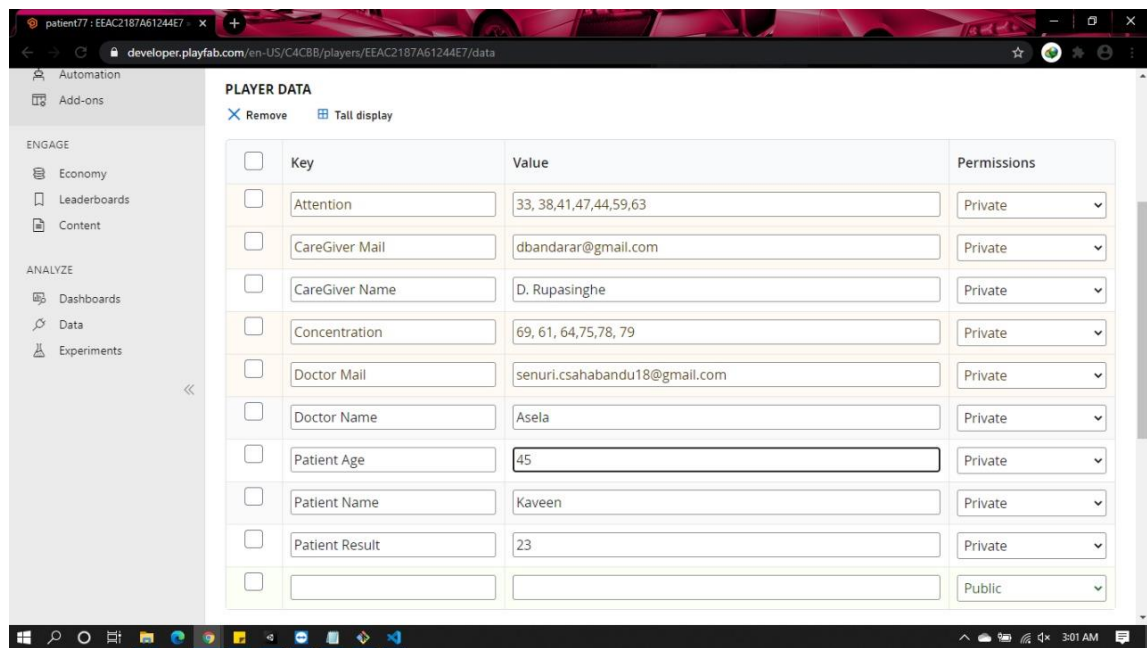
2.3.1.2 Data Management

Every application contains some amount of data and at least there should be data of users. When it comes to this component of the research, there are some data to handle. When a patient plays the game, the score has to store somewhere because patient or caregiver or doctor needs to see the cognitive skill progress of the patient. And also, when a patient registering to this system there are some important data to store securely. For this process we used a latest application development platform called as PlayFab.

PlayFab is a Backend as a Service stage zeroed in on games that is possessed by Microsoft. It is one of the most outstanding backend arrangements which can assist developers with making, oversee, dispatch and develop viable cloud-associated gaming applications. The whole toolset of PlayFab has been intended to be utilized by the

designers from all around the globe. It can let you create games for any stage, for example, PC, versatile just as reassure [16].

When a user register to this system it is like creating an account in playfab. First, the values required for storage can be stored locally as an integer value using playerpref. We can use that saved data anywhere without storing in playfab. But the reason for saying we used this playfab, because patient can access to this system using playfab credentials from any device.



<input type="checkbox"/>	Key	Value	Permissions
<input type="checkbox"/>	Attention	33, 38, 41, 47, 44, 59, 63	Private
<input type="checkbox"/>	CareGiver Mail	dbandarar@gmail.com	Private
<input type="checkbox"/>	CareGiver Name	D. Rupasinghe	Private
<input type="checkbox"/>	Concentration	69, 61, 64, 75, 78, 79	Private
<input type="checkbox"/>	Doctor Mail	senuri.csahabandu18@gmail.com	Private
<input type="checkbox"/>	Doctor Name	Asela	Private
<input type="checkbox"/>	Patient Age	45	Private
<input type="checkbox"/>	Patient Name	Kaveen	Private
<input type="checkbox"/>	Patient Result	23	Private
<input type="checkbox"/>			Public

Figure 6: Sample data in PlayFab

2.3.1.3 Sending Email to Doctor

When the patient plays the game, a progress of his cognitive functions is built inside this system. That process takes place once a week and it is shown by a graph. Although the patient and caregiver can see this progress, the doctor cannot analyze it. The solution is to build this system so that all reports can be sent to the doctor via email. According to this game, a report on the progress of the patient's cognitive functions is sent to the doctor by email once a week.

```

public void SendEmail()
{
    MailMessage mail = new MailMessage();
    SmtpClient SmtpServer = new SmtpClient("smtp.gmail.com");
    SmtpServer.Timeout = 10000;
    SmtpServer.DeliveryMethod = SmtpDeliveryMethod.Network;
    SmtpServer.UseDefaultCredentials = false;
    SmtpServer.Port = 587;

    mail.From = new MailAddress("careumed2020@gmail.com");
    mail.To.Add(new MailAddress(PlayerPrefs.GetString("DoctorMail")));

    mail.Subject = "Week " + PlayerPrefs.GetInt("Level_Number") + " report of " + PlayerPrefs.GetString("PatientName");
    // Body start.
    mail.Body = "Patient Name : " + PlayerPrefs.GetString("PatientName") + "\n" +
        "Patient Age : " + PlayerPrefs.GetString("PatientAge") + "\n" +
        "Patient Mail : " + PlayerPrefs.GetString("PatientMail") + "\n" +
        "CareGiver Name : " + PlayerPrefs.GetString("CareGiverName") + "\n" +
        "CareGiver Mail : " + PlayerPrefs.GetString("CareGiverMail") + "\n" + "\n";

    if (PlayerPrefs.GetInt("Level_Number") == 1)
    {

```

Figure 8: Sending Email to Doctor

Before implanting this process, created a Gmail account for the system. The reason for doing so is that when a doctor receives emails from various Gmail accounts of different patients, it can be a nuisance to a doctor. There is also the possibility of ignoring emails coming from various personal accounts. When emails are received from a single Gmail account, it is easy for the doctor to identify and handle them.

```

public void OnClickWeeklyProgress()
{
    _weeklyProgress.SetActive(true);
    _overflowMenu.SetActive(false);

    if (stepNumber == 1)
    {
        _notification.SetActive(true);
        _table.SetActive(false);
    }
    else
    {
        if (!_display)
        {
            _display = true;
            _notification.SetActive(false);
            _table.SetActive(true);

            if (levelNumber == 1)
            {
                _week.text = "Week 1 Progress";

                for (int i = 0; i < PlayerPrefs.GetInt("Week1Day"); i++)
                {
                    float fillAmount = (float)PlayerPrefs.GetInt("EF_ScoreWeek1" + i) / 100.0f;
                    _progressBars[i].fillAmount = fillAmount;
                }
            }
            if (levelNumber == 2)
            {
                _week.text = "Week 2 Progress";

                for (int i = 0; i < PlayerPrefs.GetInt("Week2Day"); i++)
                {
                    float fillAmount = (float)PlayerPrefs.GetInt("EF_ScoreWeek2" + i) / 100.0f;

```

Figure 7: Implementation of progress chart

```

private void UpdateScore()
{
    if (levelNumber == 1)
    {
        _score_EF_Week1.Add((int)PlayerPrefs.GetFloat("CurrentScore"));

        if (PlayerPrefs.HasKey("EF_ScoreWeek1"))
        {
            PlayerPrefs.DeleteKey("EF_ScoreWeek1");
        }

        PlayerPrefs.SetInt("Week1Day", _score_EF_Week1.Count);

        for (int i = 0; i < _score_EF_Week1.Count; i++)
        {
            PlayerPrefs.SetInt("EF_ScoreWeek1" + i, _score_EF_Week1[i]);
        }
    }

    if (levelNumber == 2)
    {
        _score_EF_Week2.Add((int)PlayerPrefs.GetFloat("CurrentScore"));

        if (PlayerPrefs.HasKey("EF_ScoreWeek2"))
        {
            PlayerPrefs.DeleteKey("EF_ScoreWeek2");
        }

        PlayerPrefs.SetInt("Week2Day", _score_EF_Week2.Count);

        for (int i = 0; i < _score_EF_Week2.Count; i++)
        {
            PlayerPrefs.SetInt("EF_ScoreWeek2" + i, _score_EF_Week2[i]);
        }
    }
}

```

Figure 9: Update Score

Q Learning Algorithm

Research team decided to implement this application using RL which is a main branch of ML. According to the RL concept Dementia patient acts as agent of the gaming environment and based on the action performed by agent rewards will be given to the agent. RL contain two type of algorithm named model-base and model-free. For our solution we used Q- Learning algorithm which is a model-free algorithm for RL.

```

public class MainMenuControlScript : MonoBehaviour
{
    public SceneFader fader;
    public Button[] levelButtons;

    // Start is called before the first frame update
    void Start()
    {
        int levelsUnlocked = PlayerPrefs.GetInt("levelsUnlocked", 1);

        for (int i = 0; i < levelButtons.Length; i++)
        {
            if(i+1 > levelsUnlocked)
                levelButtons[i].interactable = false;
        }
    }

    public void Select(string levelName)
    {
        fader.FadeTo(levelName);
    }
}

public class SceneFader
{
    internal void FadeTo(string levelName)
    {
        throw new NotImplementedException();
    }
}

```

Figure 10: Unlocking the steps and levels

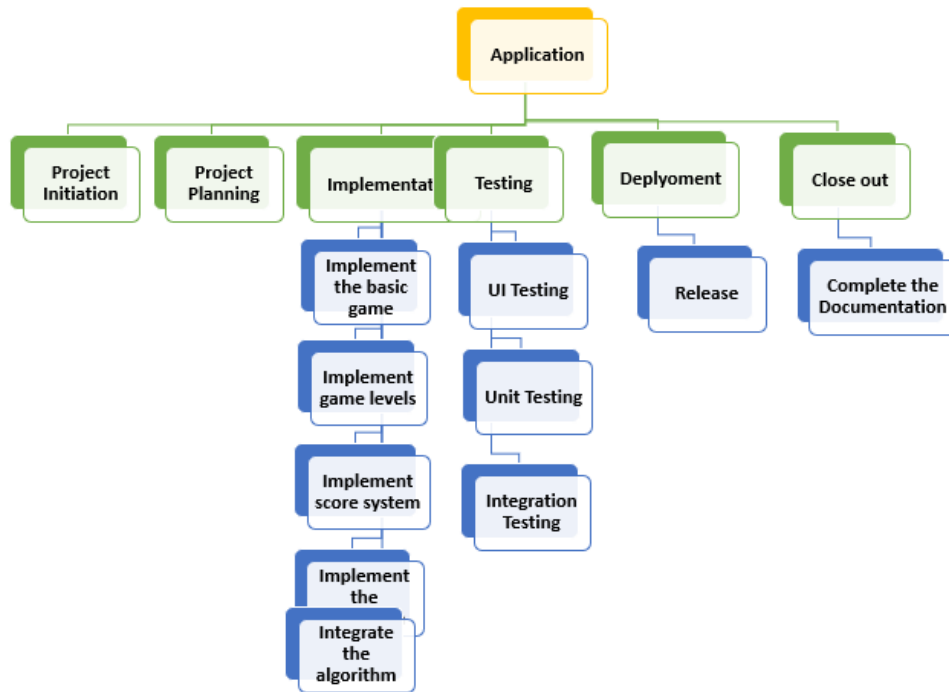


Figure 11: Work Breakdown Structure

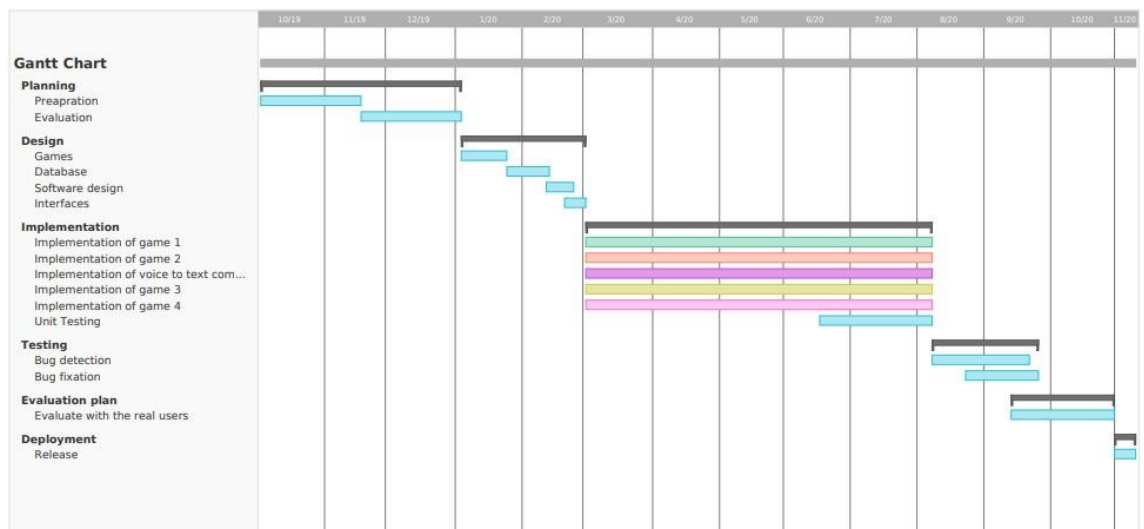


Figure 12: Gantt Chart

2.3.2 Testing

The “Personalized solution for Dementia Patients with continuous monitoring” application is unit tested via all the implementations, in order to ensure the individual module functioned according to the expected output. The reason for existing is to approve that every unit of the product code proceeds true to form. Unit Testing is finished during the development (coding period) of an application. Unit Tests segregate a part of code and check its rightness. A unit might be an individual function, method, module, or object.

There are various computerized apparatuses accessible to help with unit testing. The Unity Test Framework (UTF) empowers Unity clients to test their code in both Edit Mode and Play Mode, and furthermore on track stages, for example, Standalone, Android, iOS, and so forth. This bundle gives a standard test framework to clients of Unity and engineers at Unity with the goal that both profit by similar highlights and can compose tests a similar way. UTF utilizes a Unity incorporation of NUnit library, which is an open-source unit testing library for .Net languages. It is a balanced and more elucidating naming for the toolset also called Unity Test Runner [17].

Below are examples of tests performed by the Unity Test Runner.

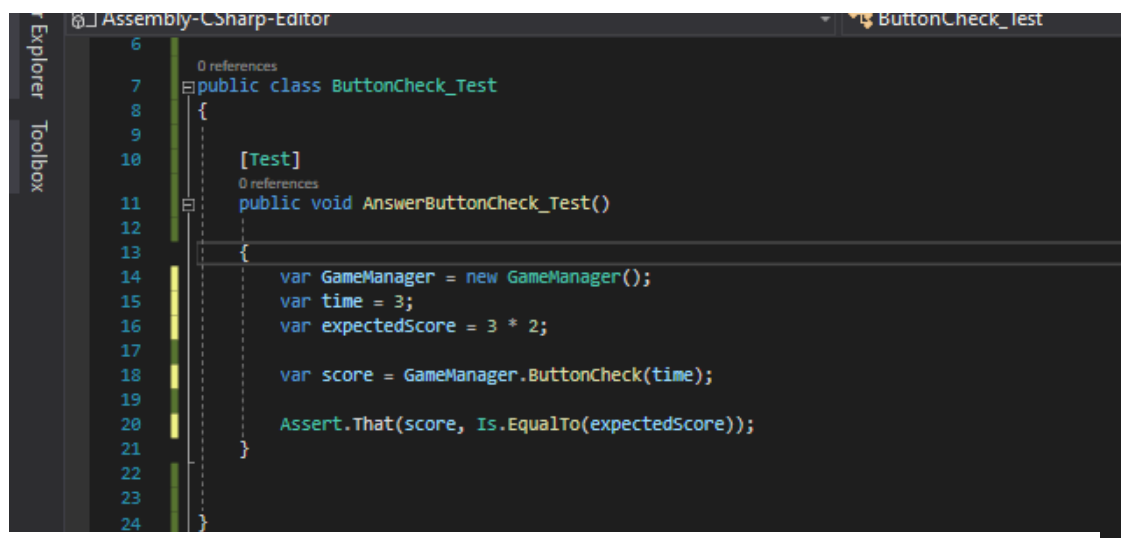
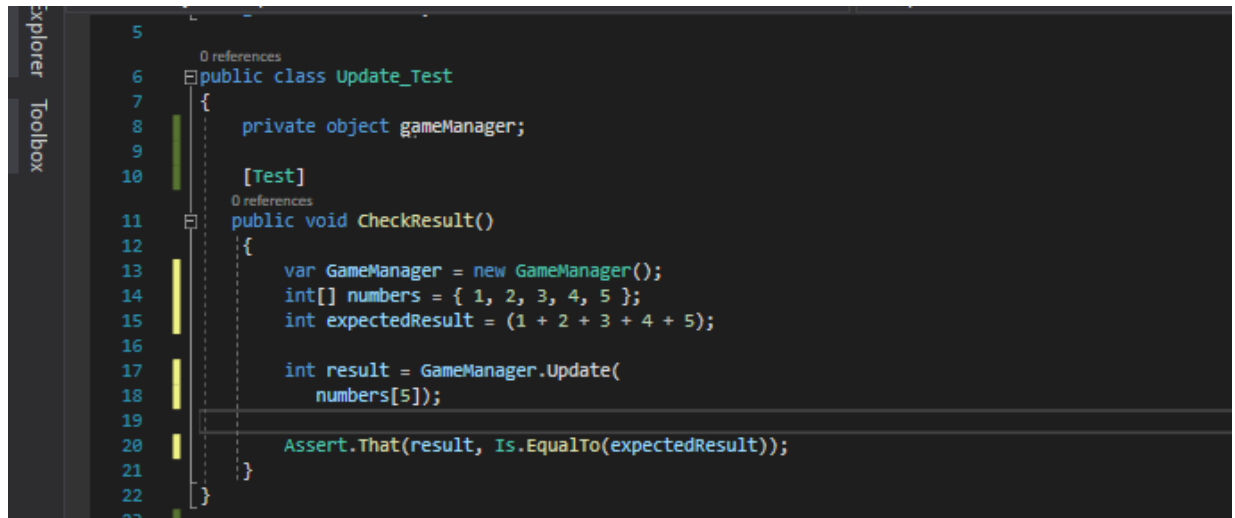


Figure 13: Test Class for checking score



```

5
6 0 references
7 public class Update_Test
8 {
9     private object gameManager;
10
11     [Test]
12     0 references
13     public void CheckResult()
14     {
15         var GameManager = new GameManager();
16         int[] numbers = { 1, 2, 3, 4, 5 };
17         int expectedResult = (1 + 2 + 3 + 4 + 5);
18
19         int result = GameManager.Update(
20             numbers[5]);
21
22         Assert.That(result, Is.EqualTo(expectedResult));
23     }

```

Figure 14: Test Class for calculating math problem

In this game, it should be tested whether it shows the correct answer to the math problem shown once (Figure 14). Only if there is such a correct answer can the person doing the game move forward without any problem. Therefore, it is important to test the most important part of this game without confusing the patient.

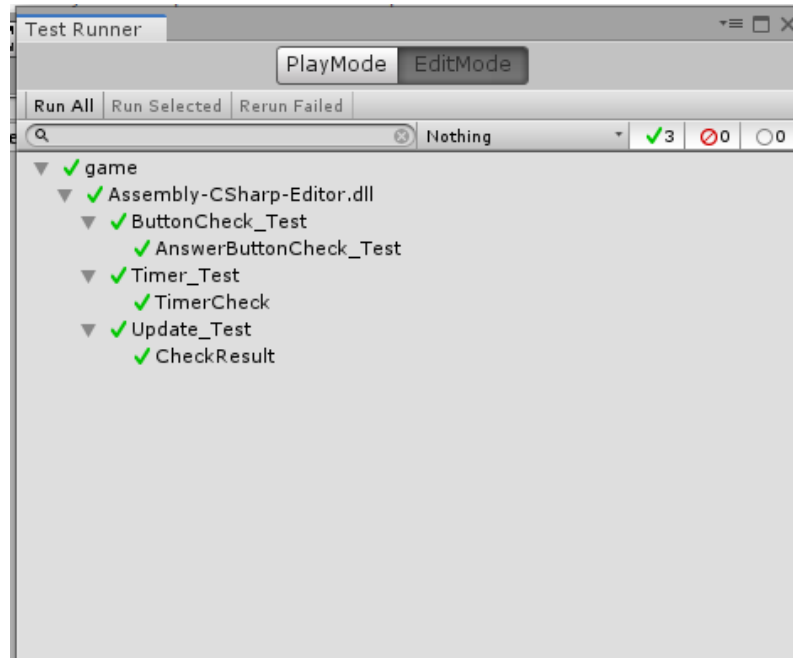


Figure 15: Test cases are running on Unity Test Runner

Table 2: The patient selects an answer for a mathematical problem

Test ID	01
Description	The patient selects an answer for a mathematical problem.
Pre-condition	A number set should be displayed.
Steps	<ol style="list-style-type: none"> 1. “Start” the game. 2. Select the correct answer from the three multiple choices.
Extensions	If the patient selects a wrong answer, the button turns red and the score will increase otherwise it turns green.
Expected output	The button turned green and score increased.
Actual output	The button turned green and score increased.

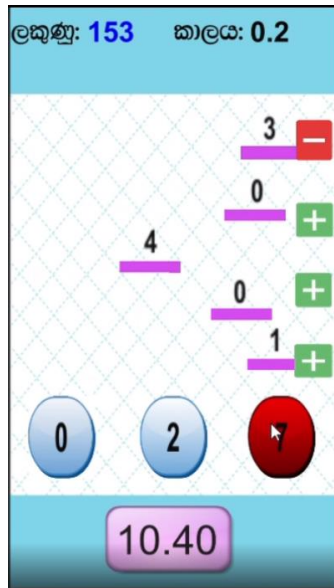


Figure 17: Selecting a wrong answer

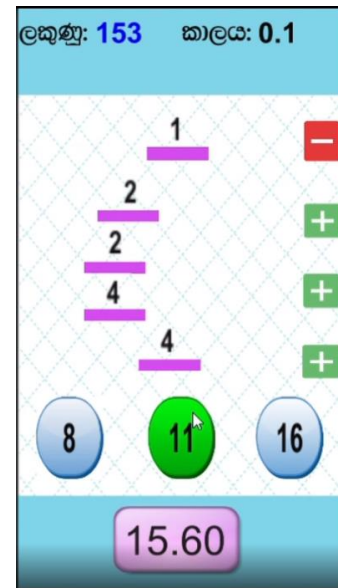


Figure 16: Selecting a correct answer

Table 3: Test case for checking the timer for changing number sets.

Test ID	02
Description	Once the patient answer is selected, the timer for changing the number sets is recalculated from 0.
Pre-condition	The patient should be selected an answer.
Steps	<ol style="list-style-type: none"> 1. “Start” the game. 2. First time select an answer from the three multiple choices. 3. The second time an answer is not selected.
Extensions	If the patient selects an answer, the timer goes back to 0 and starts again.
Expected output	<p>The first time, after selecting an answer the timer starts again from 0.</p> <p>The second time, after the full fixed time is over, start again from 0.</p>
Actual output	<p>The first time, after selecting an answer the timer starts again from 0.</p> <p>The second time, after the full fixed time is over, start again from 0.</p>

In this game there are two timers. One is to change the number sets and the other one is to finish the game. This test case about checking the timer for the changing number sets (Table 4.2).

Performance Testing

For the evaluation cycle of this application, the research group gets two examples of patients with dementia. The most significant component of this application is that it predicts the following level of the game as indicated by the performance of the past game that the patient has played. Consequently, this application referred to as a personalized application. Moreover, the fundamental reason for assessing this application is the

appropriateness of the customized application over the normal application. One example of patients will utilize this customized application for a time of one month. As referenced before, the idea of the RL calculation utilized for this personalization cycle. The subsequent gathering will utilize the same game application that does exclude a RL calculation. One month after the course of events, the framework assessment measure can be finished by watching the records of every patient gathering and assessing whether the framework is worthy or not.

2.4 Commercialization

As many times mentioned earlier, Dementia has become the most well-known disease over the globally. The same problem has occurred in Sri Lanka as well. This research was done due to a requirement received from Dr.Chathurie Suraweera (Senior Consultant at National Hospital, Colombo/ Senior Lecturer in Department of Psychiatry, Faculty of Medicine, University of Colombo). Therefore, this can be introduced as a real-world requirement. As well as, it can be said that such an application is essential for a dementia patient. Since this is a doctor's requirement, a doctor will not hesitate to introduce such an application. After checking the MMSE test of the patients who come to the doctor, if the patient needs this application for their treatment, the doctor can introduce it.

Basically, several factors influenced the doctor to feel the need for such an application. First of all, we already know that there is no cure for Dementia but, there are some kind of prescribed drugs for control this syndrome. In addition to these medications, the doctor may prescribe some other treatments. They are physical activities. But patient has to see a doctor regularly to do them. The doctor said that it would be great for the patient and the caregiver if there was anything, they could do to do such activities at home.

This system is based on the four major components of Dementia. Therefore, any kind of dementia patient can use this as a treatment for their sickness. Also, the best thing to send this application to Dementia patients is that it is made in Sinhala language. However, there are plenty of applications like this for dementia patients to use but they are all made in English language and their environment is not very suitable for the culture of our country.

But most of the time the English knowledge of the older generation in our country can be lost at the best level. It seems that there is no mobile application made in the language of our country specially for this disease. Therefore, having such a feature is a great help to commercialize this application among the people.

3. Results and Discussion

3.1 Results

The principle and the hugest consequence of making Customized Application for Dementia patients is to help those patients by giving recovery in an insightful way using different kinds of games and exercises. The first thing that catches your eye when you look at any application is its appearance. The main feature of this component is the game. (Figure 15)

As mentioned earlier, there are 7 steps in each level. Patient can see the his/her particular progress from a graph. Each step of the game running two minutes and patient should solve math calculations as much as within that two minutes. Progress graph is generated by using count of correct tries (Figure 16).

Generating the progress = $(\text{Count of correct tries} / 120 \text{ seconds}) * 100\%$

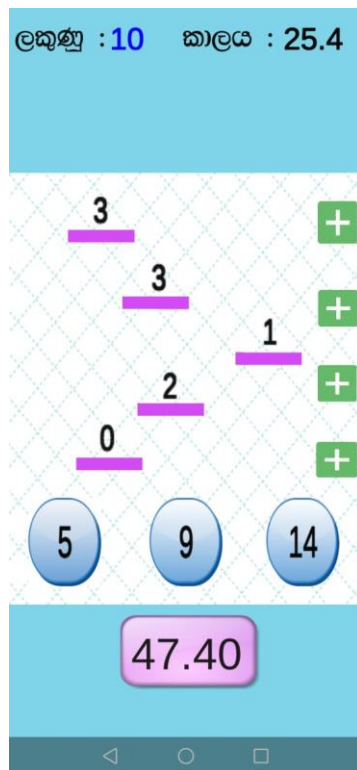


Figure 19: Interface of the game

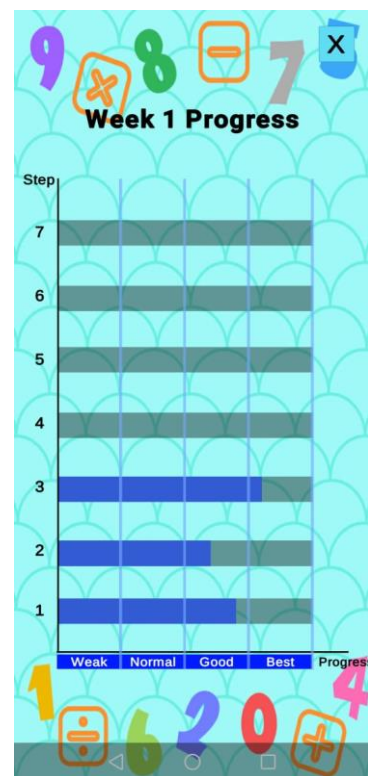


Figure 18: Progress chart

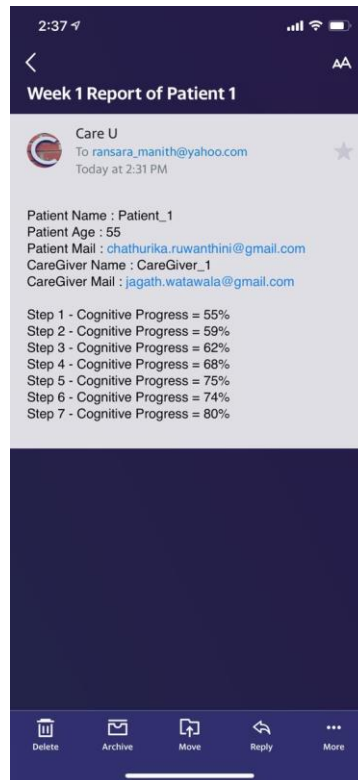


Figure 20: Sample test of sending progress report to doctor.

Then, we achieved a special result of this application which is the feature of connection between the Patient's doctor and this application. End of every week, a report of weekly progress will send to the doctor via an email.

3.2 Research Findings

The main objective here is to implement a game that can enhance the executive functioning skills of Dementia patients and help them to function better in their daily lives. That game is made in Sinhala language because it was essential to make this application in Sinhala language. The reason is that there is no currently available application in Sinhala that is suitable for our country. This includes a special feature. In short term, it can be introduced as a personalized application. To put it another way, the next steps vary

depending on how the patient plays the game. The reason for doing so is that not all people have the same level of intelligence. Each's logical ability varies.

We used reinforcement learning algorithms such as Q-Learning, Deep Q-Learning to get the predictions for the next level game variables to give users a customized game. In some games had to implement the algorithm using more than one algorithm because of the limitations they had.

We gathered and analysed the progress results of the users using same application with and with using machine learning technologies. With the results we can say the personalized application shows good results than the other.

3.3 Discussion

This section mainly focuses on discussing the problems that faced during design and implementation and how those issues were resolved. In addition, this section discusses how to improve the system and succeed in gaining the achievements.

The research study " Cognitive Rehabilitation based Personalized Solution for Dementia Patients utilizing Reinforcement Learning " was begun on November 2019 to discover a best customized answer for recovery of Dementia tolerant through an electronic gadget. The arrangement was recognized as a versatile application with games and activities utilizing present day technologies like Reinforcement Learning and Deep Neural Network.

The first question we face is to which cognitive functions to choose for this application. Then we arranged several meetings with the external supervisor and talked about it and made a final decision. Various problems arose in designing games and activities to suit selected cognitive functions. This is because each of the cognitive functions must be designed in the same way as the treatments given by the doctor. When implementing the algorithms for predicting next steps of some games there were some issues came up

because the selected ML area. According to the Q learning algorithm it was hard to apply without fixed number of actions. Therefore, as a solution for that used the Deep Q learning algorithm also.

When integrating four parts which were executed independently, there were numerous bugs. The greatest issue was framework smashing. In there, in the wake of incorporating parts, the email framework utilizing SMTP was crashed. In this way, we needed to actualize it again as a result of it.

4. Conclusion

Dementia patients need exercises for Cognitive restoration. To give the patients customized treatments, an easy to use application was created in an intuitive manner including games and exercises. These games and exercises are under four fundamental utilitarian zones from Frontal and Temporal projections of Cerebral cortex. The primary goal of each game or action is to improve the pertinent cogitative functionalities of the patients in customized way. The games are executed in contact screen and all the vital spots both Sinhala and English dialects are utilized taking out the hole among Sinhala and English and the innovation hole for the older individuals. This will assist the patients with getting redid and most fit recovery for the Dementia patients.

Concerning the future work, the application can be improved by expanding the precision of anticipating the following degree of the games. We would like to present more games covering the other utilitarian zones identified with Frontal flap and Temporal projections of the Cerebral cortex. What's more, to incorporate the test to distinguish the Dementia patients utilizing ML.

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8. Glossary

Dementia - Disorder in which there is decay in memory, thinking, conduct and the capacity to perform ordinary exercises.

Executive Functions - Lot of intellectual cycles that are important for the psychological control of conduct:

Reinforcement Learning - Area of machine learning concerned with how software agents ought to take actions in an environment in order to maximize the notion of cumulative reward.

PlayFab - Complete backend stage for live games with oversight game administrations, ongoing investigation.

7. Appendices

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class Set1 : MonoBehaviour
{
    private GameManagerScript GMS;

    public Text[] numbersText = new Text[5];
    public int[] numbers = new int[5];

    public float time;
    public float roundLength;

    public Text timeText;

    public Button[] buttons;

    public float[] Answers;

    public float result;

    public float score;
    public Text scoreText;

    public float Level;
    public int[] maxScore = new int[30];
    public Text levelText;

    public AudioSource source;
    public AudioClip[] clips = new AudioClip[2];

    private int _correctTries = 0;

    // Start is called before the first frame update
    void Start()
    {
        GMS = GameObject.Find("Manager").GetComponent<GameManagerScript>();

        time = 0.1f;
        source = gameObject.AddComponent<AudioSource>();

        for (int i = 0; i < maxScore.Length; i++)
        {
            maxScore[i] = (i + 100) * (i + 1);
        }
    }

    // Update is called once per frame
    void Update()
    {
        if (GMS.counterDownDone == true)
```

```

{
    time -= Time.deltaTime;
    timeText.text = time.ToString("f1");

    displayResults();

    for (int i = 0; i < maxScore.Length; i++)
    {
        if (score >= maxScore[i])
        {
            Level = i + 1;
            levelText.text = "LEVEL : " + Level.ToString();
        }
    }

    if (time <= 0)
    {
        time = roundLength;
        randomNums();
        result = numbers[0] + numbers[1] + numbers[2] + numbers[3] +
numbers[4];
        displayResults();

        Answers[0] = result;
        Answers[1] = result + Random.Range(1, 6);
        Answers[2] = result - Random.Range(1, 6);
        ShuffleArray(Answers);

        for (int i = 0; i < buttons.Length; i++)
        {
            buttons[i].image.color = Color.white;
        }
    }
}

void randomNums()
{
    if (GMS.counterDownDone == true)
    {
        for (int i = 0; i < numbers.Length; i++)
        {
            numbers[i] = Random.Range(0, 5);
            numbersText[i].text = numbers[i].ToString();
        }
    }
}

void displayResults()
{
    if (GMS.counterDownDone == true)
    {
        for (int i = 0; i < buttons.Length; i++)
        {

```



```

        buttons[i].transform.GetChild(0).GetComponent<Text>().text =
Answers[i].ToString();
    }
}

public static void ShuffleArray<T>(T[] arr)
{
    for (int i = arr.Length - 1; i > 0; i--)
    {
        int r = Random.Range(0, i);
        T tmp = arr[i];
        arr[i] = arr[r];
        arr[r] = tmp;
    }
}

public void ButtonCheck(int buttonNum)
{
    if (buttons[buttonNum].transform.GetChild(0).GetComponent<Text>().text ==
result.ToString())
    {
        Debug.Log("Correct !");
        buttons[buttonNum].image.color = Color.green;
        score += 10;
        scoreText.text = score.ToString("0");
        source.PlayOneShot(clips[0]);
        _correctTries++;

        PlayerPrefs.SetInt("CurrentCorrectCount", _correctTries);
        PlayerPrefs.SetFloat("CurrentScore", score);
    }
    else
    {
        Debug.Log("Wrong !");
        buttons[buttonNum].image.color = Color.red;
        //score -= 15;
        scoreText.text = score.ToString("0");
        source.PlayOneShot(clips[1]);
    }

    time = 0.3f;
    if (score >= 0)
    {
        scoreText.color = Color.blue;
    }
    else
    {
        scoreText.color = Color.red;
    }
}
}

```

```

using System;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class MainMenuControlScript : MonoBehaviour
{
    public SceneFader fader;
    public Button[] levelButtons;

    // Start is called before the first frame update
    void Start()
    {
        int levelsUnlocked = PlayerPrefs.GetInt("levelsUnlocked", 1);

        for (int i = 0; i < levelButtons.Length; i++)
        {
            if(i+1 > levelsUnlocked)
                levelButtons[i].interactable = false;
        }
    }

    public void Select(string levelName)
    {
        fader.FadeTo(levelName);
    }
}

public class SceneFader
{
    internal void FadeTo(string levelName)
    {
        throw new NotImplementedException();
    }
}

```