

# **Brain Gains**

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## Declaration

I hereby certify that this material, which I now submit for assessment on the program of study as part of **B.Sc.Computer Science and Software Engineering** qualification, is *entirely* my own work and has not been taken from the work of others - save and to the extent that such work has been cited and acknowledged within the text of my work.

I hereby acknowledge and accept that this thesis may be distributed to future final year students, as an example of the standard expected of final year projects.

Signed: Akil Rufus Tenali

Date: 23/03/2021

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## **Abstract**

The decline of our cognitive abilities leads to a loss of everyday functions, such as, thinking, reading and remembering. With Dementia projected to double in the next 25 years in Ireland, it is vital to take preventative actions now. This application, Brain Gains, aims to provide a platform to play a variety of games and help users learn about slowing cognitive decline. This rehabilitation tool is fit to allow users who prefer video games an opportunity to improve cognitive abilities. This project provides games, which are backed by studies completed by professionals, to create effective and simple games. When users desire to complete a certain task, it creates a better environment for them to improve their cognitive functions.

Compliance becomes vital in this process, the more willing the user is to play the game, the higher chance at improving cognitive functions. As seen through various articles and testing completed during this project.

# Chapter one: Introduction

## Summary

The goal of this project is to develop a web application on which users can play games and learn about cognitive decline. The primary user group is people who want to improve their cognitive abilities and keep their cognitive functions healthy. After playing the games in the application, the users will be able to educate themselves on Dementia and what can be done to slow the cognitive decline.

### 1.1 Topic addressed in this project

The main aim of this project is to create a web application where users can play games to improve their cognitive abilities, educate themselves on what cognitive decline is and how we can slow it. They will be shown information on what actions they can take to help them in the future and provide them with an option for slowing cognitive decline with this application.

### 1.2 Motivation

Dementia is a loss of cognitive functions, such as talking, thinking, remembering; they can be menial everyday actions such as following a routine. This makes everyday life difficult and can even hinder relationships with family and others.. In Ireland numbers will double in the next 25 years, In Ireland numbers will double in the next years, demonstrating a need to proactively alert the population at this current time so they can adequately prepare for or prevent this outcome. There is, as of now, no cure for Dementia; it can be due to genetics, injury, or other means, but only preventive actions can be taken. Slowing the cognitive decline, therefore, is currently the only thing that is achievable. There are five things we can include in our everyday lives to help us slow our cognitive decline and keep our cognitive functions healthy. One method is to mentally challenge yourself, and the goal of this application is to provide a way for users to do that.

### 1.3 Problem statement

The focus of this application is to be accessible and inexpensive to the user. There are various applications that have been made to help tackle cognitive decline, but they can be complex to understand and play. This application aims to create more diversity and games that are simple so that users can come back and play again at any time. By including a competitive aspect to the game, it drives them to perform better than previous attempts. There are no set games that are better to help with cognitive decline, therefore it is beneficial to expand the variety of games in order to create more opportunities for users to engage in different ways [each time].

### 1.4 Approach

The following chapters details my development process of this application. A set of goals will be set out to give guidance to the project throughout development. To develop this application, the Agile Methodology will be used, and consistent testing will be carried out on users.

Before beginning to develop the application, I decided to pick a few applications on the market that appeared to share my goals and study them. To see how I could improve on, take idea inspiration from, and follow as a guideline of what is the standard on the market presently.

App Name	Pros	Cons
Big Brain Academy	<ul style="list-style-type: none"><li>- Color, Catching UI</li><li>- Simple to use</li><li>- Fun games</li><li>- Fun competitive games</li></ul>	<ul style="list-style-type: none"><li>- Out of date</li><li>- Seems suited only to kids</li><li>- Not widely available</li></ul>
Lumosity	<ul style="list-style-type: none"><li>- Clean UI</li><li>- Great visual stats</li><li>- History tracker</li><li>- Fun games</li><li>- User accessible</li></ul>	<ul style="list-style-type: none"><li>- Can be expensive for users</li><li>- Games can be complicated</li></ul>
Elevate	<ul style="list-style-type: none"><li>- Clean UI</li><li>- Performance Tracker</li><li>- Achievement incentives</li><li>- Simple games</li></ul>	<ul style="list-style-type: none"><li>- Pay to unlock full app</li><li>-</li></ul>

Table 1 – Market Research

These applications were of great help when it came to coming up with a design for the UI of the application and ideating what games should be developed for the application. It provided great insight into layout and user accessibility.

React.js was chosen for development because of its library for web development. The variety of resources React opens to the developer is immense and the components' structure style is like Ruby on Rails, which I have experience with. React is fast, simple, and responsive for web development and is a great way to implement single page applications. It allows it to be accessible to both mobile and web users.

The application is hosted on Heroku, a container-based hosting service. It is simple and accessible to set up. It has its own Command Line Interface and can also link to a specific GitHub Repo and deploy with ease.

Git was used to keep track of and hold the project for code management. It is a popular option for version control and was impactful in the development process. It allowed me to make various branches and merge them when it was working remotely and locally. It also allowed me to rollback to a past version if a current version was not functioning as it was supposed to.



## **1.5 Metrics**

During the development of the application, I will test the application myself by using Firefox's developer tools to make sure that it will function properly and be compatible with different devices. After completing the games, I will open the application to a few users to test the game. I will create two user groups, both playing the game at two recorded sessions, with one playing the game continually and one playing it only twice. With those results acquired, I will compare results and the two groups and how the performance differed. I will also ask them to give feedback on the application, in particular whether they would play it again, were they able to use it well enough and any other general comments.

## **1.6 Project**

This project resulted in several achievements; ones completed were as follows:

- 1) Develop a fully functional web application
- 2) Create at least two games users can play
- 3) Provide an information page to inform users [on what?]
- 4) Host the web application
- 5) Understand better what is useful for users for slowing cognitive decline

# Chapter two: Technical Background

## Summary

This chapter goes into detail about my material and technical research that went into the development of the project.

## 2.1 Topic material

### 2.1.1 Memory

*What is Memory?*

Memory is the process to acquire, store, retain and be able to retrieve that information. There are three processes involved in memory: **encoding**, **storage**, and **retrieval**. . (*What Is Dementia?*, n.d.)

To be able to create new memories, we begin with the process known as **Encoding**; *visual*, *acoustic*, *elaborative*, and *semantic* are the 4 types of encoding. These all represent different areas that we can process and receive information from. . (*What Is Dementia?*, n.d.)

**Encoding**: Encoding is the process by which we learn information and how we take it in and understand it. (*What Is Dementia?*, n.d.)

*Visual Encoding*: The process of encoding images and visual sensory information, including the creation of mental images. This is stored in iconic memory before being moved to long-term memory. (*What Is Dementia?*, n.d.)

*Acoustic Encoding*: This is the use of auditory stimuli or hearing to implant memories. This is aided by a phonological loop, which is the process of repeating something said or heard to remember it. (*What Is Dementia?*, n.d.)

*Elaborative Encoding*: This is using old memories to relate to new information that is being received. This depends on already-known information as much as it does on new information. Studies have shown this is an effective way to improve retention in long-term memory. (*Lumen*, n.d.)

*Semantic Encoding*: This involves the use of sensory input that has specific meaning or can be related to a specific context. Such as Chunking and mnemonics; examples such as remembering a food based on what colour it is. (*Lumen*, n.d.)

**Storage**: Storage refers to how much is being stored and for how long. There are two different types of memory: *Long-term* and *Short-term* memory. Memory is first encoded into short-term memory and, if necessary, it is moved into long-term memory. (*Lumen*, n.d.)

**Retrieval**: This is the process of being able to search and recall memories from either short or long-term.

## 2.1.2 Issues with Memory/Memory Loss

There can be various issues with memory, whether it's lethologic, the tip-of-the-tongue phenomenon, or more severe cases such as Dementia.

*What is Dementia?*

**Dementia** is the loss of cognitive functions such as remembering, thinking, speaking, to an extent that interferes with the person's everyday life. (NIA, 2021)``

There are several types of Dementia such as:

- Alzheimer's Disease
- Lewy Body Disease
- Vascular Dementia
- Front-temporal Dementia
- Early Onset Dementia

*What Causes Dementia?*

Dementia is the term to describe a group of conditions that cause damage to the brain cells. Dementia is caused by damage to or loss of nerve cells and their connections in the brain . (Mayo Clinic, 2017), whether it's physical damage or genetics or lack of education etc. . (Mayo Clinic, 2017), whether its physical damage or genetics or lack of education etc. (Pierse et al., 2019) Dementia affects people differently and causes various symptoms.

With Alzheimer's specifically, it is a slow cognitive decline over years, caused by Tau and Amyloid, proteins in your brain, clumping together to disrupt the memory process. There is a progressive build-up of abnormal clumps of protein that causes damage to the nerve cells in the brain.

*Risk Factors*

There is an assortment of Risk Factors when it comes to Dementia, some being non-changeable and some changeable to lessen the risk factor. (Mayo Clinic, 2017)

Non-Changeable:

- Age
- Family History of Dementia
- Down Syndrome

Changeable:

- Diet and Exercise
- Excessive Alcohol Use
- Cardiovascular Risk Factors
- Depression
- Diabetes
- Smoking

- Air pollution
- Head Trauma
- Sleep Disturbance
- Vitamin and Nutritional Deficiencies
- Medication that can worsen memory

### 2.1.3 Tackling Dementia [up for reconsideration]

Currently in Ireland over 64,000 people have Dementia and those numbers will double in the next 25 years to over 150,000 by 2045. There are as much as 11,000 new cases of Dementia in Ireland every year: 1 in 10 being under the age of 65. (Ienca et al., 2017)

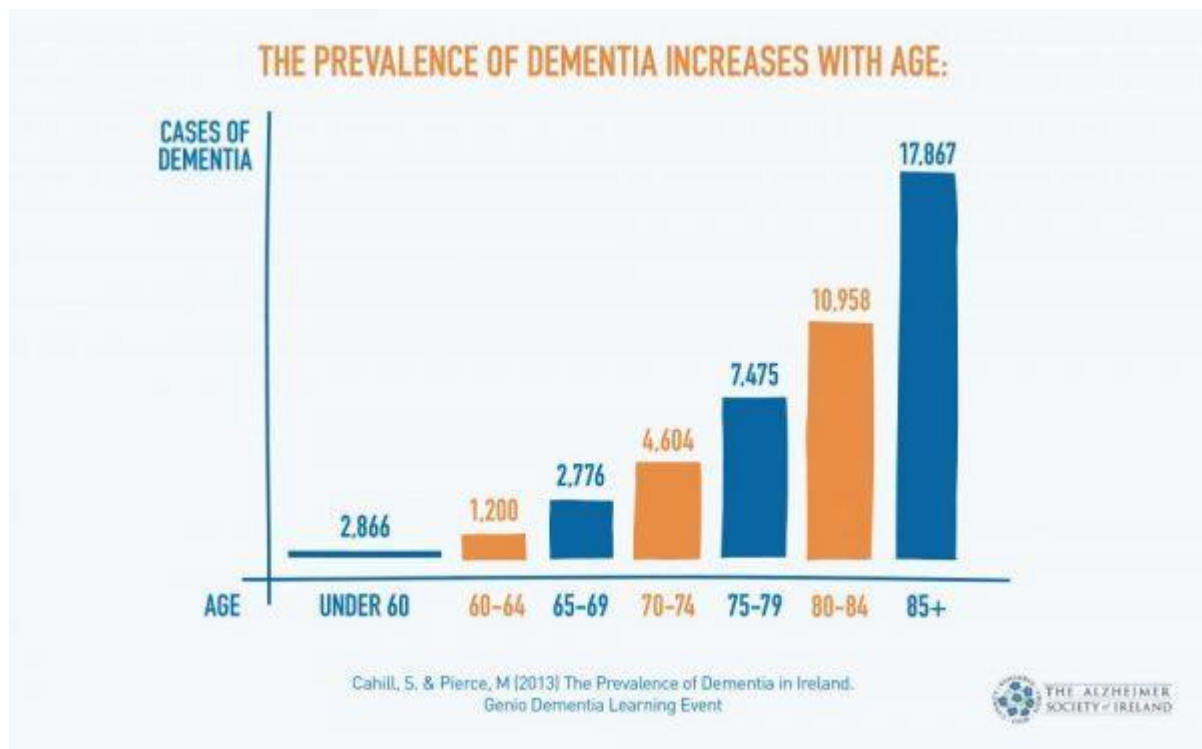


Figure 1 – Dementia statistics in Ireland through the various age groups.

#### *What can be done?*

There are a variety of things we can do to slow the cognitive decline, to take preventative action now.

These are 5 Steps we can take to reduce risk of dementia:

1. Be Physically Active
2. Eat a Healthy Diet
3. Take care of your heart
4. Mentally challenge yourself
5. Be socially engaged

Mentally Challenging yourself is an excellent way to help reduce risk and slow cognitive decline, and this can be achieved through playing games such as chess, sudoku, crosswords or even digital games. Playing Matching card games or scrambling words can be a great addition to your arsenal of keeping your brain active.

From people with Down Syndrome [7] to games made specifically for Alzheimer's [8], video and digital games have become a great resource with a plethora of potential and more areas to explore.

This is what my thesis proposes to examine, what can we do to help people keep their cognitive ability well and active.

Video games have the potential to induce higher rates of intervention compliance compared to other cognitive interventions. [9] With the information that I have collected and studied for some participants, video games can be a great resource for them cognitively and mentally.

## **2.2 Technical material**

Here I discuss the various technical materials I researched and the technology I chose to use in my project.

### **2.2.1 React.JS**

React was one of my first choices when it came to choosing what library to use, as it is helpful for developers for building user interfaces. React is a component-based JavaScript library; these components make application building smooth and simpler. These Components are a mix of HTML and JavaScript and contain all the logic that is needed to run it. React uses a unique syntax called JSX, which allows us to write HTML elements in JavaScript and sets them into a DOM. (*React – A JavaScript Library for Building User Interfaces*, n.d.)

DOM stands for Document Object Model, which is a Programming interface for web documents. It represents the page, so it is accessible for the documents to change structure, style, and content. It in a sense is an object and nodes, which lets programming languages interact with it.

### **2.2.2 Git**

I used Git throughout my project to keep track of my progress and keep my files together in one place for the convenience of my work and proved to be extremely useful for my project.

Git is a distributed version control system that is designed to handle small and large projects while being open and free source. Git has a small footprint while performing very fast with features such as cheap local branching, convenient staging areas, and multiple workflows.

Git makes it easy to create different versions of the project and be able to compare them, whether it's past versions compared to current projects or various branches. This makes it easier to restore past versions of the project, making it great for consistency.

Since Git has a local and remote workspace it makes working on a big team efficient and backing up easy. If files were lost, it would make retrieval easy, and having the whole project up on GitHub made sure no updates to the project were lost. (*Git*, n.d.)

### **2.2.3 Heroku**

Heroku was used to host the application and was simple and seamless to set up. Heroku is a container-based cloud platform and makes deploying a web application flexible and viable to developers.

Heroku has GitHub integration and their own Command Line Interface (CLI). Once Heroku is linked with GitHub you can choose which Repository to connect to and it will install its packages and deploy the container. Likewise, you can create your application through Heroku or their Git CLI and deploy through that. (*What Is Heroku* | *Heroku*, n.d.)

### **2.2.4 Bootstrap**

Bootstrap is a front-end framework, made open-source for web developers. It is built on HTML, JavaScript and CSS and is designed to help make mobile and web applications responsive. It works with components that act like snippets and can be added into code with ease. Import Bootstrap and have access to the Bootstrap library with a variety of resources for web development.

It made the process of creating the layout of the website simple and efficient. Being able to use a navbar component helped with setting up the page and giving it a pleasant look. (Bootstrap, n.d.)

## **2.3 Analysis**

This project is aimed at creating a web application that can aid users in slowing their cognitive decline and improve cognitive abilities. There have been several papers and studies conducted on assistive technologies used to help those who are cognitively impaired.

The paper Cognitive Function and Assistive Technology for Cognition (ATC) (Gillespie, A., Best, C., & O'Neill, B., 2012) discusses the relationship between assistive technology for cognition and how effective it can be towards users in supporting them cognitively. This support can be found anywhere, from pen and paper to technology. Reviews have found ATC helps in providing a framework for prescriptions based on cognitive deficits. This opens areas of research and development for ATC. In a paper discussing personalized technology for the cognitively impaired, it was shown that children with Down Syndrome were able to improve functions after having games catered to engage them. It was good in motivating users and helping with tele-rehabilitation and was found to be beneficial for children with Down Syndrome but also beneficial for those cognitively impaired in different aspects. It created a higher response in attention, memory, and executive control; for example, a (Buzzi et al., 2019) classroom game such as Special Words.

In relation to this Video games have been studied specifically as a resource that can be used to improve cognitive abilities. A causal relationship with video games can lead to improvements in visual and attention skills. As stated in a research paper on (Boot et al., 2013), the expert gamers performed better in memory, attention, and executive control than new gamers. Expert gamers have been seen to

outperform newer gamers, having better perception and cognitive measures. Gaming seemed to have a promising outcome when the new gamers also improved on basic skills after playing for a few hours. The process was tested on Airforce pilots; the ones who played space fortress performed better than the ones who did not. Big Brain Academy from Nintendo has been seen to be effective on training your brain cognitively. It targets 5 categories: Thinking, Memorizing, Analyse, Computing and Identifying. It has also been seen to be better integrated than professional psychostimulant games given to those suffering with Dementia to aid them. (McCallum & Boletsis, 2013)

This is also seen in Do action games to improve perception and cognition. Gamers have outperformed non-gamers on perception, and cognitive measures. It can be difficult to see distinct results in the comparison of before and after using video games to increase cognitive abilities. Or it may not seem significant enough to merit it as a viable method, but with correct testing and time periods it can be effective. In a study, it was seen after 5-6 weeks that there was a significant long-term benefit in users who played video games to help with cognitive decline. The authors of a study concluded that memory function mediates the results to the same forms of cognitive training. [preventing Alzheimer's and...]

There is no clear evidence to show that video games or technology are the most effective way to help with cognitive impairment, but in a study done it had a higher compliance rate. (Boot et al., 2013) In this study it was shown that some games had a higher rate for interventions, meaning they preferred to enjoy playing the game. One action game, Mario Kart Racing, had the lowest compliance rate, which suggests one needs to be careful when recommending game intervention. It was found that an increased compliance was key to improving cognitive abilities in a user. When the user is willing to play the game, there is a better engagement, leading to better results in the improvements of abilities.

These higher levels of engagement were seen when users partook in therapeutic games specifically assigned to Dementia users. This game was a one-on-one game, described more in detail in (Boot et al., 2013). They had a higher level of compliance as it was personal and could see that the patients with Alzheimer's Disease had preserved cognitive abilities. This meant that the users suffering with cognitive impairment had cognitive abilities still available in them, but sometimes were unable to activate or access them. Having games where users have a higher compliance rate means that they are more willing to play them, enabling them to improve. The main aim becomes creating games that users may enjoy and want to play, enabling them to have a better chance to improve their skills, slowing their cognitive decline. (Boot et al., 2013) (Williams, JW, Plassman BL, Burke J, Benjamin S., 2010)

## Chapter three: The Problem

### Summary

The problem that is being addressed is the cognitive decline of people and what can be done to slow that decline and how can technology help with this. Here the user requirements are shown, which is desired and vital for the development of this application. This application aims to inform and aid users in their cognitive functions.

### 3.1 Project UML documentation

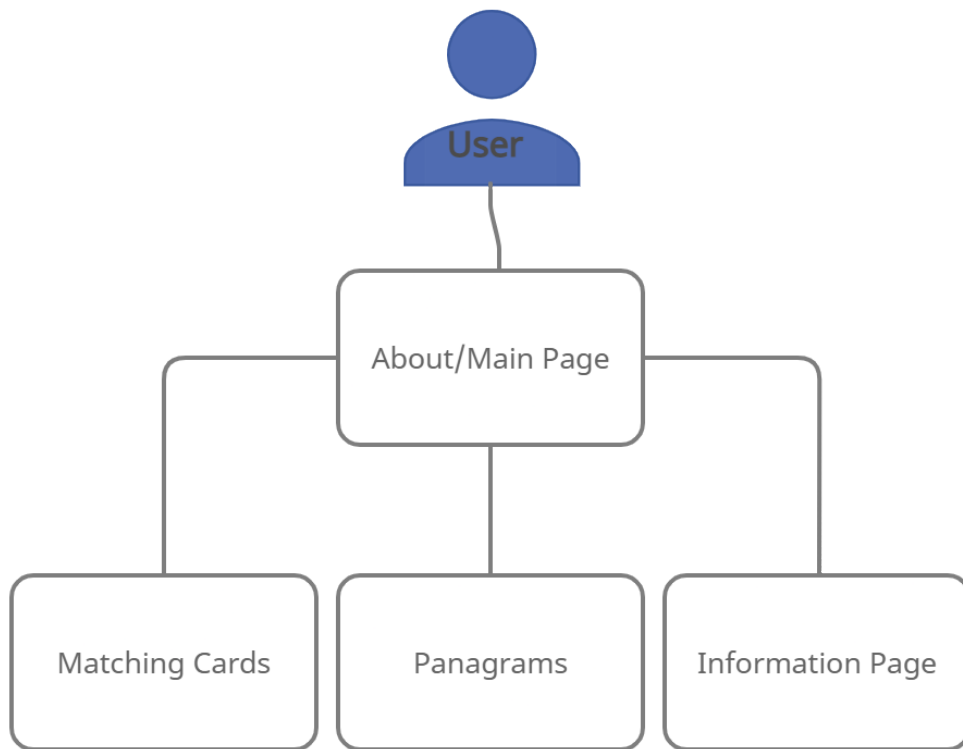


Figure 2 - Initial User Diagram for this project.

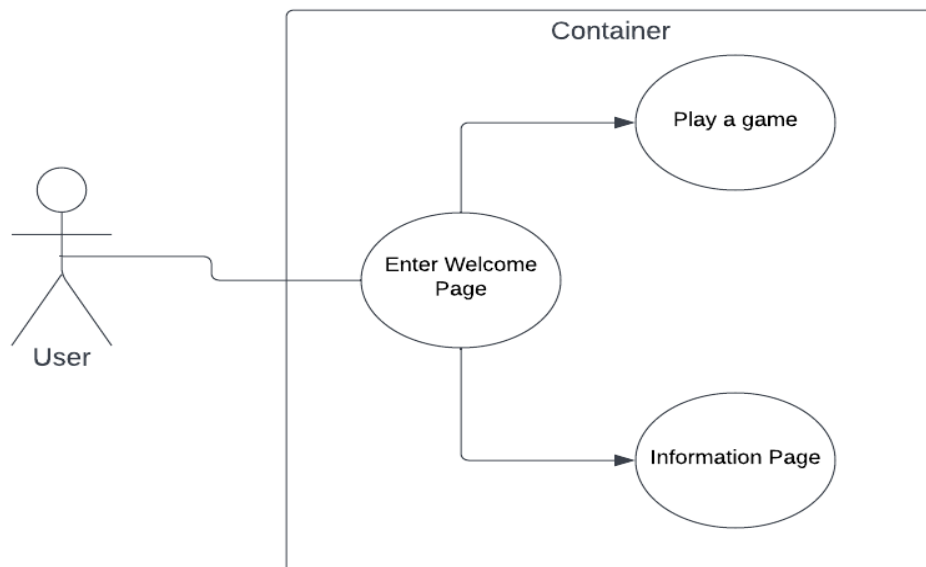


Figure 3 - Use Case Diagram



### 3.2 Problem analysis

To understand what functionalities were needed for this project I created a table to list all the desired requirements. This guided the process to include these key requirements into the application when developing.

Requirements	
Number 1	Create a page to educate users on Dementia and Cognitive Decline
Number 2	Create easy access so users gain Awareness and direct them to official medical websites and professionals
Number 3	Have simple games for user to understand and play
Number 4	Easy Access for mobile and web users

Table 2 - Requirement Table

There is no sure-fire way to slow the cognitive decline of people, it is an inevitable outcome, but there are things you can do to help someone early on. This application is only a tool to guide a user on their process of aiding or improving their cognitive functions, which is the extent of this project.

# Chapter four: The Solution

## Summary

This chapter details the development process the application went through. It entails the various implementations, memorizing methods, design approach and the games I decided to develop.

### 4.1.1 Low Level [Memorizing Methods]

The study of various memorizing methods was a topic that felt necessary to investigate to see what could be applied in this aspect. Visualizing is a method used to imagine doing a certain task to try memorizing it better or picture an object in your mind so it can keep a better copy of it in your storage. This can be very effective for people who prefer to be visually stimulated and fits with the first game in the aspect of visually trying to remember where the different colour cards are.

### 4.1.2 Implementation

This project was developed using the Agile development method. I planned it on Miro, and I would go back on a weekly basis and review what I needed to work on next. Miro was a great way to plan the project, it allowed for very easy addition to the backlog and once something was completed, I was easily able to add it to the completed tasks tab. This helped in keeping a consistent and regular workflow throughout the project. I was able to list all the key main features that were important to the project and break them down further. This made it manageable to work in, making the work seem doable and far less daunting.

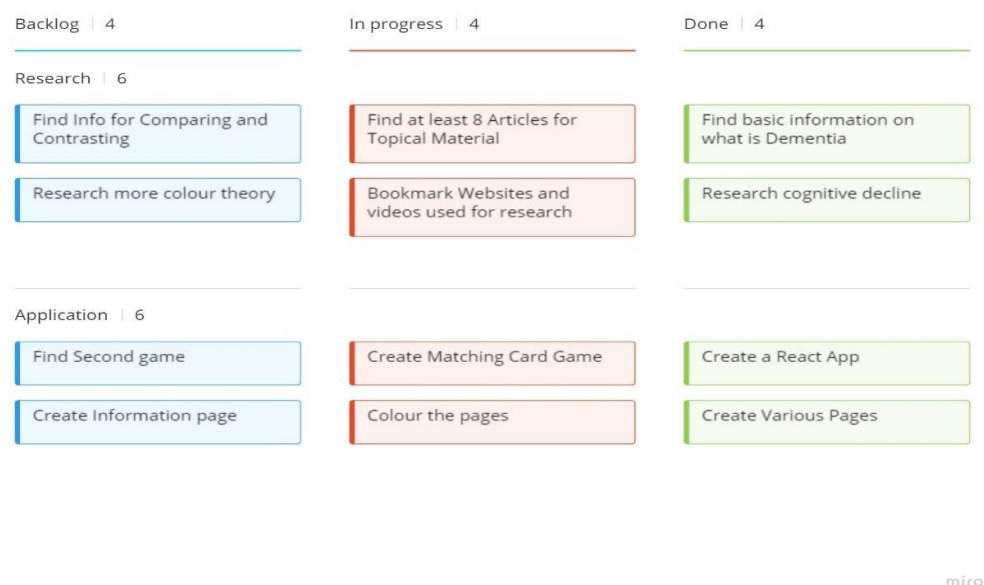


Figure 4 – Agile Development Table

## 4.2.1 Design Approach

This project was designed on Mock Flow [mock flow] from the beginning ideation stages to the final product design at the end. Mock flow was a simple and resourceful website where the wireframes could be created online, including a variety of templates, such as ones for web applications.

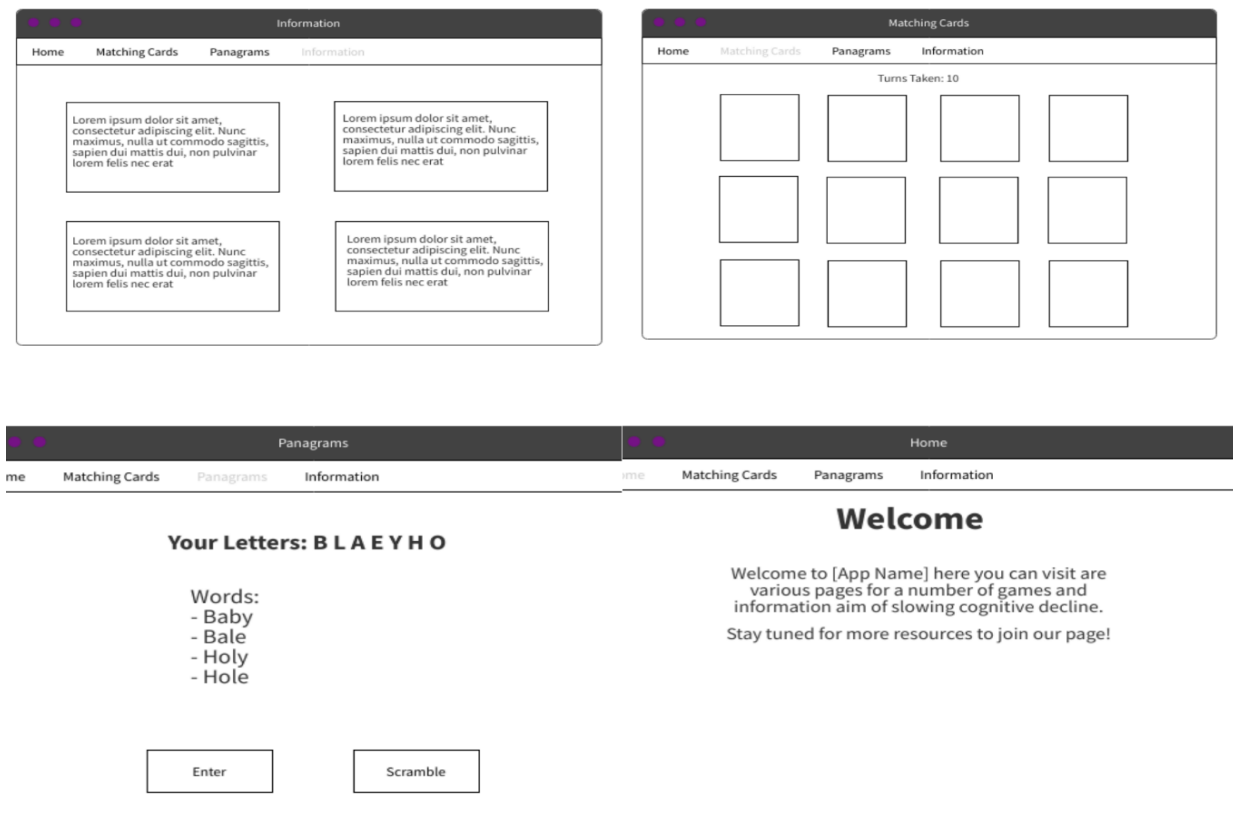


Figure 5 - Wireframes

When it came to designing, colour theory was an important topic that was researched thoroughly. For example, what colours would be beneficial to use, the meaning behind colours and the psychological effect they have on the brain. The Golden Ratio Rule was also adhered to when it came to choosing what colours to use where. The ratio is 60:30:10. The main colour being 60%, 30% being an accent or secondary colour, and the 10% used for the logo and some minimal text.

Two colours that were ideated on at the start were blue and green; Blue indicating calmness and security, which would be good for a learning space for users to feel comfortable in. Green represented growth and renewal, which was fitting for the main purpose of the application.

However, in the end I decided to go with purple as my main colour, along with a shade of white and black/grey. Purple, meaning ambition and creativity, and aesthetically pleasing, was chosen to be the final colour. White and black/grey were chosen to be softer colours to accompany the deep purple, to make the user feel more welcomed. Looking into how Apple uses colours, they put lots of funding into colour theory for all their products, and it subtly has a positive impact on users, even if colour theory

may seem like a secondary concern. This is a reason as to why Apple excel in simplicity in their design but remain professional and appealing to all their users.

## 4.4 Application Features [Games]

### 4.4.1 Matching Cards

This is a common game that most people have played in their life, but can still be effective in that simplicity. The main aim of this game is to test users on their short-term memory, to be able to remember where the colours lie and match them to their corresponding pair. This will aid them to multitask in a short period by remembering what card lies where and thinking of completing the remainder ones as well as trying to complete it in the least amount of turns possible. This is a short and simple game but can be very effective when it comes to encoding memory. The game allows the user to encode memory of the card and be able to recall that in a short span of time. The encoded memory wouldn't be stored in long-term storage, but this activity helps in advancing that cognitive function to encode memory better or at least practice encoding minimal levels of information. If the information is not encoded correctly or not effectively, it would not be stored well and would not be recallable, so encoding stably and efficiently becomes an essential process.

```
76     return (
77       <div className="app">
78         <div className="matching">
79           <h1> Matching Cards</h1>
80           <button onClick={shuffleCards}>New Game</button>
81           <div className="card-grid">
82             {cards.map(card => (
83               <SingleCard
84                 key={card.id}
85                 card={card}
86                 handleChoice={handleChoice}
87                 flipped={card === choiceOne || card === choiceTwo || card.matched}
88                 disabled={disabled}
89               />
90             ))}
91           </div>
92         </div>
93         <p>Turns: {turns}</p>
94       </div>
95     );
96   };
```

Figure 6 - MathingCards.js

### MatchingCards.js

This is the page where the card arrays are created, where they are shuffled, and the logic for comparing and handling choices takes place. Cards are taken from the image file and stored in the array as well as a duplicate for each card to allow for pairs in the game.

### Matching Function

In this function it takes the images stored in the card array and shuffles them into a random order. This function also handles choice, so comparing the two choices made by the player and dictates whether the choices are a matching pair or not, if not the cards flip back, and the game continues. The cards have a matched attribute and if that is set to true, the cards will stay face-up and no longer be clickable.

```

5   const cardImages = [
6     {"src": "/img/red-1.png", matched: false},
7     {"src": "/img/blue-1.png", matched: false},
8     {"src": "/img/green-1.png", matched: false},
9     {"src": "/img/purple-1.png", matched: false},
10    {"src": "/img/yellow-1.png", matched: false},
11    {"src": "/img/pink-1.png", matched: false}
12  ]
13
14  function Matching() {
15
16    const [cards, setCards] = useState([])
17    const [turns, setTurns] = useState(0)
18    const [choiceOne, setChoiceOne] = useState(null)
19    const [choiceTwo, setChoiceTwo] = useState(null)
20    const [disabled, setDisabled] = useState(false)
21
22    //shuffle cards
23    const shuffleCards = () => {
24      const shuffledCards = [...cardImages, ...cardImages]
25      .sort(() => Math.random() - 0.5)
26      .map((card) =>({ ...card, id: Math.random() })))
27      setChoiceOne(null)
28      setChoiceTwo(null)
29      setCards(shuffledCards)
30      setTurns(0)
31    }

```

Figure 7 - Matching Function

## Singlecard.js

This JavaScript file is the object card, it holds the flipped operator and the click function of these cards. While also displaying the card back and front, it is linked to the Singlecard.css file which holds the styles for the individual cards.

```

3  export default function SingleCard({card, handleChoice, flipped, disabled}) {
4
5    const handleClick = () => {
6      if (!disabled) {
7        handleChoice(card)
8      }
9    }
10
11    return (
12      <div className="card" key={card.id}>
13        <div className={flipped ? "flipped" : ""}>
14          <img className="front" src={card.src} alt="card front" />
15          
16        </div>
17      </div>
18    )
19  }
20

```

Figure 8 - SingleCard.js

## 4.4.2 Word Scramble

This game was inspired by the New York Times weekly Spelling Bee game [Spelling Bee] and a game played in my primary school. The role of this game is to tackle and aim for long-term memory and the retrieval of memory. The user is shown a list of seven letters and must create as many words as possible from that set. The idea of this game is to guide the users in practicing their retrieval of their memory, this pushes them to explore their long-term memory in hopes of remembering any word that would fit the requirement. This game is a great way to constantly keep thinking and practice memory retrieval from your storage, which is key for some of those suffering from poor storage retrieval. They struggle with recalling information from their memory storage so playing this game is a great way to sharpen that ability and help prevent the decline of that cognitive function.

### Pangrams.js

Here the letters were randomized using a for loop and a makeletterset() function to output the random letters. Then the words submitted by the user will be compared to the bank of possible words, if the guess matches a word, then they will gain one point.

```
7
8  function makeletterset() {
9    letterset=" ";
10
11    for (let i = 0; i < 7; i++) {
12      //letterset += alphabet.charAt(Math.floor(Math.random() * alphabet.length)) + " ";
13      letterset += vowels.charAt(Math.floor(Math.random() * alphabet.length)) + " ";
14      letterset += constants.charAt(Math.floor(Math.random() * alphabet.length)) + " ";
15      //console.log(letterset);
16    }
17    document.getElementById("demo").innerHTML=letterset;
18    console.log(letterset);
19    return letterset;
20  }
21
```

Figure 8 - Pangrams.js

## 4.5 Problems Encountered

Here is a summary of some of the problems and issues I encountered throughout this project, which are a good reminder for future work and showcase what influenced my learning curve.

- First Time using React. (*React – A JavaScript Library for Building User Interfaces*, n.d.)

This was the first time I used React in a project, and at the start React seemed to have no set structure when it came to using it and was confusing to organize it. After reading the React documentation I had a better understanding of components and how to structure the project. It was better to be simple than more complex to not get lost in my code.

- Narrowing down game ideas

At the beginning the main task was to figure out what games to include in the application, I had to focus on researching and educating myself on what areas are vital to know what games to develop; this caused a delay in developing the game, which led me to choosing only two games for the application.

- Keeping track of all the different resources and references

Research was a big part of this project; having to integrate all the various articles, websites and resources into this project was daunting. Comparing and contrasting is important to display all the information I gained throughout the project and implementing these into the application.

## Chapter five: Evaluation

### Summary

This chapter shows what evaluating methods I used to estimate the performance of the application. Solution Verification, Software Design Verification, Software Verification, User Acceptance Testing.

### 5.1 Solution Verification

This is the Evaluation of the requirements that were ideated and listed in the previous chapter. Most of them were achieved, barring the fourth one. Initially React native was going to be used as well to suit mobile users. However, when it came down to creating it, it was deemed unnecessary at the given time to host the application up on an app store. Including time constraints, it was abandoned; in future work the extension of a mobile application will be taken into consideration.

Requirements		Completed?
Number 1	Create a page to educate users on Dementia and Cognitive Decline	Yes
Number 2	Create easy access so users gain Awareness and direct them to official medical websites and professionals	Yes
Number 3	Have simple games for user to understand and play	Yes
Number 4	Easy Access for mobile and web users	No

Figure 9 - Solution Verification

### 5.2 Software Design Verification

Firefox has built-in developer tools for web applications such as to be able to edit and debug HTML, CSS, and JavaScript.

Firefox was a simple and accessible way to verify the design of the application using all its variety of resources at hand for the developer. Responsive Design allowed testing of responsive window sizes on various devices. Throughout every development level it was tested, giving clear guidance as to how the user was able to view it. Firefox's Console log allowed for testing the application on outputs and on inner

works, while the Inspector and Debugger allowed for checking on code in different parts of the web application and found errors and bugs when running.

## 5.3 Software Verification

Google Lighthouse was chosen for testing the quality of web pages, it is open source and is an automated tool to all web developers through Google Chrome built-in tools. Google Lighthouse audits performance, accessibility, search engine and optimization of web pages.

There are categories it produces a score for in form 1 – 100: Performance, Accessibility, Best Practices and SEO (Search Engine Optimization). Once running you will be given a grade, such as seen in this figure.

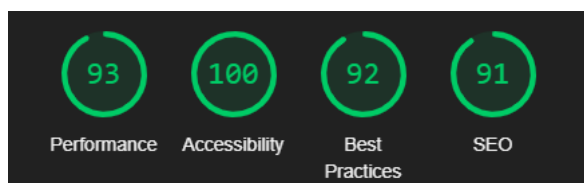


Figure 10 - Lighthouse performance

This figure shows the score that this web application received after running Lighthouse on it. There were only a few things to work on to help it reach an even higher level. For example, in Performance, reducing unused JavaScript code and setting an exact width and height on some images would increase the score. The rest follow suit in having to improve small things that can raise the standard.

### 5.3.1 User Acceptance Testing

After the development of the second game was complete, a small set of users were given access to the web application to try the games. Their results were recorded, and an average was compiled into these tables.

A feedback table was created to allow users to express their opinions, positive and negative, towards the application to help further the development. Users were asked to answer three questions: 1) Were you able to use it well enough? 2) Would you play it again? 3) Other Comments



## Feedback

User No.	Usability [1-5]	Play again?	Other
#1	5	yes	Make Matching Cards harder
#2	4	yes	hints for second game
#3	3	no	example for games
#4	3	yes	nicer card images
#5	4	yes	no comment
#6	3	yes	nice games

Table 3 - Feedback Table

### 5.4 Validation/Measurements

To see how valid the application was in helping slow cognitive decline, two tests were carried out on two user groups with different conditions and they were compared on performance. One user set had continuous practice every 2 days, and the other played the game only twice, once at the beginning and once after two weeks, and the results were then compared.

This helps us view the progress made by the two groups and what can be taken away from using this web application, allowing us to measure the usefulness of the platform.

### 5.4.1 Results

#### User Set 1

#	Age	Turns in Game 1	Points in Game 2
1	20	8	11
2	15	13	12
3	72	20	5

Table 4 – Userset 1 Test 1

#### User Set 2

#	Age	Turns in Game 1	Points in Game 2
4	34	9	11
5	19	14	12
6	50	10	14

Table 5 - Userset 2 Test 1

**User Set 1 - After Two Weeks**

#	Age	Turns in Game 1	Points in Game 2
4	20	11	15
5	15	14	14
6	72	12	19

Table 6 - User set 1 Test 2

**User Set 2 - After Two Weeks**

#	Age	Turns in Game 1	Points in Game 2
4	34	10	8
5	19	12	13
6	50	16	16

Table 7 – Use set 2 Test 2

### 5.4.2 Explanation of Results

These four tables are results from two different test periods; the first two represents the first test done by the user groups, and the last two of the same groups completed after two weeks. The first user set played the two games every two days, having continuous practice with the games, while the second user set played the game only twice, at both recorded test sessions.

### **5.4.3 Analysis of Results**

If we look at the User Set 1, we can see after two weeks they had a slight increase in performance. This group played the two games every second day once, so naturally they became more familiar with it. This led to better performance in the games at the second test session.

In comparison, User Set 2 only played the games twice, once at each recorded session. As seen on the table they did not have continual practice with the games, resulting in slight differences in the two recorded sessions.

From this, we can understand that continuous practice in the games leads to an increased performance in the games, which we can assume to be an improvement in their cognitive ability in these games. This was a set of tests conducted over a small span of time, but opens the possibilities to the use of technology in training for people with cognitive impairment.

## **Chapter six: Conclusion**

### **Summary**

Chapter 6 identifies and discusses the implications of my work.

### **5.2 Results discussion**

What was noticed was that, after two weeks, there was a small increase in performance of the user group that continually played the game. This shows that with more interaction and time with the game, there was a performance boost. This opens up the possibilities of more games being made available to help with slowing cognitive decline. However, they were only given two weeks and that is not enough time to be able to understand if they improved solely from playing the game for sure.

Due to Covid, there was a limitation on who and how many tests I could carry out. This caused my test pool to be relatively small, increasing the margin of error. Throughout the test period, it was reiterated to me that compliance plays a much bigger role. When users have a desire to play a game, their performance goes higher. Meaning there is no set game that is the best, but it depends on whether the user wants to play it or not; this increases the opportunity to slow cognitive decline. This threatens the validity for my initial aim of using this game to overall help cognitive functions, but shows that the application still proves its effectiveness to a more niche and different market.

### **5.3 Project Approach**

The Agile Methodology was used to develop this application. This worked well as I had used it before in previous projects and was effective. Being able to complete weekly tasks by breaking them down made it manageable in seeing what the timeline would be. I researched a plethora of articles, papers and memorizing methods to implement into the application and games.

### **5.3 Future Work**

While I was able to complete this application, and most of the goals set out were completed, there were some that were unfinished. This was due to time constraints and after this paper I aim to continue to work on this application, implementing more functionalities into it.

There were other games I wanted to add into it, such as a version of Tetris and include a leaderboard to compare to friends. I would also like to be able to add integration into social media, maybe even create filters linked to the application. There are still more areas to target and more I plan to do with the application. Creating a mobile application on the application store would be desirable as well.

With time after this project, I will continue to work on this and be able to use the application as a platform for awareness and provide help to users, no matter what stage of their cognitive journey they are in.

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# Appendices

## **Appendix 1                      Website and Source Code**

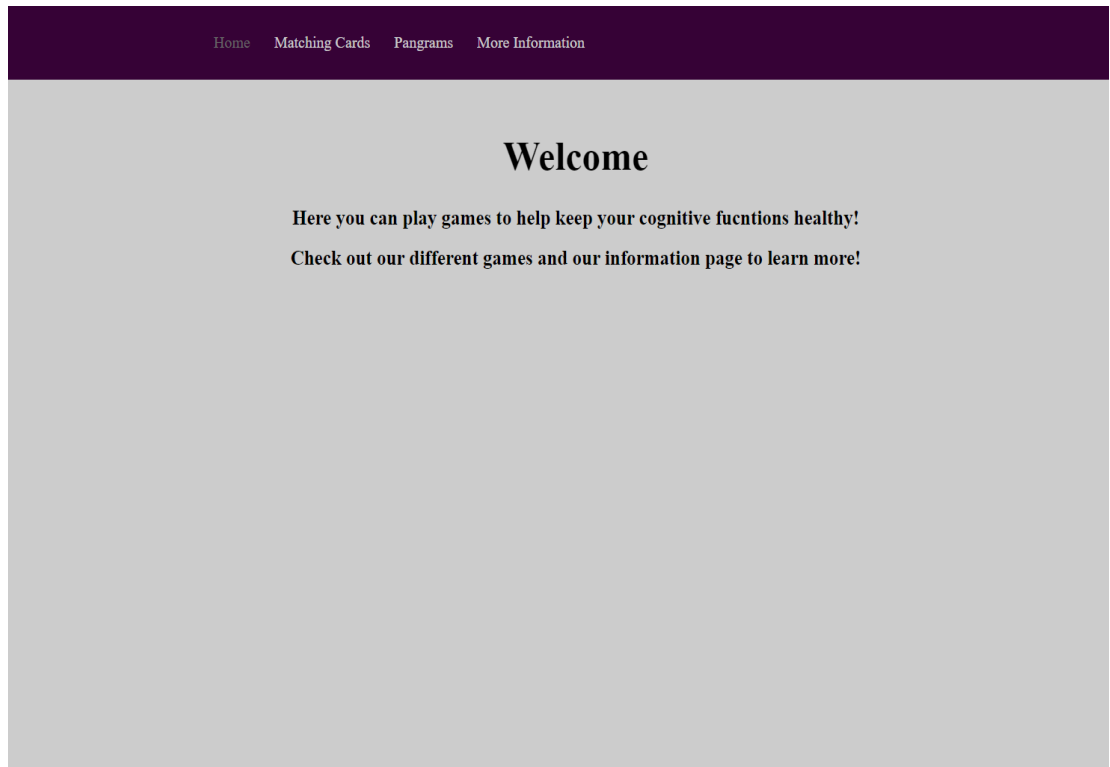
Website Link: <https://my-react-thesis.herokuapp.com/>

Github: <https://github.com/RufusTenali/Thesis>



## Appendix 4

## Screen shots of the project implementation



[Home](#) [Matching Cards](#) [Pangrams](#) [More Information](#)

Matching Cards

New Game

Turns: 0

[Home](#) [Matching Cards](#) [Pangrams](#) [More Information](#)

Matching Cards

New Game

Turns: 6

