

# Genius – Brain Training Mobile Application for the Elderly

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**Abstract—** In 2020, there were 234 thousand or so people in Mauritius who were over 60. From 36 thousand in 1971 to 234 thousand in 2020, this age group has increased significantly. Mauritius is at the forefront of Africa in proactively recognizing aging as a serious problem for the wellbeing and competitiveness of its society and economy. Alzheimer's disease and dementia are two age-related illnesses that are becoming more common in older people, posing a frightening challenge not just for those who have them but also for their family and caregivers. It is therefore crucial to participate in activities that maintain a healthy and active neurological system because as we age, the nerves in our brains tend to deteriorate. The primary aim of this paper is hence to create a mobile serious game, *Genius* that can help to maintain the cognitive abilities of the elderly people. *Genius* consists of several games aiming at improving the memory, attention, problem-solving, speed, concentration, reflex, communication and language skills of the user. This mobile application can be used by elders in retirement homes initially under the supervision of a healthcare assistant or by independent elders. *Genius* has been tested in a Non-Governmental Organization based in Mauritius and has been appreciated by the users including the caregivers. We anticipate that the use of the mobile serious game *Genius* will be very beneficial for the aging population of Mauritius and can eventually help in reducing the risks of dementia.

**Keywords—** Alzheimer, aging population, brain training, dementia, mobile serious game

## I. INTRODUCTION

The global population is aging quickly. The percentage of elderly individuals worldwide is predicted to nearly double between 2015 and 2050, rising from roughly 12 to 22 percent [1]. The elderly group consists of people who are older than 60 years old. This journey through life can be fascinating and relaxing, but it can also be rather difficult because of conditions due to aging. There is a lot of physical and mental health issues that older adults of this age may experience. Dementia is one of the most prevalent mental and neurological conditions in this age range [1]. With age, people's cerebral capacity decreases, which has an adverse effect on their ability to remember previously acquired information or even new information. A reduction in brain activities, and numerous skills to maintain normal brain functioning may have negative impact on the mental health of those people [2].

Alzheimer's disease is the most common type of dementia, which is a progressive neurologic disorder that causes brain cells to die [3]. It is a continuous decline in cognitive, behavioral and social skills that adversely affects an individual's capacity to live independently. Memory problems are usually one of the first symptoms of Alzheimer's, though they can vary from person to person. Other aspects of thinking, such as finding the right words, vision/spatial issues, and impaired judgment or reasoning, may also indicate Alzheimer's disease in its early stages [4].

We are confronted with limited success of Alzheimer's disease pharmacological treatments. Although available medications reduce some symptoms, there are no treatments to slow the progression of the underlying illness. Many clinical tests and trials for the development of new pharmacological treatments have failed in recent years. Moreover, pharmacological treatments are expensive and may have side effects [5]. Therefore, a new approach would be more beneficial. As several studies suggest, technology can play an important role in providing integrated solutions in various areas related to patients' health and well-being. It has helped a lot in many sectors and one of them is indeed the healthcare sector [6].

The normal aging process is related to brain changes that result in a weakening of some specific cognitive areas in healthy individuals. As a result, there is growing interest in discovering ways to keep our brains sharp by preserving or improving the cognitive functions [7]. This is the underlying concept behind the creation of serious games, which are digital applications designed for purposes other than entertainment, such as training and education, marketing, communicating, or enhancing user aptitudes or cognitive/physical functions [8]. These games can be customized to meet a variety of healthcare simulation training requirements [9]. Video games have the potential to create new forms of perception and achievement. These games training can potentially improve cognitive control in the elderly. Serious games are now widely recognized as beneficial non-pharmacological tools for evaluating patients' functional deterioration, as well as assisting patients' recovery process, evaluations and enhancement [10].

The primary aim of this work is to provide the senior citizens with a mobile serious game that will serve as a brain training application helping them to exercise their brain on a regular basis through continuous play thereby improving their cognitive skills and thus lowering the risk of having dementia disease. The remainder of this paper is structured as follows. Some related works are highlighted in section II while section III presents a comparative analysis of these related works. Section IV highlights the architecture of our system, *Genius*. The system prototype and testing of the application are presented in section V. Section VI highlights the evaluation of *Genius* and finally section VII concludes the paper.

## II. RELATED WORKS

Pharmacological treatment for memory disorder diseases is expensive and may have its drug side effects. To reduce this harmful treatment, other treatment such as training the brain through serious game are being applied. This section surveys some existing serious games targeting elderly people that aim at preventing cognitive impairment or prevent the progress of the dementia disease.

[Neuro]-therapy [10], a psychotherapy game was designed and developed based on some specific criteria of psychotherapy-intervention for memory impairment people. The criteria was categorized into four main categories namely *Device, Features, Interface* and *Gameplay*. The design of [Neuro]-therapy puzzle game met all the conditions by focusing on the needs of the elderly people. This [Neuro]-therapy was designed using a set of jigsaw puzzles which comprised of three main categories namely classic, face, and edibles. Players had to rearrange the puzzles of an image to form the whole picture. The puzzles games were of varying levels of difficulties to enhance the memory of the players.

Cabrera-Tigre et al. [11] implemented an interactive system that used serious games and personal area networks to provide senior persons with cooperative playful activities. The concept also included electronics kits to encourage visual awareness, spatial reasoning, and visuomotor coordination. The basic areas that were targeted during the app-based therapy were orientation and attention, memory, and language. The intention of the authors was to provide ongoing training procedures to improve motor capabilities in the fundamental usage of technology instruments through interactive applications, thereby aiming at improving the coordination of the hands and eyes movements. Encouraging results were obtained when the proposal was tested on 30 elderly persons.

Lumosity [12] is a serious game design to help people improve things like processing speed, memory, flexibility, attention and problem-solving skills. It has over 40 games for adults where the latter would be able to see the progress and therefore can distinguish how much their brain need exercises. The Lumosity application assessed vital aspects related to short-term memory loss, the visual-spatial part and the ability to recall previously seen elements. Complete Brain Workout [12] is another serious game where it is divided into five different key areas which are mathematical, memory, reasoning, language and three-dimensional. All the games start from very basic to complex. Increasing the level aimed at training the user's brain to gain speed. Both games were played by dementia patients over a period of 10 weeks. The results obtained were positive and it was concluded that the games helped to reduce the impact of the dementia disease.

The game Lebensnetz [13] is a serious game that was developed to maintain and increase the mental, physical and social health, and well-being of people with dementia. The game name translates to 'life network' and refers to the opportunities to organize and share past life experiences in the game. The concept can be described as a game that tries to reduce forgetfulness and to increase remembrance. Players are challenged to execute reasonable physical activity. Furthermore, social interactions are encouraged by the game. The goal is to provide a means for dementia prevention as well as dementia therapy in the early stages of the disease through physical, mental and social activity. The game is a tool for reminiscence as players are able to input their own photographs and other documents, organize them and share with family members, friends and supporting carers. Moreover, minigames such as memory game with pictures were also implemented.

Amicasa [14] is a serious game developed for multimodal training performed by clients and caregivers utilizing easily adjustable services on a tablet PC. Lack of information regarding how brain processes change over time is a major

obstacle to understanding dementia. Eye tracking data from nonobtrusive sensing during the game were collected for this reason in order to enable ongoing monitoring of dementia profiles. The Amicasa is an interaction platform with 200 task units, a number that is constantly rising thanks to new themes that include an enticing knowledge and exercise library. The training's game character draws the player in and inspires knowledge acquisition and physical exercises. Some of the units include the training of memory and remembrance, visual memory, completing gaps in texts, interactive associations with pictures, forms and colors, search games, physical activities and playful cognitive test.

Smart Thinker [15] is a free computerized serious game for adults who are 55 years of age or older. The user will have to login or sign in and then select the cognitive skill he/she wants to enhance. The games according to the chosen skill will then be displayed. Smart Thinker also motivates the players by rewarding them for high scores and provides feedback. Smart Thinker is designed to be simple and user-friendly. It guides the user through demonstration about how to play the games. Attention skills assessment has been done and Smart Thinker was proven to contribute to a big extent to enhancing attention and memory skills through the different games namely a word game (multiple choice question game), color games, logic (number games) and Rock Paper Scissors game. The game was tested with 59 participants who played the game over a period of 6 months. About 45% of all participants stated that the memory games were very helpful to their short-term memory helping them to recall events. Approximately 63% mentioned that the games helped them to focus better thereby also enhancing their attention skills.

Different serious games namely Brain Age game, Tetris puzzle game and Brain Metrix have been identified in [16] that are helpful for the elderly to improve the brain cognitive functions. The Brain Age game is a video game series including arts and letters, reading aloud, puzzles and solving arithmetic problems which will keep the cerebral functions of the user's brain always active and thus prevents memory deterioration. The Brain Metrix is an educational website with brain training programs where the elderly can train and test their brain, memory, the brain creativity and reflexes. The Brain Metrix consist of many games; 8 Queens, Sudoku, Arrange Game, Brain Reflection, Chess Game, Cognitive Training, Concentration Game, IQ Test, Memory Game, Memory Test and Reflex Test. The Brain Metrix's brain training games allow the user to improve their concentration and increase their reflection speed which is helpful for the prevention and treatment of dementia.

### III. ANALYSIS

The features, strengths and weaknesses of the games surveyed in the previous section have been analyzed and a comparison table has been presented in Table I.

Most of the serious games discussed were developed to improve the memory, attention, speed, language, reasoning and concentration of the user. [13] and [14] also address communication and motor skills. [12] and [16] have discussed upon improving reflex skills as well. Except for [13] and [14], all the other serious games discussed have simple interface and design so as to allow easy interaction. The games were easy and simple enough for the elderly with low cognitive function to learn. Additionally, some games were familiar or matching the lifestyle of the older adults for easy memory

TABLE I. COMPARISON OF EXISTING SERIOUS GAMES

Game	Features	Strengths	Weaknesses
[Neuro] – therapy [10]	Simple graphic display, Natural language, clear instructions, games are familiar to the elderly, level of difficulty, fun games, encouragement	Promote memory, attention, reasoning, concentration and speed Game is familiar to the elderly Help is provided to the user	May be difficult in the beginning to complete games due to the timer
Crossword [11]	Friendly interface, Easy to play, Need no guidance, Entertaining	Promote memory, logical thinking, attention and language skills Provide help to the user through hints	Difficulty for some people with poor vocabulary
Lumosity [12]	Friendly interface, Fun and Entertaining, Provide progress	Promote attention, reasoning, reflex, speed, memory, language and concentration skills. People improve through regularly playing the game	May need a trainer at the start No multiplayer, no team, no collaboration
Complete Brain Workout [12]	Low cognitive requirements, simplicity in design, Challenging, Motivation, Feedback	Fun game with colorful/engaging graphics Promote attention, speed, memory, language, concentration and reasoning. Leveling which motivate the user to keep on playing and try to move to the next level	May need a trainer at the start
Lebensnetz [13]	Games related to the past and present habits and daily routines, simple and easy to play, provide feedback and rewards.	Promote the use of memory and communication. Applicable to events of daily living	The interface is not so user friendly
Amicasa [14]	Contain playful cognitive test and physical activities, entertaining, Interactive association, Search Game	Promote memory, language, speed, communication and concentration skills. The game is entertaining	May face difficulty to play, need a trainer.
Smart Thinker [15]	A challenging game interface designed to be user friendly and simple by walking the players through a demonstration to help them play the game.	Promote attention, reasoning, language and use of memory Fun game with colorful/engaging graphics	Can be difficult for some people to understand specific words
Brain Age game [16]	Fun and easy game, Simple Interface, clear instructions, will keep the cerebral functions of the user's brain always active	Can play alone. Promote reasoning, memory, language and attention skills.	Can be difficult for people with visual problems
Brain Metrix [16]	Low cognitive requirements, simplicity in design, need no guidance, Leveling difficulty, Motivation, Feedback, encouraging and positive messages	Promote memory, concentration, speed, attention, reasoning, reflex and language skills.	Can be difficult for people with visual problems. Some user may need a trainer.

recall. [10], [12] and [16] consisted of games where the level increased gradually to avoid discouraging the users from playing the game. Positive and encouraging messages were shown to avoid frustration when the user failed a challenge. Moreover, feedback and rewards were provided to the player as soon a game was completed in order to keep the motivation for playing and therefore benefiting from the games.

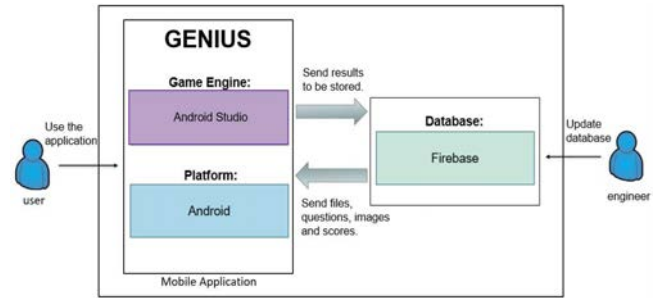
Researchers indicated that keeping the mind sharp have a positive effect on people with cognitive impairment [7] and serious games can be as equally effective as pharmacological treatment to patients with memory disorder. However, after analyzing the existing games, it was found that no single serious game seem to target all the cognitive skills namely the memory, attention, problem-solving, speed, concentration, reflex, communication and language skills of the user, hence the purpose of our system, *Genius*.

#### IV. SYSTEM ARCHITECTURE

This section discusses the system architecture of *Genius* which consists of a mobile application where users can play a variety of games and have their scores saved in online database. Fig. 1 displays the high-level architectural diagram of the whole system.

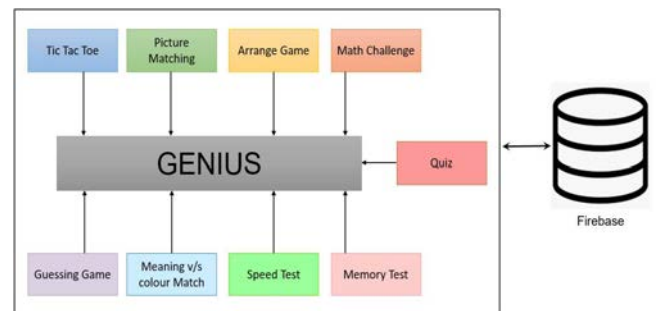
The main components of *Genius* are as follows:

- The users are the elderly people who will use the application by playing the different games to train their brain.
- Genius* has been implemented using Android Studio and hence the application is able to run only on Android platforms initially. It consists of several mini games that aim at enhancing one or more cognitive skills.

Fig. 1. High-Level Architecture of *Genius*

- Firebase has been used as the online database for the development of this serious game. The player's score for the different games is hence stored online. Moreover, questions and images used for several games are retrieved from Firebase. An administrator/engineer can periodically modify some of the questions/answers on the database and the application will be dynamically updated.

A more detailed design of *Genius* is illustrated in Fig. 2.

Fig. 2. Detailed Design of *Genius*

The various games selected for *Genius* were chosen for development following a thorough analysis of several research works and already-commercialized applications. The mini games aim at improving the *memory, attention, problem solving, speed, concentration, reflex, communication* and *language* skills of the user. Table II shows the skills that are being targeted by the different games.

The proposed games are:

- Tic-Tac-Toe

This game tests the player's ability to solve problems and come up with a plan to win. It is a multiplayer game where the player plays against an opponent. The game is won by the first person who obtains 3-Xs in a single column, row, or diagonally. The player needs to be focused and very attentive to the action of his opponent to be able to find a strategy to win the game, thereby improving his attention, concentration and reasoning skills amongst others. The game also encourages verbal communication between the opponents.

- Picture Matching

The game consists of several levels where the difficulty increases as the level increases. A set of cards is used in the game and the player's task is to pair up the cards with same images by flipping both face up. It compels the player to keep in mind the locations of already observed images in order to locate its match. Here, memory, concentration and attention are the skills being emphasized. Moreover, the number of attempts made to find all the pairs will be counted and the scores will be calculated based on this number of attempts.

- Arrange Game

The arrange game consist of a 4 by 4 grid, and each grid contains a number. The numbers are from 1 to 15 and one grid is blank. The player will have to find a way, thereby targeting the problem-solving skill, to arrange the numbers in ascending order by moving the number either up, down, right or left from the empty grid. To be able to complete the puzzle with the fewest movements so as to obtain a higher score, the user must pay close attention and maintain a high level of concentration.

- Math Challenge

This game gives the user option to choose among the different operations (+, -, ×, ÷) and continues with the operation chosen. The user will need to solve the equations thereby improving the problem-solving abilities of the player as well as the memory since the player will have to remember how to perform the operations. The player will also need to be attentive and concentrated since a timer is provided and the player has to get maximum correct answers in an amount of time. The player's score is calculated according on how many correct answers were obtained in 30 seconds.

- Quiz Game

The goal of this game is to impart general information and teach various health issues to seniors. The players will gain knowledge, become more health-conscious and hopefully adopt a healthier lifestyle as a result of playing this game. The user's hearing, language, and problem-solving skills will all be targeted. This is because they must determine the correct answer to the question that has been voiced out. The player must first listen to the question before attempting the multiple-choice questions.

- Guessing Game

This is a learning game with the aim of making the elders remember regular objects thereby enhancing memory as well as language and reasoning skills. The player will be asked to guess the name of an object. The dynamic object image is fetched from the online database and it is displayed on the screen along with the different alphabets required to form the name of the object as well as other random alphabets. By clicking on the alphabets, the player will have to form the name of the object. The score is updated for a correct guess.

- Meaning v/s Color Game

The game contains 2 boxes and in each one a color-name is written in different colors. The player has to guess whether the meaning of the first word matches the color of the second word. If they matched, the player has to click on the 'Yes' button else click on 'No' button. The player will have to remember which word's meaning matches with which word's color thereby improving the memory, attention and problem-solving skills of the latter. Moreover, a timer is provided to increase the level of difficulty forcing the player to be more focused and rapid.

- Speed Test

The game tests the reflex and speed of the player. In this game a box is displayed on the screen and the player will have to click on the 'start' button and wait for the color of the box to change. As soon as the color changes the player will have to click on the box and his/her reaction time will be calculated. The reaction time will be equal to the time from which the player clicks on the box minus the time the color of the box changes. The player must be focused and need to react very quickly since the lesser the reaction time, the higher the score.

- Memory Test

A sequence of 5 characters will be displayed on the screen. The player has to be focused, attentive and quick as a timer of 5 seconds is set for the user to remember the character's sequence. After the 5 seconds are over, the existing sequence of characters will disappear. The player then needs to re-write the sequence in the input field provided and the system

TABLE II. SKILLS TARGETTED BY THE GENIUS GAMES

Game	Memory	Attention	Problem-solving/Reasoning	Speed	Concentration	Communication	Reflex	Language
Tic Tac Toe		✓	✓		✓	✓		
Picture Matching	✓	✓			✓			
Arrange Game		✓	✓		✓			
Math Challenge	✓	✓	✓	✓				
Quiz	✓		✓					✓
Guessing Game	✓		✓					✓
Meaning v/s Color	✓	✓	✓	✓	✓		✓	
Speed Test				✓	✓		✓	
Memory Test	✓	✓		✓	✓			

validates whether it is correct or not. The game is dynamic and the difficulty of the game increases by showing other sequences with greater length if the player has completed the previous levels.

Since *Genius* would be used primarily by the elderly people who might suffer from dementia, the colors had to be carefully chosen. The application favors blue and green colors, as these are ‘calming’ colors while the red color and contrasting objects were used whenever it is important to catch the attention of the player. Moreover, bigger fonts, buttons and text have been used for important words throughout *Genius*.

## V. PROTOTYPE IMPLEMENTATION AND TESTING

The mobile serious game *Genius* was developed using Android Studio Chipmunk 2021.2.1. Java was used as programming language to create the Android application. The game has been tested on three different mobile phones, namely: Huawei nova 9 SE, Huawei nova 3i and Samsung SM-260F.

Fig. 3 illustrates the *registration page* on the left, the *main menu interface* where all the different games can be accessed in the middle and on the right, a snapshot of the *Tic-Tac-Toe Game* is shown. Fig. 4 shows snapshots of the *Picture Matching* game on the left, the *Arrange* game in the middle and the *Math Challenge* game on the right. Fig. 5 displays the interfaces of the *Quiz* game on the left, the *Guessing* game in the middle and on the right the *Meaning v/s Color Match* game is illustrated. Finally, Fig. 6 displays the interfaces of the *Speed Test* game on the left, the *Memory Test* game in the middle and on the right the *Statistics/game scores* interface.

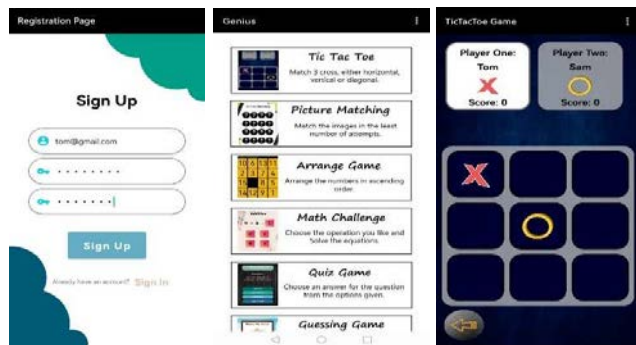


Fig. 3. Registration, Main Menu and Tic-Tac-Toe interfaces

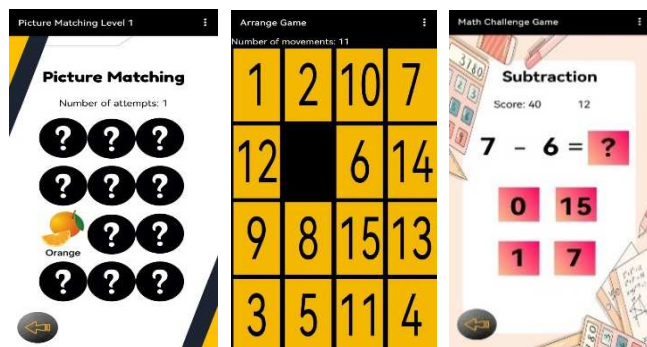


Fig. 4. Picture Matching, Arrange Game and Math Challenge layouts

Due to the COVID-19 pandemic and the government restrictions imposed in Mauritius regarding large gatherings, a large scale testing of *Genius* could not be carried out. Therefore, a user acceptance test was carried out at a Non-Governmental Organization namely the *Hospice Saint Jean de Dieu* in Pamplemousses, Mauritius. 6 elders and caregivers at

*Hospice Saint Jean de Dieu* were asked to test the mobile application and provide their feedback on the mini-games. Table III summarizes their thoughts, feedback, proposals and recommendations on each game which were eventually taken into consideration to enhance the gaming experience.

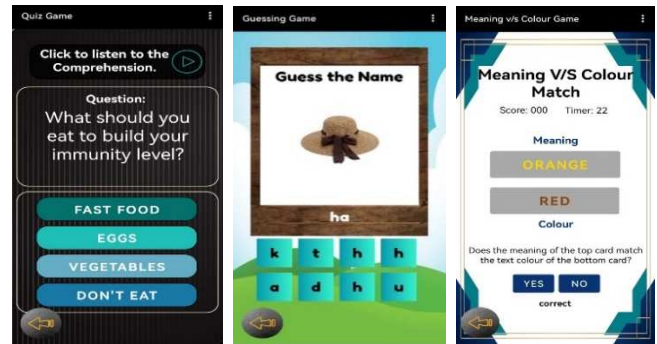


Fig. 5. Quiz, Guessing Game and Meaning v/s Color game interfaces

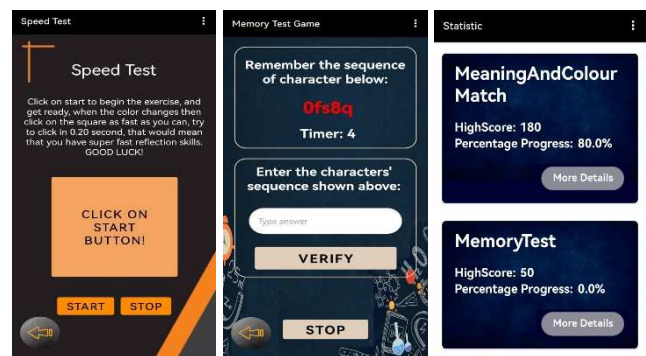


Fig. 6. Speed Test, Memory Test game and Statistic interfaces

TABLE III. FEEDBACK ON MINI GAMES

Game	Feedback	Comments
Tic-Tac-Toe	Positive	They like the fact that they could play the game with a friend and they were enjoying the game.
Picture Matching	Positive	The players find the game easy to understand and play. They were learning the names of the object, while trying to match both pairs at the same time. They could play the game but required several attempts since they could not memorize the position of the images.
Arrange Game	Positive	They encountered some difficulties at the start but eventually loved playing this game. They were playing over and over again. Since the fonts and color used were carefully chosen, they could recognise the numbers.
Math Challenge	Positive	Performing the different operations was easy for the elderly. They were making some mistakes but they were more motivated to try again and get the correct answers.
Quiz Game	Neutral	Some questions were slightly difficult for some of them. Listening to the question several times helped them in getting the answers.
Guessing Game	Positive	The elders liked to try writing the name of the objects and they appreciated the game. They found the colors lively and were enthusiastic.
Meaning v/s Color	Neutral to negative	This game was a bit difficult for them to understand and play. Explanations had to be provided several times.
Speed Test	Positive	They found the game easy to play with an attractive interface. They were motivated to play since they wanted to get a better score.
Memory Test	Neutral to negative	They had difficulty to remember the sequence and they were unhappy not to be able to get the correct answer. After several attempts they could get one correct answer and eventually started to appreciate the game.



TABLE IV. EVALUATION ON SKILLS TARGETED WITH RESPECT TO EXISTING GAMES

Game	Memory	Attention	Problem-solving/Reasoning	Speed	Concentration	Communication	Reflex	Language
Complete Brain Workout [12]	✓	✓	✓	✓	✓			✓
Lumosity [12]	✓	✓	✓	✓			✓	✓
Amicasa [14]	✓	✓			✓	✓		✓
Smart Thinker [15]	✓	✓						
Brain Metrix [16]	✓	✓	✓	✓	✓		✓	✓
<b>Genius</b>	✓	✓	✓	✓	✓	✓	✓	✓

## VI. EVALUATION

An evaluation of *Genius* against some of the games surveyed in section II was carried out with respect to the skills that the different games aim at enhancing and the results are illustrated in Table IV. As shown in the table, *Genius* is targeting most if not all of the skills that an elderly need to improve in order to reduce the risk of the dementia disease.

Elders and caregivers who tested *Genius* were generally satisfied with the different mini-games proposed. They however highlighted some limitations. They were of the opinion that other games such as the board games namely carrom, chess and checkers, being more friendly to them, could be added to the application as those games also require critical thinking and problem-solving skills which will be very helpful to the older adults. They also mentioned that the application could have features like different languages since not all of them could understand English very well.

## VII. CONCLUSION

Although there are no proven techniques to treat dementia, there exist many ways to deal with cognitive disabilities. Scientists have recommended the aging population to stay mentally active with activities such as playing games, reading and learning new skills amongst others. A thorough analysis of existing games was carried out and the important skills that need to be enhanced were identified. The primary contribution of this paper is the creation of a mobile serious game for the elderly, *Genius*, consisting of several mini games with the goal of improving various skills such as *memory*, *attention*, *problem-solving*, *speed*, *concentration*, *reflex*, *communication* and *language* so as to keep on sharpening the brain and decreasing the risk for the nerves to degenerate. The games have been tested in a non-governmental organization based in Mauritius and the elderly people who tested the application were quite satisfied with the games developed.

Although positive feedback was obtained, *Genius* can be enhanced in several ways. Firstly, as recommended by the people who tested the application, the game can be designed in several languages and board multiplayer games can be added. Secondly, an interface should be made for caregivers/doctors allowing them to view their patient scores to be able to analyze and understand the mental conditions of the elderly people and eventually provide appropriate care. Finally, a thorough testing should be carried out on several patients over a long period in order to observe the effectiveness of playing the game. The changes in the cognitive skills of the players should be measured to better evaluate the effects of playing *Genius* and confirm the enhancements in terms of *memory*, *attention*, *problem-solving*, *speed*, *concentration*, *reflex*, *communication* and *language* of the players.

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