

AIDE, cognitive support for people with memory loss

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Abstract

This project addresses the design and development of an application to support cognitive stimulation exercises, aimed at people with cognitive impairment with Alzheimer's disease in the early stages.

For this purpose, a study of cognitive abilities, their affectations and treatments has been made, as well as the design of interfaces oriented to the needs of elderly people or those affected by the disease.

A study has been made on the existing technologies in the market that offer similar services reviewing good solutions both in the game-like activities implemented and in the graphic interface design choices.

The specification, design and implementation of an application consisting of two graphical interfaces has been elaborated. One intended for the senior (player) to perform the activities and the other one for the tutor to keep track of the large person's progress and to configurate the activities.

The system is a three-layer application and has been developed with technologies CSS, Javascript and HTML (client with React Native), FastAPI (server), and with PostgreSQL (database).

A working prototype of two games that work reminiscence, attention and memory have been implemented running with a web browser:

- *Who's Who*, which works with family photos.
- *Questions and answers*, which works with the senior's personal information.

1. Introduction

In this project an application is designed to be a support in cognitive stimulation exercises with which people in an early stage of disease affecting cognitive skills such as attention, memory and perception can perform different game-like activities. The project has followed the principles of user centered design.

The goals of the project were:

- Design and develop engaging activities in a digital environment based on the particular needs and preferences of aged people living with dementia.
- Develop two different GUI, one for the user to play the game and the other one for the tutor with utilities of configuration and follow up of the user's activities.
- Design an environment that allows configuration to adapt and customize the games, for instance using

senior personal information introducing photographs of family members and acquaintances and other familiar content to work (at least) on reminiscence, attention and memory.

- Design a system that stores, retrieves and reports information about the user's activity.

2. Theoretical framework

Dementia's disease is a global problem. Nearly 10 million new cases of dementia are diagnosed worldwide each year.(Fundación Pasqual Maragall,undated).

Currently, more than 55 million people worldwide suffer from Alzheimer's or other types of dementia. Of these, almost 10 million live in Europe and about 960,000 in Spain. It is estimated that at present, 10% of people over the age of 65 and one third of people over 85 suffer from some form of dementia. (Fundación Pasqual Maragall,undated).[2]

Dementia is the result of various diseases and injuries affecting the brain and Alzheimer's is the most common form of dementia and can account for between 60% and 70% of cases. It remains one of the health conditions that most concern Spanish society (63%), just behind cancer (68%) and ahead of stroke (57%) and heart attack (46%) (Fundación Pasqual Maragall,undated).[2]

According to the World Health Organization dementia is a syndrome that can be caused by a number of diseases which over time destroy nerve cells and damage the brain, typically leading to deterioration in cognitive function (i.e. the ability to process thought) beyond what might be expected from the usual consequences of biological aging. (World Health Organization, 2023). [3]

While consciousness is not affected, the impairment in cognitive function is commonly accompanied, and occasionally preceded, by changes in mood, emotional control, behavior, or motivation. Dementia has severe physical, psychological, social and economic impacts, not only for people living with dementia, but also for their carers, families and society at large. (World Health Organization, 2023).[3]

Most types of dementia cannot be cured, but there are ways to control the symptoms and improve the quality of life of people living with dementia and their relatives. Patients can improve with pharmacological treatments and therapies, often used together. In this report we will focus on non-pharmacological treatment.

The non-pharmacological treatment includes techniques that can contribute to slowing down cognitive and functional deterioration in daily life. They are treatments that favor the quality of life and can help to control possible behavioral alterations that the affected person may present (Bitbrain,

2018) such as cognitive stimulation, reminiscence, music therapy, art therapy, reality orientation, sensory stimulation, animal therapy, physical exercise or psychomotor therapy. (Fundación Pasqual Maragall, 2023).

Cognitive skills are the basic skills the brain uses to think, read, learn, remember, reason, and pay attention. They work in a complementary way, one with the other and form a kind of network of knowledge that you use in your daily life.

A gradual cognitive deterioration at a normal rate is part of aging, it's something that happens, but when the rate of deterioration is rapid and progressive it indicates dementia (which is not a normal part of healthy aging).

Cognitive stimulation is a set of activities to improve the effectiveness of cognitive and executive abilities, it aims to preserve cognitive abilities for as long as possible and it is especially indicated for people in mild and moderate stages of the disease to try to slow down cognitive deterioration. (Bob Woods, Elisa Aguirre, Aimee E Spector, Martin Orrell, 2012).[4]

Rehabilitation with cognitive stimulation consists of performing different activities that work on cognitive abilities. Some of these exercises can be performed at rest, such as mathematical calculations, or they can involve physical movement, such as dancing. These rehabilitation activities work executive functions such as memory, concentration, sustained attention and processing speed.[5][6][7]

3. Graphic user interfaces for aged population

The interaction with a graphic interface of a computer or other digital devices become difficult or challenging As people get older. Visual acuity deteriorates, which diminishes certain abilities and makes some tasks difficult. Clicking accurately on a target , or reading correctly, can become costly and tiring. And also, frequently the perception of colors changes (e.g. shades of blue may look faded and lose color contrast in the design). In addition, many people have motor problems and find it very difficult to execute a specific and small movement.[8][9]

The easier family font to read are the Sans Serif fonts with a large size. The perfect size in icons and buttons is 2.05cm x 2.05cm and the separation between touchable components depends on the size of the clickable objects: the smaller the clickable objects are, the bigger should be the distance between them.

The color palette is also very important. They cannot be vibrant or dark colors, low pigmentation is preferred to look more like pastel or light colors. The contrast in the colors is very important, to maximize contrast, colors with large distance between them in the chromatic circle are preferred.

the it has to be chosen The interaction with the system have to be easy and adapt to the senior user capabilities to make the experience satisfactory (Sergey Polyuk, undated)

4. Benchmarking

The benchmarking compared applications such as:

- Luminosity
- Elevate

- NeuroNation
- NeuronUP
- Imentia
- Rehametrics
- The serious games
- AIDE

Elevate is fine for activities with a standard normative cognitive profile, but not for users with disabilities. It has deep navigation and its design is not suitable for an older population with motor or vision problems.

NeuronUP runs in a web browser and is difficult for an elderly person to operate. This application is often used as a support in clinics or centers, and is usually used in the company of clinical staff. The clinician part of the design has deep and complicated navigation but the game screens are well designed.

In Serious Games the usability of the activities depends on the game and the characteristics, cognitive impairment, environment and conditions of the player. They are perfect if we consider games dedicated to older people or that teach sequential behaviors, reasoning and other cognitive skills. These games are often used as part of therapy and are done in the company of specialists.[10]

Positive aspects of commercial applications such as graphic design or navigation in applications such as Luminosity, NeuroNation, Rehametrics and Imentia or the game screens of NeuronUP are good references and has been taken into account.

None of them offer to work on activities based on customized photographs of family members or acquaintances or with the senior's personal information.

5. Specifications

The system features two modules, one named "screen module" or "senior module" and another named "tutor module".

They are two different target users. On one hand the one who is going to play the cognitive stimulation exercises (Senior) and on the other hand the one who is going to keep track of the activity done in the games and upload pictures (Tutor). So the final users can be named as "senior" and "tutor".

Since the project has two end users, interfaces must be created to suit each of them.

A compilation of the functional and non-functional requirements of the application has been made and the use cases for the functional requirements have been described.

The activities are carried out on a touch screen interface in the "senior module" and the tutors can configure options and have access to the results obtained by the senior through the "tutor module". The games are based on tactile interaction and can also emit clapping and cheering sounds as feedback and verbal reinforcement.

6. Application design

The project is based on a server-client model.

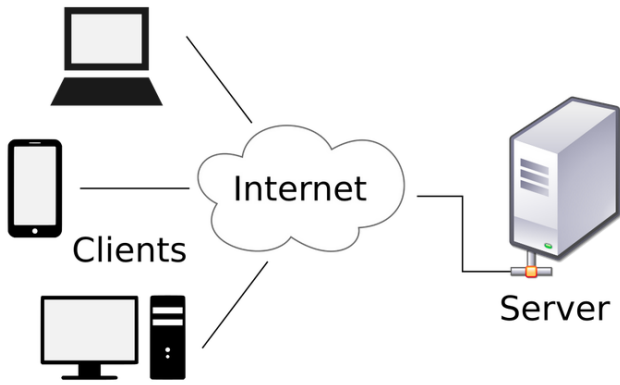


Fig. 1. Server-client architecture

It is a 3-tier application, that means it has three layers:

- Presentation tier
- Application tier
- Data tier

The presentation tier (the front end) is made with React Native[12], the application tier with FastAPI [11] (the back end) and the data tier with a relational database, PostgreSQL.

The conceptual model is described by an UML class diagram. The UML class diagrams have been used in the project to graphically represent the concepts to manage and the relationships between them. Let's analyze the class diagram in parts.

The first relationship we see starting by the left is an association. Given a Photo and a Person we have a Position of that person in the specific photo and being in a specific position confers on that person physical characteristics for that particular photo.

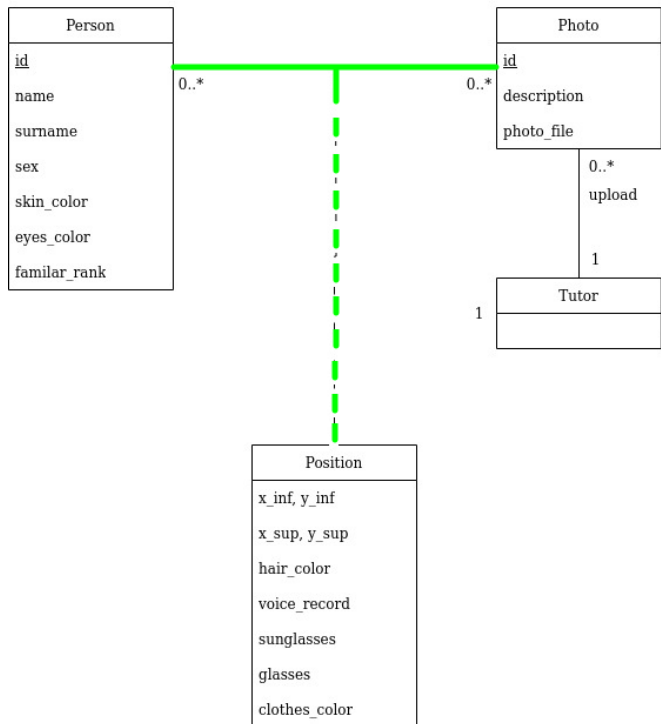


Fig. 2. First part of the UML

The second part of the concepts diagram we see forms a cycle with the relationships between the concepts Photo, Customized_act, Tutor and Senior.

A Tutor can have one or more Senior associated with him/her and these seniors will have customizable activities (Customized_act).

The photographs (Photo) that the Tutor uploads that make up a customizable activity for a senior must be photographs of that specific senior's family or acquaintances.

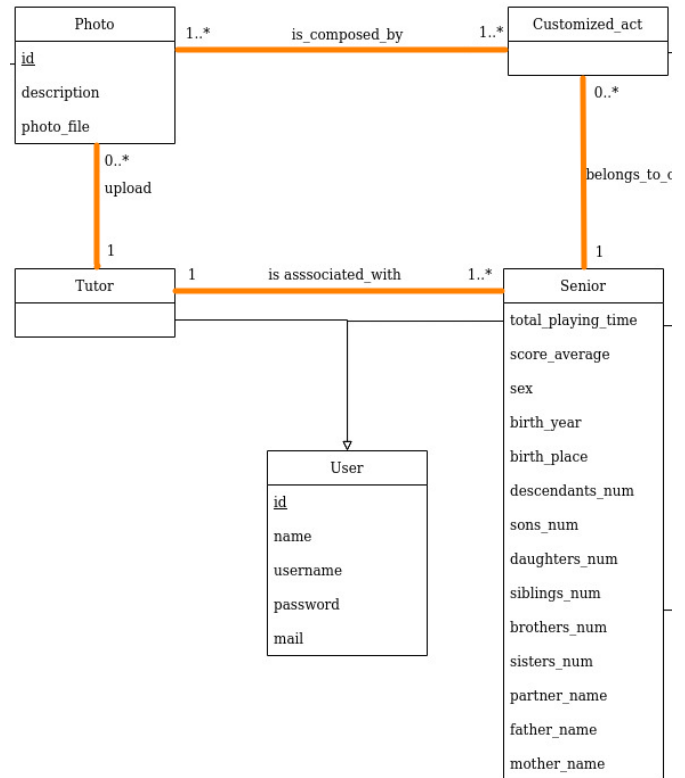


Fig. 3. Second part of the UML

The third relationships group has a specification in it. First we see that a Tutor can have more than one Senior associated, but a Senior can only have one Tutor (the relationship named *is_associated_with*).

Furthermore, there are two types of users: Tutor and Senior. Actually, although the classes tutor and senior exist, they are only classes to differentiate one role from the other because they store different information, but they are both of the User class, which means that both of them has the attributes a User has.

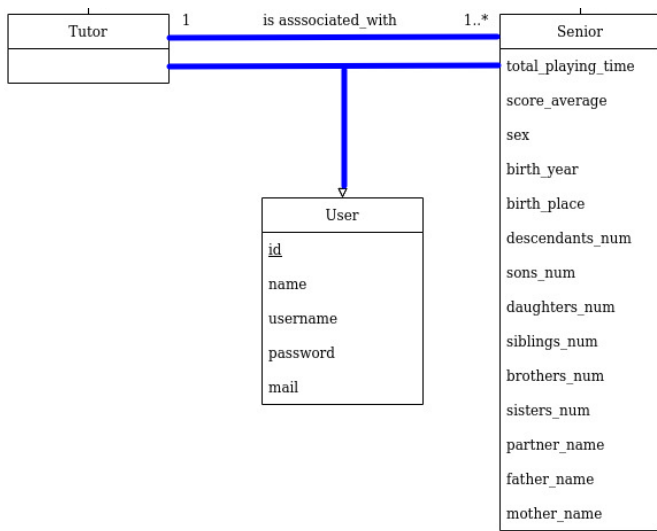


Fig. 4. third part of the UML

The fourth relationship is a specification too. There are two types of activities: the customized ones (Customized_act) and the generic ones (Generic act). Both of the classes Generic_act and Customized_act have the Activity class attributes because actually they are from the class Activity.

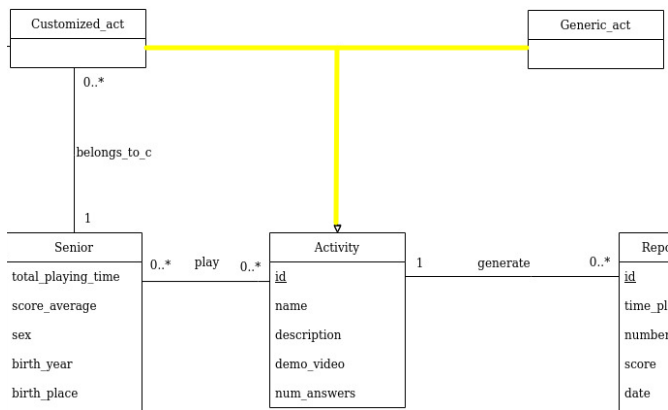


Fig. 5. fourth part of the UML

The fifth and the last part of the UML is a cycle between the relationships, it is between the concepts Senior, Activity and Report_activity. When there are cycles between the relationships there may be aspects that we should clarify outside the diagram.

Here we see that a Senior can play activities and when he/she plays an activity an activity report is generated. But it must be clear that the activity report will always be for an activity the Senior has played, it cannot be for one that the Senior has never played. The Senior can have many activity reports, as many as attempts he does to play the activities.

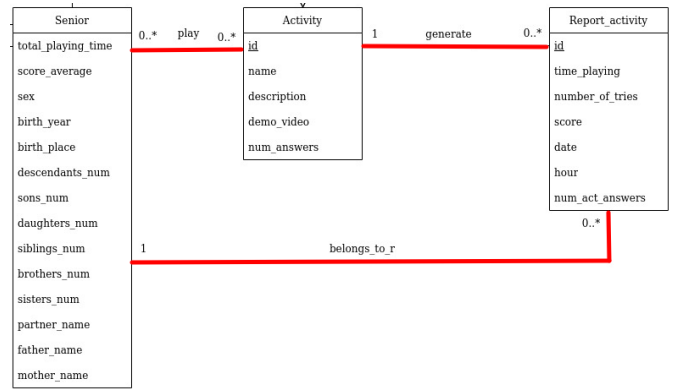


Fig. 6. Fifth part of the UML

Once the study was done within the theoretical framework on interface design, some mockups were made to see where the interface design should be oriented. Here are a few examples of the senior UI mockups:

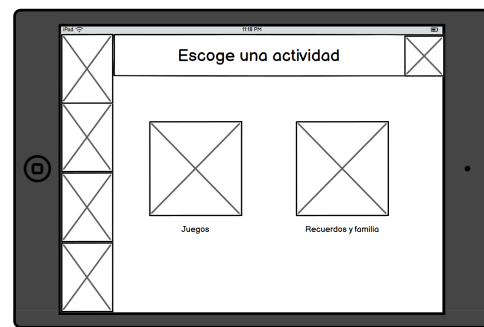


Fig. 7. Senior UI home screen mockup

It is important that the senior can access another part of the application without complications. It has 4 icons on the left side of the screen to be able to go to any other screen of the application and to close it at any time.

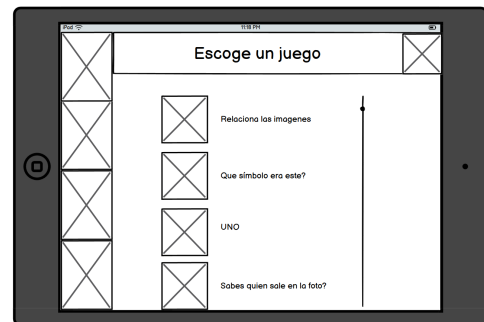


Fig. 8. Senior UI selecting a game screen mockup

The games are presented in a scroll view, as it is a touch interaction interface, you can scroll down or up the list of games with your finger.

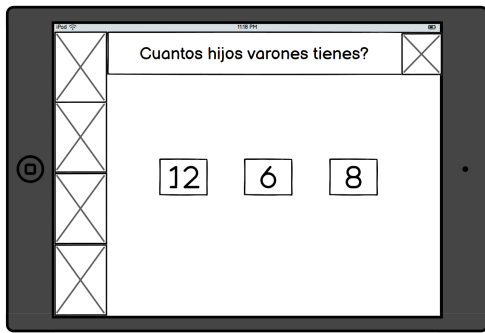


Fig. 9. Senior UI selecting playing “Questions and answers”

This activity screen shows 3 possible answers well separated and with the border of their area well differentiated from the background so that the senior has no trouble seeing it.

It is also important to give the senior a positive feedback during the interaction.

Here are a few examples of the tutor UI mockups:

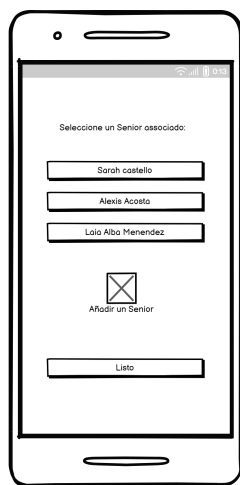


Fig. 10. Tutor UI selecting a senior screen mockup

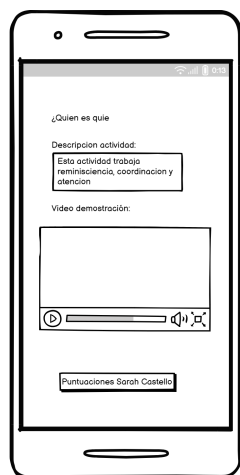


Fig. 11. Tutor UI seeing an activity information screen mockup

7. Implementation clarifications

For the frontend (first tier) React Native was chosen because of its efficiency, there's no need to recompile the code if you make modifications to the app, it instantly reflects the changes in the app, which makes it more efficient, fast while testing and coding and saves time and work.

It uses CSS, HTML and Javascript. Javascript and the React framework are widely used by developers and industries, so it seems to be a very good option to invest learning time and work to develop an application with it.

I decided to do a RESTful API for the backend (second tier). FastAPI has built-in code validation thanks to the pydantic library, which makes it detect the type of data and returns errors in json format. This reduces errors when developing your code, which translates into less time spent. I used SQLAlchemy because it is one of the object-relational mapping libraries in the Python community and has been in use for the longest time. It transforms the DB into classes and it is easier to make queries and make relationships and intermediate tables

It is easy to use because it uses toolkits to work with, which means you don't have to do everything yourself from scratch, it's already done, so it makes it easier to work with. The bad thing is that FastAPI does not have a built-in security system.

For the data tier of the project I decided to use a relational database. PostgreSQL is free to use and it facilitates data manipulation (you can do subqueries, for example) and it includes authentication and authorization, which is something very important to have the application data protected. PostgreSQL tutorials, documentation and resources are easily found if you need them because the community of developers and users using PostgreSQL is large and active. Also the migration from other database systems is easier, making the switch from MySQL, SQLite or Oracle less problematic.

8. Implemented activities and interfaces

There are two implemented activities in the senior interface:

- Who is who?
- Questions and answers

The first game consists of showing family or acquaintances images and asking to identify who fulfills a certain condition in the photograph. The person doing the activity should click on whoever fits the sentence specific announced feature. If the senior taps on the wrong person, a clue of the person's position will be displayed for 5 seconds and then the same phrase will be asked again (this procedure can be repeated only 3 times so as not to overwhelm the senior). It works memory, perception, selective attention and reminiscence.

The second game consists of asking personal questions about the senior and three options of answer to this question will be shown but just one of them will be correct. If the senior taps the good one he/she goes to the next question and if he/she taps on the wrong answer the correct one will be displayed during five seconds and then they'll have to answer the next question and at the end re-do the questions he/she failed. It works memory and attention.

A few examples of the implemented activities and interfaces:



Fig. 12. Senior home screen

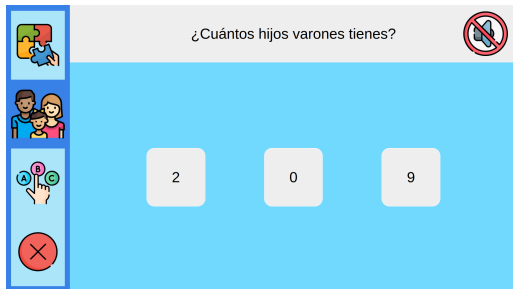


Fig. 13. "Questions and answers" activity screen

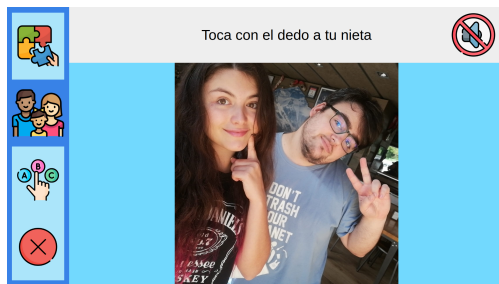


Fig. 14. "Who is who?" activity screen

The activities implemented are for the senior, but for the tutor I made an interface so that he/she can upload photos (with which the "who is who?" activity will be done) and so that he/she can keep track of the senior's progress and activity.

A few examples of the tutor interface:



Fig. 15. Tutor login screen

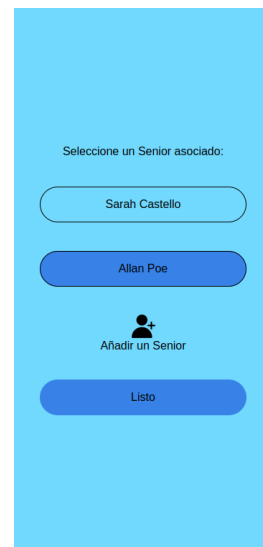


Fig. 16. Selecting a senior screen

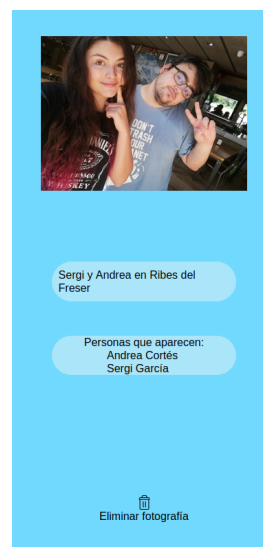


Fig. 17. Information of a photo screen



Fig. 18. Introducing a photo screen

8. Budget

The average salary of a junior computer engineer is 11,95€ per hour. I consider the realization of this project as a full time job (8h/day).

According to the percentage that the company allocates to Social Security, 35% of an employee's gross salary (more or less), an increase of 35% has been applied to the price per hour that the engineer receives to calculate the cost to the hiring company. The 35% of 11,95€ is 4,18€, which adds up to 16,13€ per hour.

Theoretical framework research	2.838,88 €
Application structure approach and researching technologies for application development	2.322,72 €
Code development, code testing and learning about used in the code development (FastAPI, React Native)	11.613,60 €
Editing the report	3.226 €
Computer amortization in 6 months	130 €
TOTAL	20.131,20 €

Table 1. Budget table

To calculate the total of the project the 35% per hour is not added to the computer amortization because it is the development tool, but is not part of the project itself.

9. Conclusions

Regarding the first objective, two different cognitive stimulation activities have been implemented, presented as engaging games: the “Who is who?” and “Questions and answers”, following the design principles specific for older users for graphic interfaces.. The activities work reminiscence, perception and attention. The ‘Who is who’ (‘Quien es quien’) activity works with familiar images and the ‘Questions and Answers’ (‘Preguntas y respuestas’) with the senior personal information. There are cognitive skills that can not be worked by a digital based application such as the activities for praxis and for gnosis. Praxis and gnosis require assistance and are experiences such as touching, smelling or tasting, that cannot be supported on a digital base.

Two graphical user interfaces have been implemented. The interfaces are shown in the practical part in a web browser as a web application but they are designed to work on different devices and as a hybrid application because the technology used allows it: the senior-oriented interface is designed to run in a medium/large or large sized screen to be more manageable for an older person.

Referring to the third and fourth objectives, the tutor’s interface enables one to keep track of the progress of the senior and to upload personal information about the seniors and photographs of family members and acquaintances and other familiar content.

The future improvements could be:

- Conversion to a hybrid application to be downloaded on different devices.
- Providing the system with audibly descriptions of the content.
- Providing the system with an audible description of the content. If the senior is playing an activity with photos, the application will read the description of the photo when it appears, for example: "It was your birthday, we were very happy and your grandson Nico came from the USA to give you a surprise" or the statements that the screens of the application have. Feedback animations and sounds to make the activities more engaging could be implemented too.
- Implement more activities, both generic and customizable.
- Make the senior's data entry more flexible when a tutor registers him/her. That would allow the data entry to be adapted to the real and possible situation that some people have. For example if the senior has no children, or if he/she has never had a partner, or if he/she does not know the name of his mother... These are questions that cannot be asked. It can be naked this way: when the tutor is entering the senior-related data the application would ask "Does the senior know his/her mother?", for example, and based on the tutor’s answer it would ask to fill in that field or not, to know whether to ask about it or not.
- Revise the code to make it very efficient so that it consumes less power, storage and RAM of the device it runs on.
- Make the application offline. Some kind of storage could be used so that the senior can play with or without internet access, when the device detects that it has connection it would synchronize the data obtained with the other side of the application and so the tutor could already see all the data.
- Make the tutor be able to enter the coordinates of the position of a person in a photo locating the person in the same photo for real, it is something that in the prototype could not be achieved due to lack of time and would be practical.

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