MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

ABDELHAMID IBN BADIS UNIVERSITY - MOSTAGANEM **Faculty of Exact Sciences and Computer Science**

Department of Mathematics and Computer Science

Major: Computer Science

BACHELOR'S DEGREE PROJECT REPORT IN COMPUTER SCIENCE

Option : **Information Systems**

THEME :

Development of a cognitive rehabilitation Web application for post-stroke patients

Student : BENKEDADRA FATIMA ZOHRA

Supervisor : Dr. HOCINE NADIA

2021 - 2022

Abstract

Serious games are a specific type of games that aim to solve certain problems related for instance to education, marketing and healthcare.The project entails the creation of a Web application that proposes a set of serious games that are approved by specialists and that are dedicated to post-stroke rehabilitation. Moreover, the application provides a management system for the therapist to keep track of the patient's progress, and to engage in the game management, precisely controlling who can play what. Hence, it is a step forward integrating technology in the field of smart and remote rehabilitation.

List of Figures

List of Tables

List of Abbreviations

CVA	Cerebrovascular accident	9
OSN	One-Sided spatial Neglect	10
JSON	JavaScript Object Notation	13
MVT	Model View Template	13
RDBMS	Relational database management system	13
API	Application Programming Interface	18

Plan

General introduction

Through time, humanity has been developing and making constant achievements in all fields. Something we are all proud of, unfortunately we are limited by the power of the body that has to deal with several obstacles if not taken care of. And one can only imagine how much more can be accomplished if not for the obstacles that numerous peoples have to live with. Especially if it's a condition that attacks the body part that makes us humans and that is known as the master of the body … the brain. The condition we are talking about here is the cerebrovascular accident or as known as a stroke. A stroke is a medical condition in which poor blood flow to the brain causes cell death [1] [11]. This condition does not affect the person's life only but also the one of his family and close ones. It can cause weakness in the functionality of all the rest of the body organs. So what happens when the barrier between a person and an achievement or at least the right of living a normal life is this medical condition?

Thankfully the specialist has found solutions to help a stroke patient to heal and get back to his old healthy self or if not make an improvement. One of the solutions is rehabilitation. By performing certain activities and tasks, the patient trains the body which consequently influences the brain plasticity. To go even further, many researchers suggest making this process more efficient by using games. In traditional rehabilitation, therapists use some objects, like cubes and balls, and ask the patient to reach them, grasp, etc. They try to let them play to engage them in the therapy session in order to obtain more important recovery results.

The use of video games for rehabilitation, also called serious games or therapeutic games [13], has been suggested by many researchers to build more interesting and intelligent games. As it speaks for itself, it's the type of games that serves an educational purpose and is designed by specialists to help stroke patients to recover.

But this process takes time from both sides, the patient and the therapist that supervise it. It can have limits when using only paper and pen. Time and speed are a problem technology has come to solve. This is the problem our project is willing to solve, importing traditional games for stroke patients to the screen. By providing two serious games that this report presents as a start for this Web application 'SeriousGames' and an interface for the therapist to stay in charge of the games and patients, we are saving time and creating a playground environment for the patient to enjoy.

This report is organized into two chapters. Chapter one consists of an explanation of what a stroke is, rehabilitation and the technologies used to make the Web application. Chapter two presents the game's logic, design and the Web application architecture.

Chapter 1. Context and motivation

1.1 Introduction

In order to develop a serious game training and management system, we must have an understanding of the terms stroke, functional motor rehabilitation and cognitive rehabilitation. This chapter clarifies each of these terms as well as the exams used to evaluate the patient.

1.2 Stroke

Cerebrovascular accident (CVA), otherwise known as a stroke, is a condition where a clot in the vessels causes a part of the brain to lose its functionality due to lack of blood. A clot can be formed in the heart due to a heart problem, or in the brain; this condition is permanent in most cases.The risk of a stroke is determined by the position of the clot and the person's medical state [12] [1].

The factors of a stroke are:

- Medical history: people who have previously had a heart attack are more exposed to the risk of a stroke.
- Age and gender: women and elderly people are likely to have a stroke.
- Current health issues: diabetes, cholesterol, heart problems, periodontal disease.
- Current body state: smoking, drinking, obesity.

There are two types of strokes we can distinguish :

- **Ischemic**: recent reports show that 70% of strokes are ischemic strokes [1]. This occurs if the blood vessel is blocked, meaning the blood can't move smoothly through the cerebral arteries.The blockage of the blood vessel can be due to cholesterol deposition. We call this a “thrombotic stroke” meaning the problem was generated locally. Alternatively, it can be caused by a clot forming in the heart.We call this an “embolism stroke”, meaning the problem was generated from the outside of the brain.
- **Hemorrhagic** : unlike ischemic stroke, only 25% of strokes are Hemorrhagic strokes [1], yet it is not less important, hemorrhagic stroke happens when a blood vessel bursts causing brain tissue to die [12]. The reason can be : blood pressure, heart attacks.. etc

1.3 Symptoms

The symptoms indicate the damaged area in the brain, can be left or right. Here are

some symptoms [1]:

- Numbness or weakness.
- Trouble speaking or understanding.
- Trouble seeing in one or both eyes.
- Dizziness or loss of balance or coordination.
- Severe headache.
- Vigilance disorders.

1.4 Stroke prevention and medical treatment

The first step in preventing a stroke is based on the detection and treatment of vascular risk factors such as: blood pressure level, excess cholesterol, diabetes, obesity level and atrial fibrillation, smoking, excessive alcohol consumption and a sedentary lifestyle [12].

The secondary prevention is based on the prescription of drugs used to reduce the vascular risk or the surgical treatment. The treatment depends on the type of the stroke, and the area damaged [11] [1].

- **Ischemic stroke** : The initial medication to take is Aspirin. Experiencing a stroke leaves the patient vulnerable to a second one, which is why we use aspirin.It prevents platelets in the blood from forming a new clot.
- **Hemorrhagic stroke** : The patient needs surgery to remove the blood and relieve pressure on the brain.

1.5 Post-Stroke : one-sided spatial neglect (OSN)

One sided spatial neglect, also known as unilateral visual impairment, is a condition that appears in post stroke patients, where the patient has [2]:

- Problems with space and distance approximation as well as trouble reaching objects.
- Problems detecting the state of the environment: the patient will use one side of the environment.

There are several therapies for this condition, for our games we adopted the next treatments [2]:

- **Constraint-induced therapy** : this therapy's main goal in our case is to encourage the arm movements. The patient will have to use his arm to do certain tasks with the mouse and that encourages arm movement. The game we developed adopts this method, it is the Bee Game.

- **Visual exploration** : in this method there are groups of objects placed in front of the patient and he must find one specific object. The game we developed follows this method and we call it the Bell Game.

1.6 Functional (motor) rehabilitation

This rehabilitation consists in designing specific tasks to perform over and over. It's shown that such rehabilitation improves the performance in different motor tasks. Our project also focuses on functional motor rehabilitation. The patient is guided to do tasks such as moving hand, searching and collecting.

The patient will play the games several times during a period of months. It is expected to have a better performance each time by the logic of functional motor rehabilitation. Once the patient's performance gets better, the therapist can level up the difficulty of tasks for instance decreasing time limit or increasing iteration number.

1.7 Cognitive rehabilitation

Cognition is the group of processes that keep a person connected to his environment, such as vision, speaking and information processing [3]. The problem with OSN patients is not having the ability to perform such things, or do so with a lack of precision. Cognitive rehabilitation takes into account OSN, but firstly there are certain cognition exams to perform.

Cognition exams are used to evaluate OSN, in our project we are interested in three exams :

- **Assessment exercise** : in this exercise the screen is divided into 5 paths, one next to another. All paths start from the extreme bottom middle of the screen. The patient starts from the bottom middle and must move all the way to the end of the path.
    - the goal : reach the end of all paths in sequential order in a limited time, starting from the right bottom path and ending with the left bottom path.
    - the patient must do for each path :
        - go to the start position.
        - map the path.
    - At the end of the test the patient's performance can be computed by considering if: the patient mapped all paths, neglected certain paths or that the patient did not move.
- **Target reaching test** : this test evaluates the time a patient took to perform a certain task that requires arm movement. It's preferred for the patient to use the weakest arm.

- the goal : collect all targets in a limited time.
- the patient must do for each target :
  - go to start.
  - collect the target.
- results :
  - all targets collected.
  - all targets neglected.
  - certain targets neglected.

- **Hemi-corporal neglect test** by BISIACH and al. 1986 [3]: will be referred to as '**the Bell Test**'. This test consists of finding the bells distributed randomly all over the page among other objects in a limited time. In the original test's protocol the patient must do the test with one eye closed and do it again with both eyes.
  - the goal : finding all bells in a limited time.
  - the patient must do :
    - search for the bell.
    - find the bell and reach it.
    - select/mark the bell once reached using a pen.
  - at the end of the test the patient's result will be evaluated as follows:
    - 0 : the bell was selected without hesitation.
    - 1 : the bell was selected with hesitation.
    - 2 : the patient reached the bell but got interrupted during the phase.
    - 3 : the bell was not reached nor selected.

1.8 Project objective

The objective of our project is to implement two serious games "Bell game" and "Bee game" as well as to provide the result of the games for the therapist. The objective is to provide the next :

- Solutions for the patient :
  - The possibility of playing the two serious games from the comfort of their home.
  - Playing with the supervision of a therapist.
- Solutions for the therapist :
  - Control over the patient's account (creation, update, deletion).
  - The creation of game levels with limited options.
  - Decision making of who can play what.
  - Viewing patients' performance, and login data.
- Solutions for the game developer :
  - Complete control over patient and therapist data.
  - Complete control over games and game levels.

1.9 Resources : languages and technologies

1.9.1 Back-end

For the server side and the patient/therapist manager it uses the **python framework Django** [4]. It is based on MVT (template, view, model) architecture. It is true that it is made for the backend. Yet it provides some functionalities for template and form building, and most importantly is that it provides an admin site that is very helpful for user and permission management, also an authentication system and more. This is why it serves this project's objective.

1.9.2 Front-end

The technologies used are **HTML**, **CSS** and **JavaScript** (JS) for the games implementation since JS provides a native library for canvas manipulation, image displaying, mouse tracking, etc

As for the therapist's app, the **django admin site** is used with few modifications because of the limited time of our project.

1.9.3 Data management

JavaScript Object Notation (JSON) [5] is used to represent the data exchanged between both ends. As well for the storage of dynamic data in the database.

Sqlite3 [6] is a relational database management system (RDBMS) used by django, there is no direct interaction or raw queries performed, it's all done through models. For the nature of RDBMS tables the JSON objects are saved as character strings automatically and it is treated like a JSON in the eyes of the developer thanks to the api django provides.

1.10 Organization

The development of our project was started by the study of the context which is post-stroke rehabilitation. We then defined the main functionalities of our Web application that follows some selected rehabilitation strategies. Our second objective through this project was also to study Python Django and Javascript while developing our project. The following Gantt chart shows the main steps of our project.

Gantt chart is a tool to organize the project tasks during a period of time, the gantt chart can contain dates as well [7].

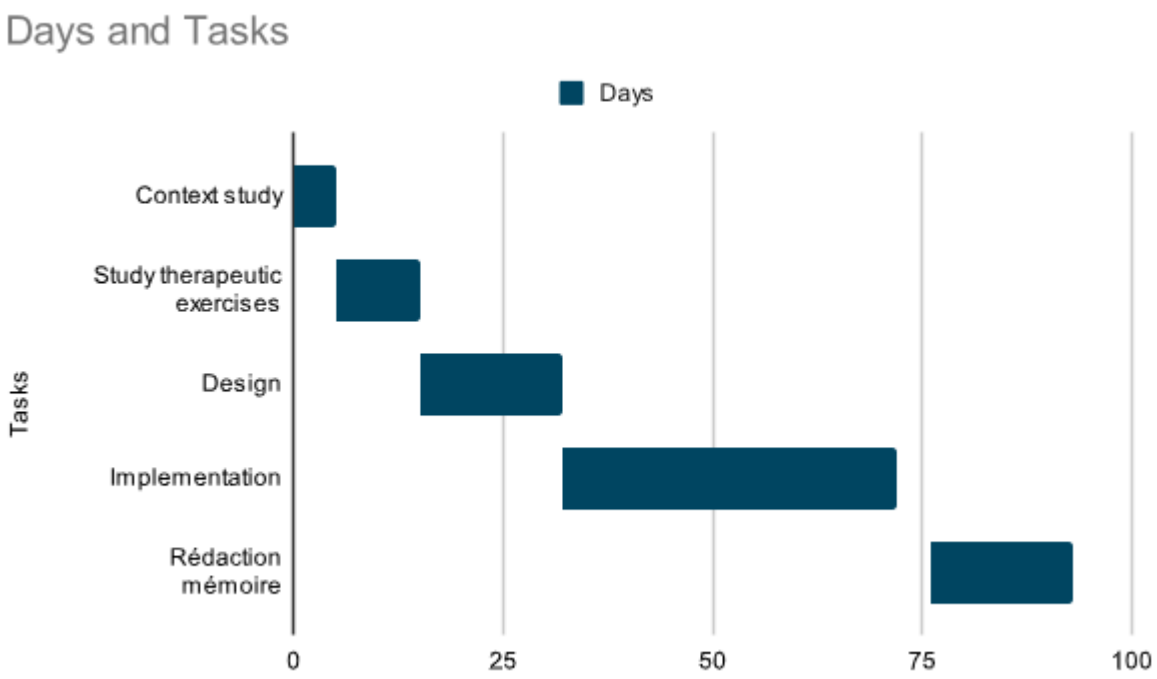


Figure 1. Gantt chart for the Web application SeriousGames

1.11 Conclusion

A stroke causes problems in the brain functioning and performance hence a problem in all body parts related to the affected area. In order to help post stroke patients functional motor rehabilitation and cognitive rehabilitation is considered. Our project objective is to develop serious games for rehabilitation. Serious games have emerged as an interesting new rehabilitation strategy that aims to support and motivate patients in home-therapy as well as give the therapist the possibility to manage various patients. In the next chapter there will be more of what the games are and the structure of the Web application.

Chapter 2. Design and implementation of online serious games for rehabilitation

1.1. Introduction

In order to develop a game there are 6 phases we pass by, first of all the concept or planning is this stage we discuss why we should create this game. After the pre-production, this stage is all about choosing the used technologies, the assets and making the game design. It is followed by the production stage, where we implement the game. after that the post-production stage where we can launch the game for the public [9]. This chapter takes us through the stages of pre-production and production of the development of the two serious games bee game and bell game. Also it includes the conception of the therapist site.

1.2. Design

Game design is a phase of the pre-production in the game development process [9]. This phase is carried out through the pre-production of a document that describes the representation of the game architecture, game assets, objectives, game rules and game mechanics. The game design document also includes all targets of the game, especially the therapist who participates in the patient's management system.

1.2.1. Use case diagram

- Admin: the game developer has control over everything from the games to accounts.
- Therapist: takes control over the patients account and manages the game levels creation and assignment.
- Patient: the patient has access to the games only. The patient is directed to the bee game first and bell game second.

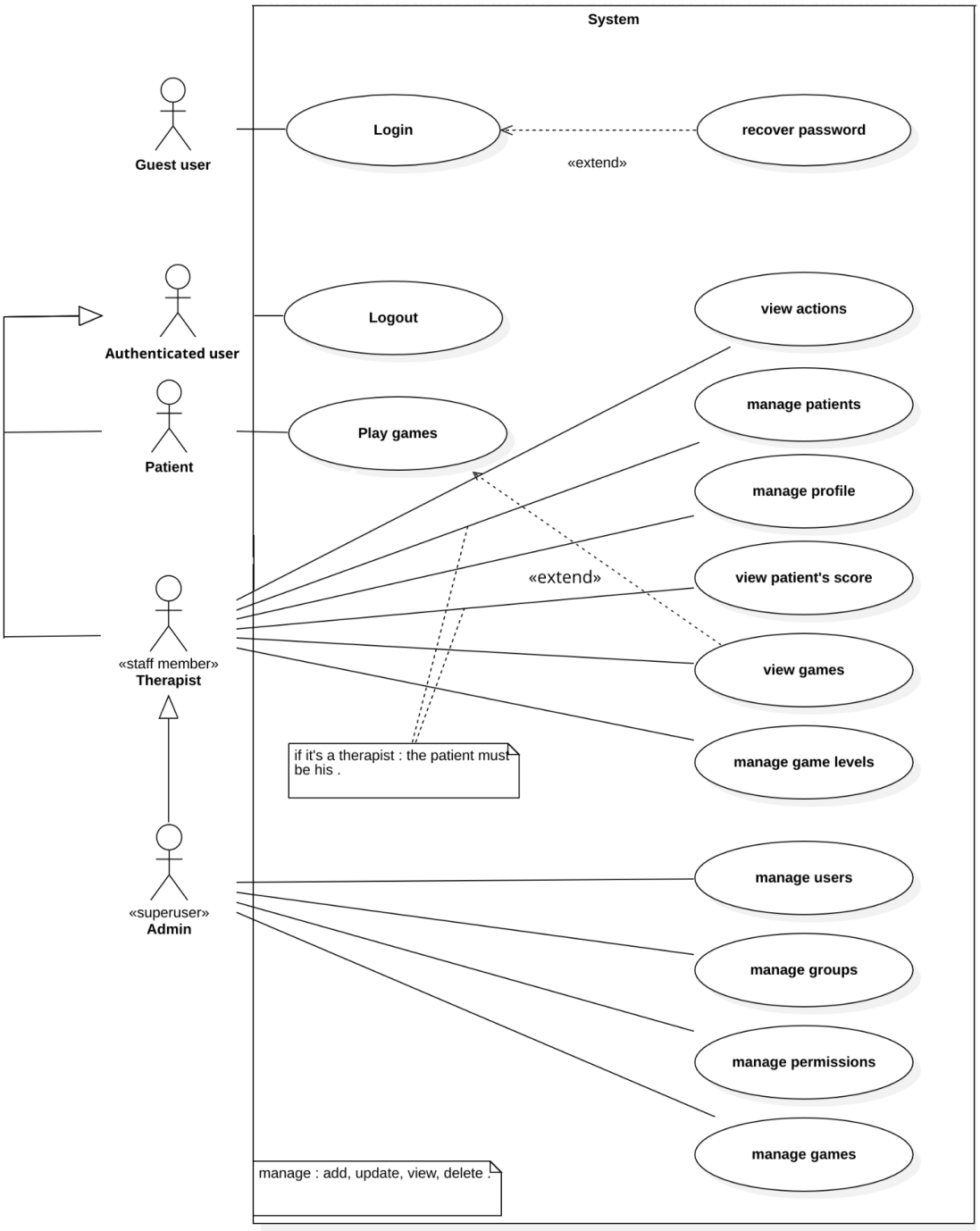


Figure 2 - Web application's use case diagram

1.2.2. Class diagram

- patient_app:
  - *Score*: this is a class that contains the score as JSON as well as other parameters, each time a patient plays a game a score is added to the database.

- *PatientScore*: this class is being created automatically when a patient is added. it relates a patient with his score.
- *Patient*: the patient is a user who is created by a therapist.
- *Game*: the developer can define the game attributes, and the score JSON object format.
- *Game Level*: this class contains a game attributes object with values assigned by the therapist.

- django.contrib.auth:
  - *User*: all users belong to this class the therapist is a staff user, the admin or game developer is a superuser.
  - *Permission*: this is the class of user permission, what the user can and cannot do, the default permissions are ‘add’, ‘change’, ‘delete’ and ‘view’. each registered model is managed thanks to these permissions.
  - *PermissionMixin*: handles different permissions .
  - *AbstractBaseUser*: contains the authentication functionalities.
  - *AbstractUser*: contains the user fields (username, is_staff …).
  - *Group*: the admin site gives the ability to create groups to set permission, we have 2 groups created from the admin site the Therapist group and the Patients group.

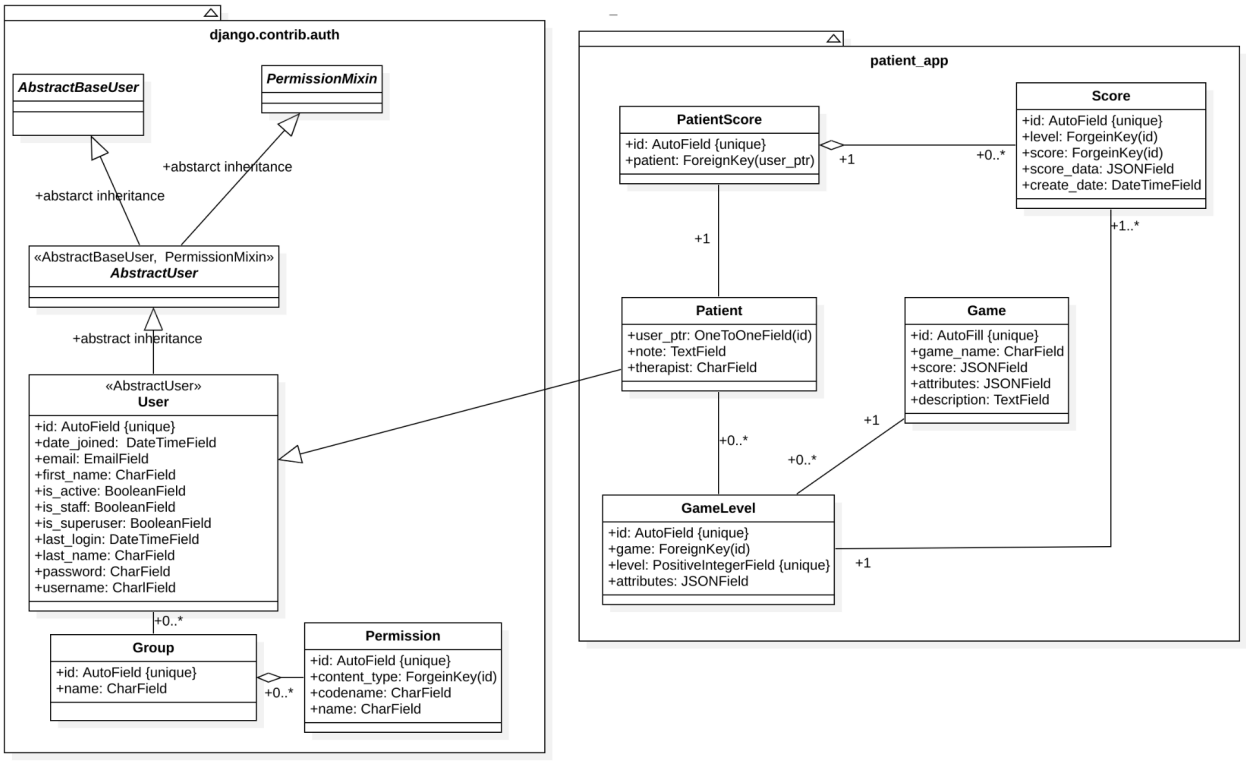


Figure 3 - Class diagram

1.3. Game design document

This is the game design document for the two games Bee game and Bell game. We would like to mention that all the used resources in this project are free and don't require a License.

1.3.1. Input method

The only allowed input method is the mouse. the patient can not physically click the mouse nor the keyboard that's why that wasn't taken into consideration. the patient can only move the mouse.

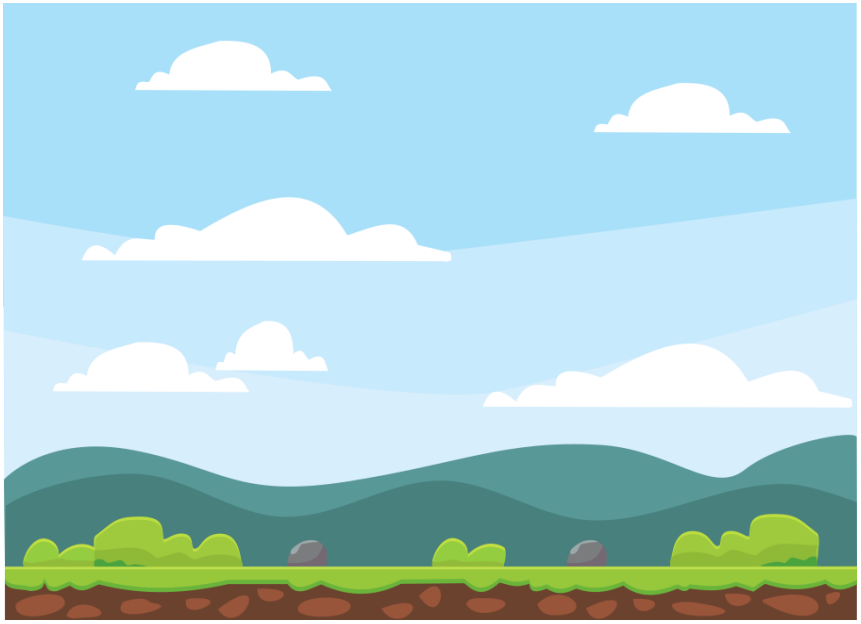
However there is one optional click event the patient can perform if possible to request the full screen mode which is provided using the Fullscreen API (Application Programming Interface) which is a gated user activation API[1]. We were obliged to do so in order to accomplish the bee game objective which is to encourage the patient's arm movement.

[1] In Javascript a gated user activation API is an API that requires user interaction, it doesn't accept automated events mostly click and keyboard events [10]. example: FullScreen, Pointer Lock, Web Audio.

1.3.2. Mini game 1: Bee game for upper limb rehabilitation

Game assets

Table 1 - Bee game assets

<table>
<tr>
<td> 
Figure 4 - Bee character (game ressource)</td>
<td> 
Figure 5 - Star (game ressource)</td>
<td> 
Figure 6 - correct mark (game ressource)</td>
</tr>
<tr>
<td> 
Figure 7 - pointer (game ressource)</td>
<td> 
Figure 8 - mouse (game ressource)</td>
<td> 
Figure 9 - hand (game ressource)</td>
</tr>
<tr>
<td colspan="3"> 
Figure 10 - nature background (game ressource)</td>
</tr>
</table>

Environment

The game environment proposes to the patient a bee positioned in the middle bottom of the screen. A timer (in seconds) is used on the top middle of the screen. The environment consists of two levels:

- **Level 1:**
    - 5 stars positioned in the next position on the screen [bottom right, top right, top middle, top left, bottom left]
    - 1 star positioned on the center of the screen (for how to play).
    - 4 lines divide the screen into 5 equal sections.
    - **Rules**
        - the player must go back to the starting point to move the bee each time the patient catches a star or the timer ends
        - the bee cannot pass the boundaries of each section meaning the player cannot go from a section to another without passing by the starting point.
        - if the time ends the star is marked as not collected
        - the player must finish the 'how to play' before starting the game.
        - if the player the bee touches the star it's marked as collected
- **Level 2:**
    - The objective is to move the bee to catch a certain number of stars defined by the therapist. The stars are placed in a position defined with the help of the Level 1 score. The positions of the stars depend on the sides the patient reached on the first part. The number of the stars is up to the therapist.
    - **Rules:**
        - the player must go back to the starting point to move the bee each time he/she catches a star or the timer ends
        - if time ends the star disappears and is marked as not collected
        - if the player the bee touches the star it's marked as collected
        - Evaluation
            - 0: if a star is collected
            - 1: if a star is not collected

Use case diagram

Play game mode 1: game is not in full screen mode, and bee movement speed is same as mouse speed.

Play game mode 2: game is in full screen mode, and the bee movement speed is delayed, so that the distance the computer mouse has to wipe to catch the target is increased.

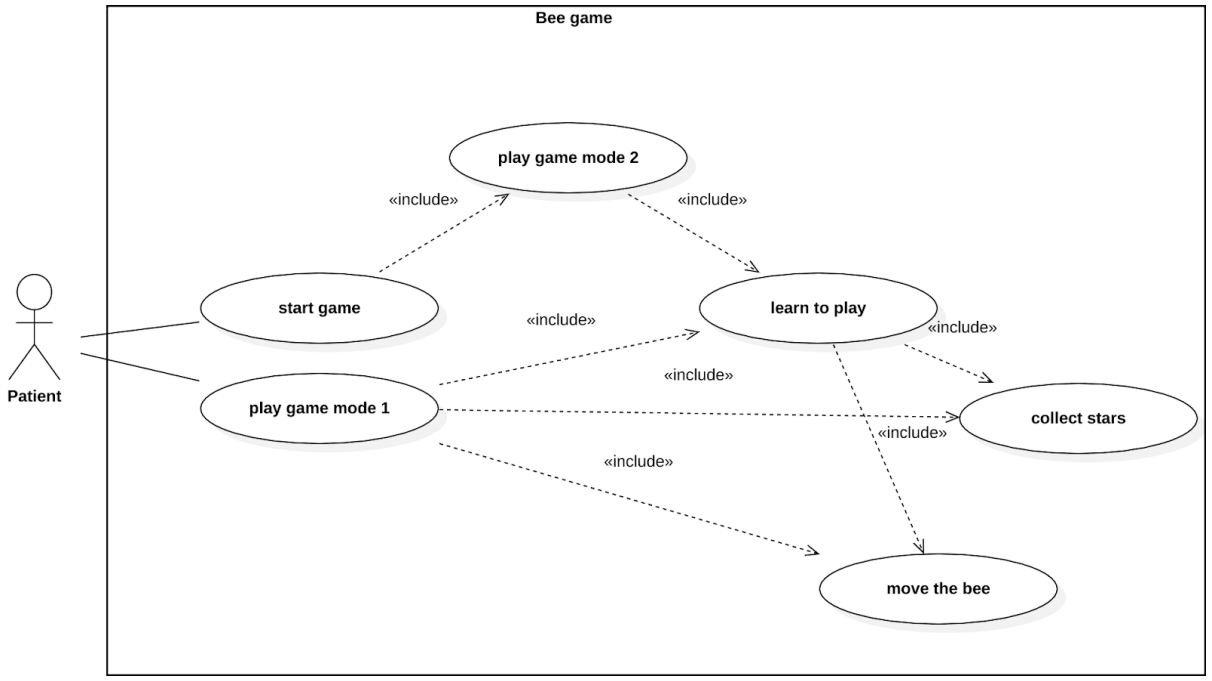


Figure 11 - Bee game use case diagram

1.3.3. Mini game 2: Bell game for cognitive rehabilitation

Game assets

Table 2 - Bell game assets

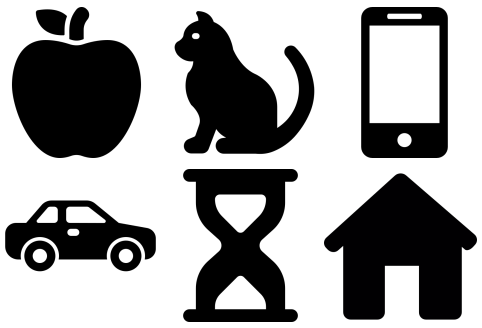
 Figure 12 - Marker (game ressource)		 Figure 14 - Bell (game ressource)

Figure 13 - Random objects (games ressource)

Environment

- a marker placed in the middle bottom of the screen.
- a timer placed on the top middle of the screen.
- a group of objects placed randomly on the screen with a space between them.
- a number of bells placed randomly with the other objects.

Objective

The player must select all the bells before the time ends.

Game Rules

- the player must pick the marker with the mouse and move it toward the bell.
- to select the bell, the player must keep the marker on the bell until a full circle is drawn over the bell.
- if a player removes the marker before the full circle is drawn the bell is marked as approached.

Evaluation

- 0: the bell is selected.
- 1: the bell is selected with hesitation.
- 2: the bell is approached but not selected.
- 3: the bell is not approached.

Use case diagram

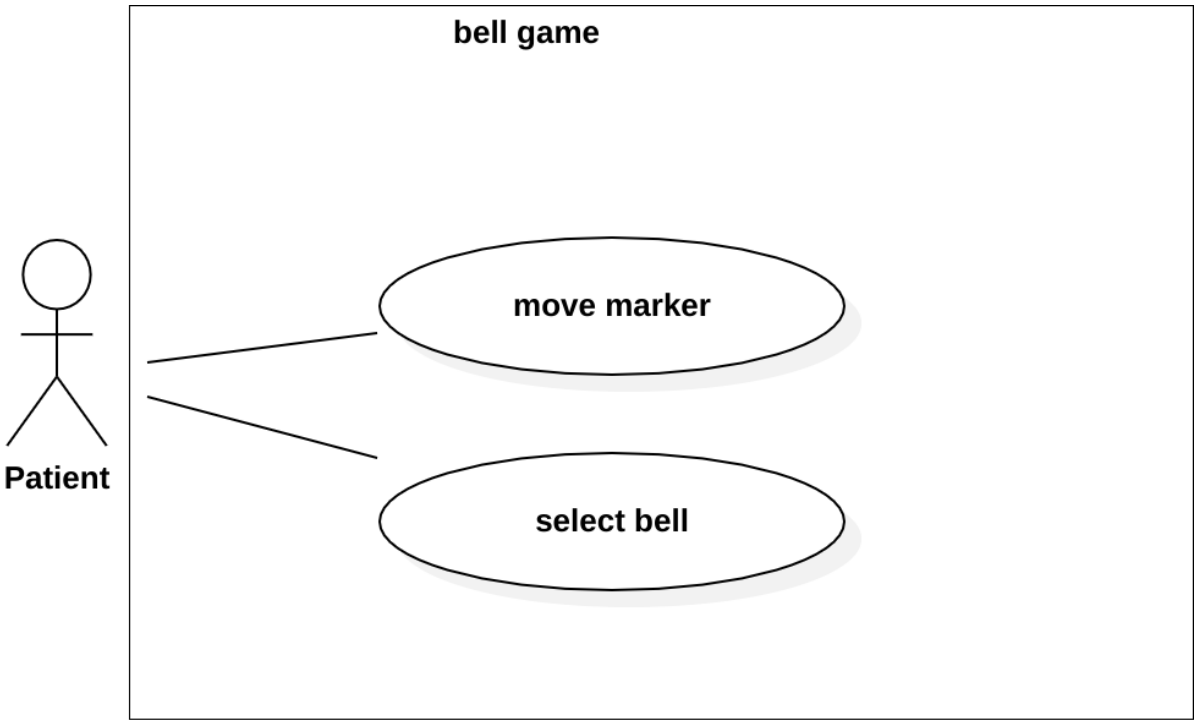


Figure 15 - Bell game user case diagram

1.4. Implementation

1.4.1. Login

The login form is customized to meet the patient's needs, hence no clicking needed except for the account recovery link. If the user is a therapist or an admin he is directed to the therapist site otherwise he is directed to the bee game.

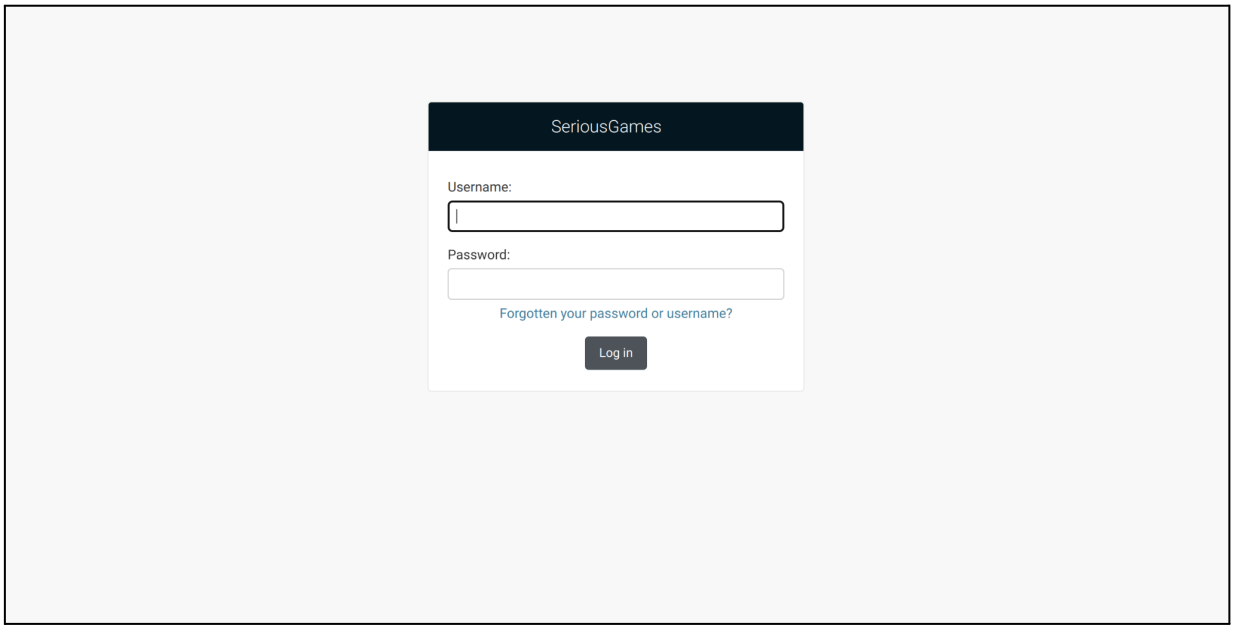


Figure 16 - Login page

1.4.2. Bee game

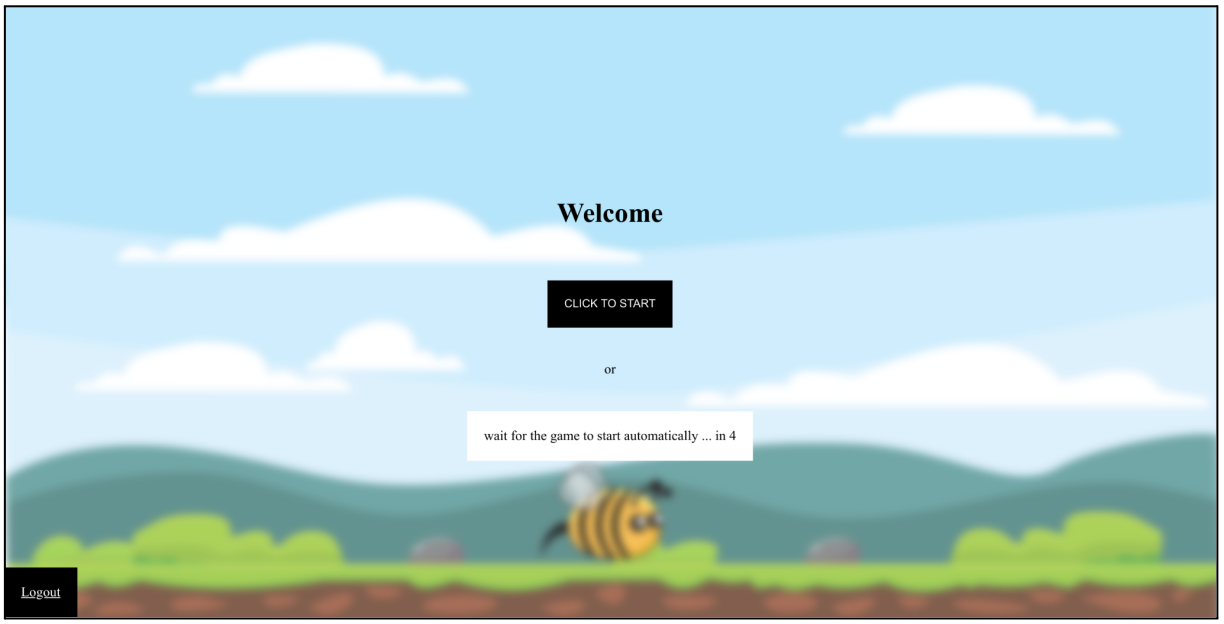


Figure 17 - Bee game start screen

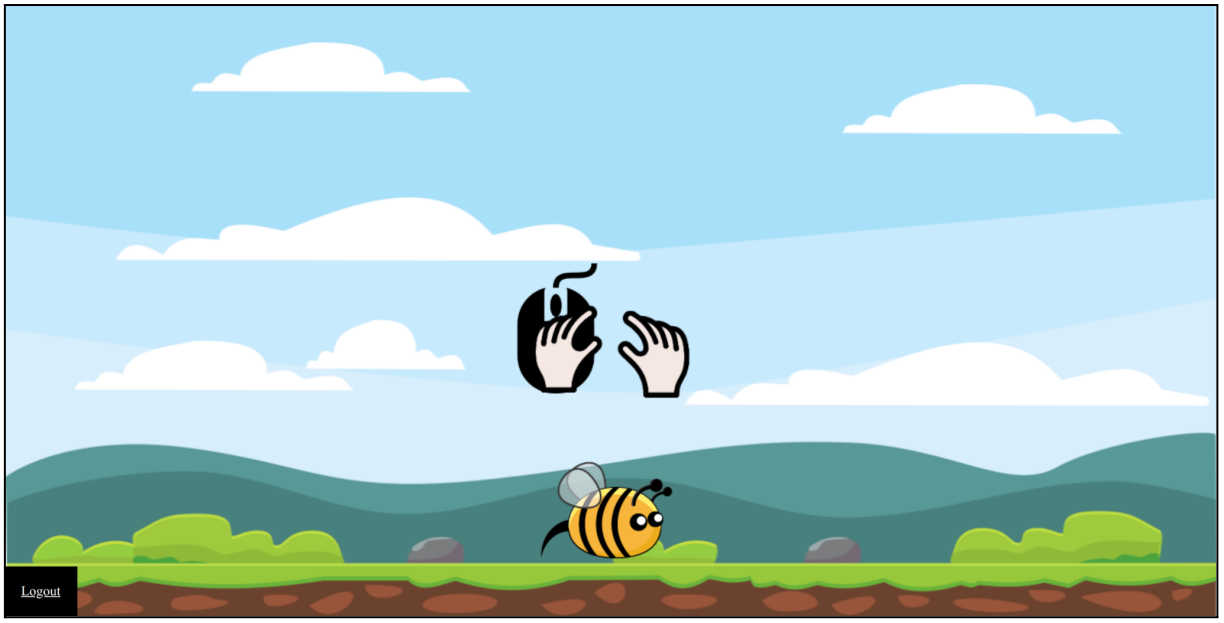


Figure 18 - Bee game learn to play

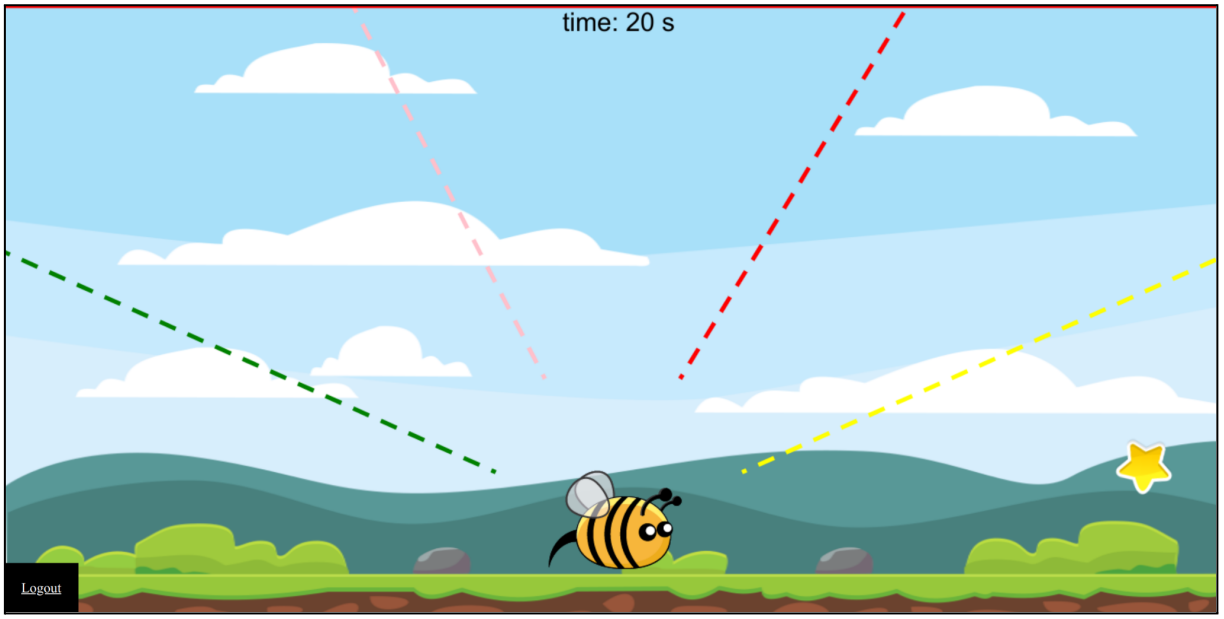


Figure 19 - Bee game part 1

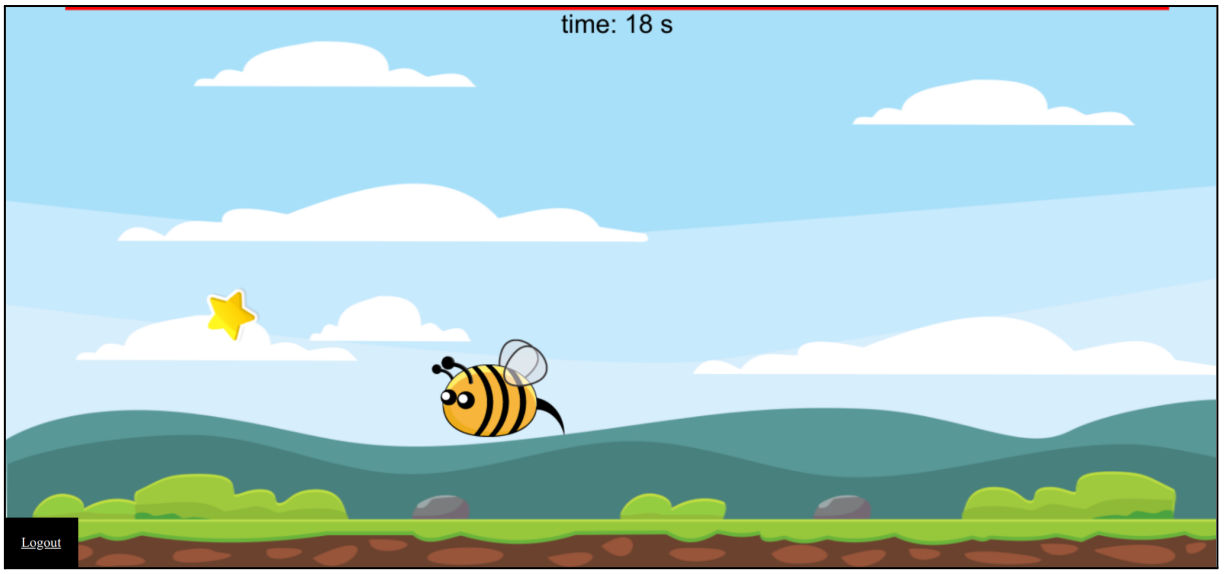


Figure 20 - Bee game part 2

1.4.3. Bell game

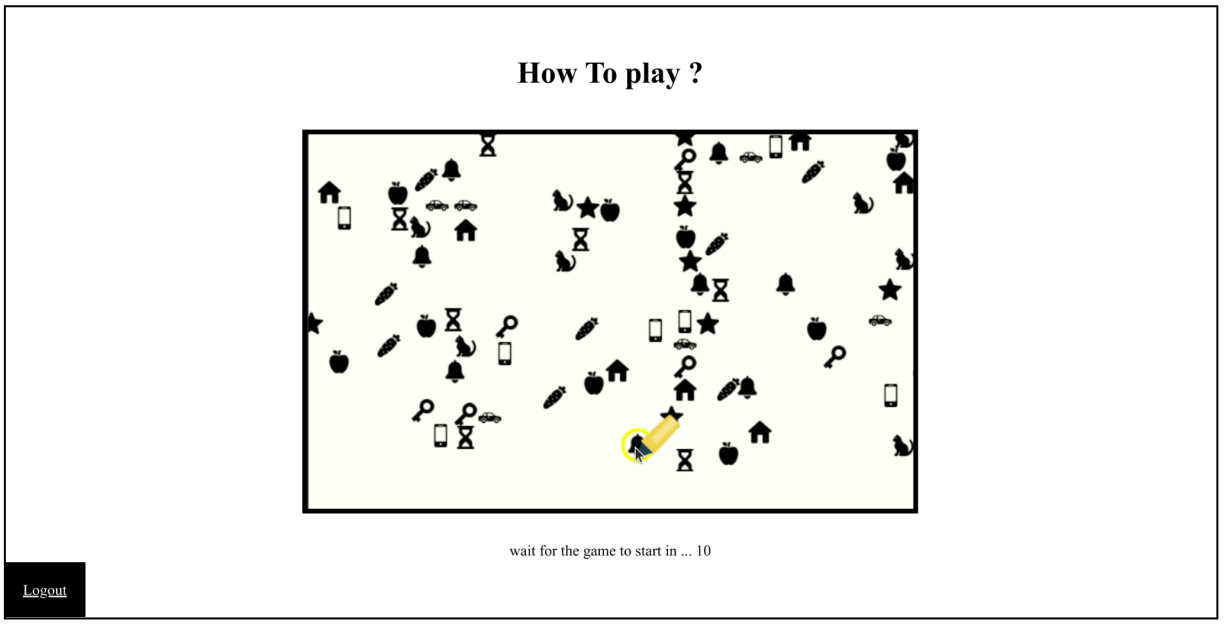


Figure 21 - Bell game start screen

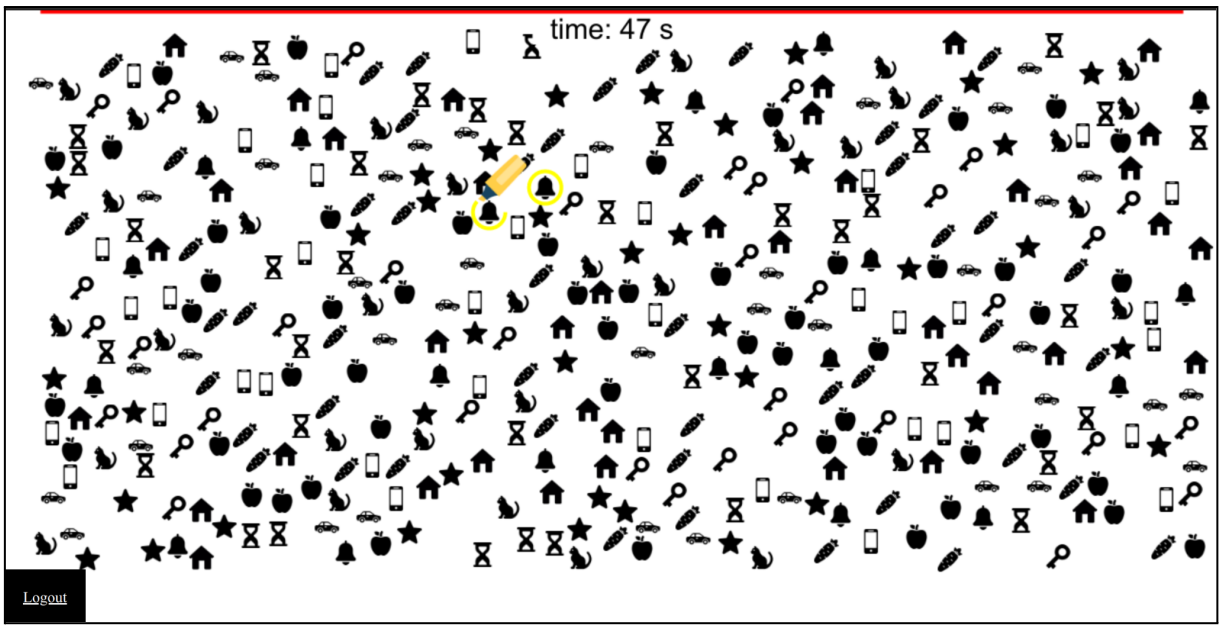


Figure 22 - Bell game play

1.4.4. Page redirection

Once the patient plays the bee game. he is directed to the bell game automatically. If the therapist didn't assign any bell game levels, the patient is directed to a 'Game not found' page and he can logout.

Figure 23 - Redirection page

1.4.5. Django admin site

1.4.5.1. Game level form

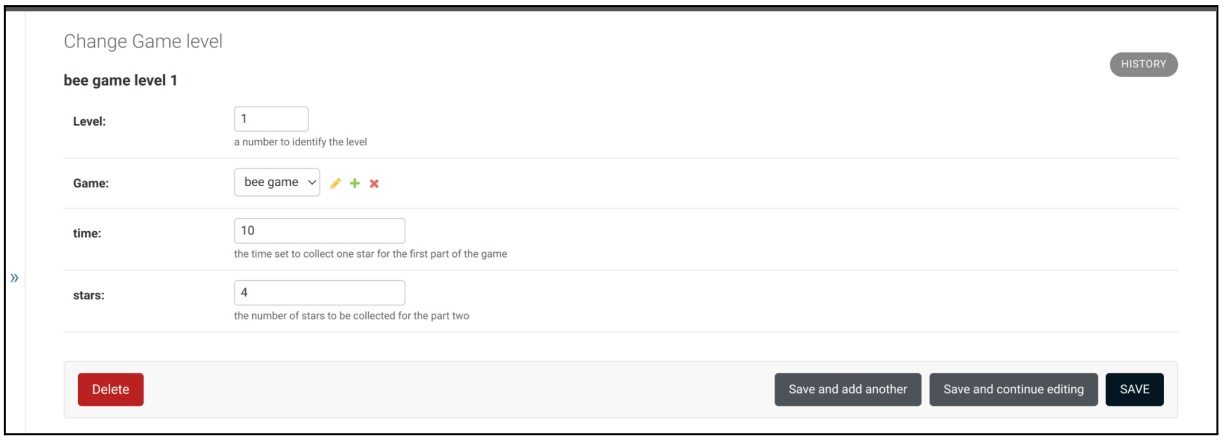


Figure 24 - Game level form

1.4.5.2. Game form

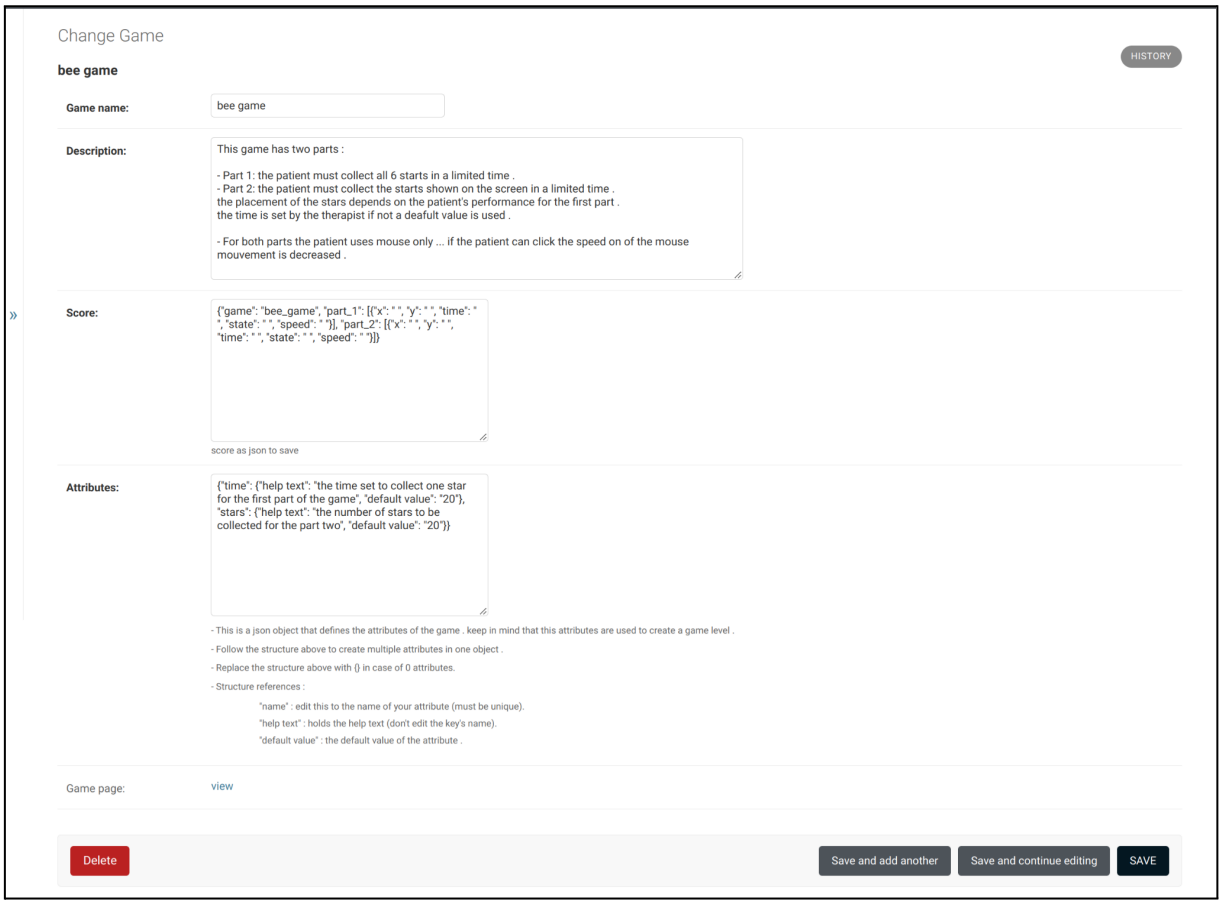


Figure 25 - Game form

1.4.5.3. Patient score

1.4.5.3.1. Score list

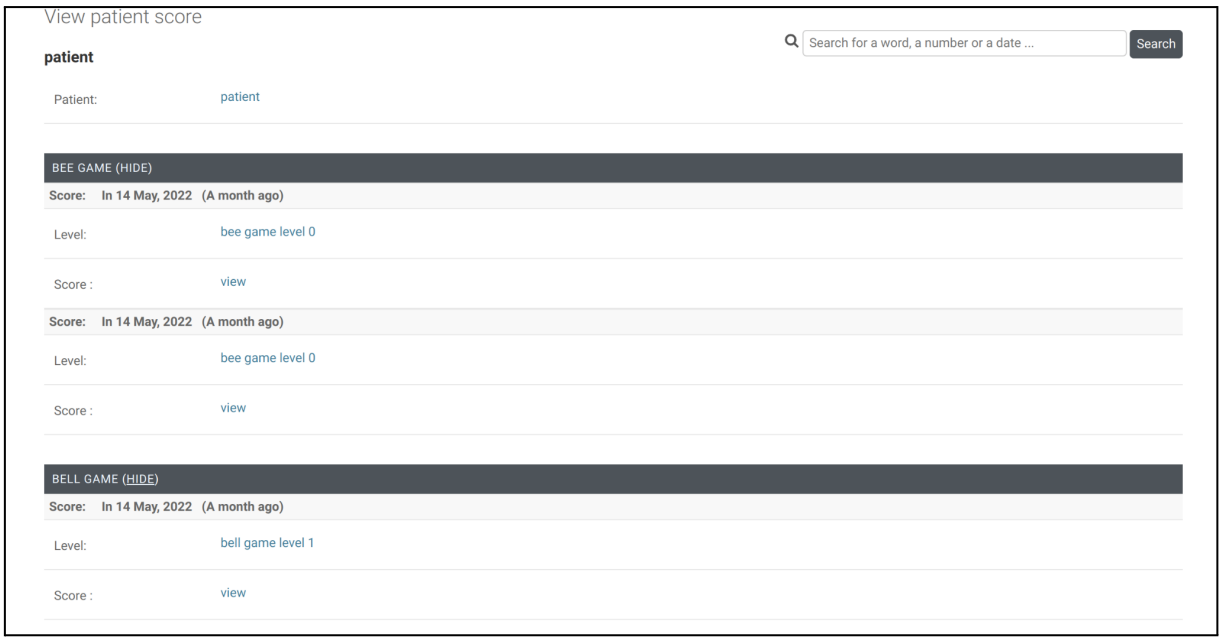


Figure 26 - Score list

1.4.5.3.2. Bee game score

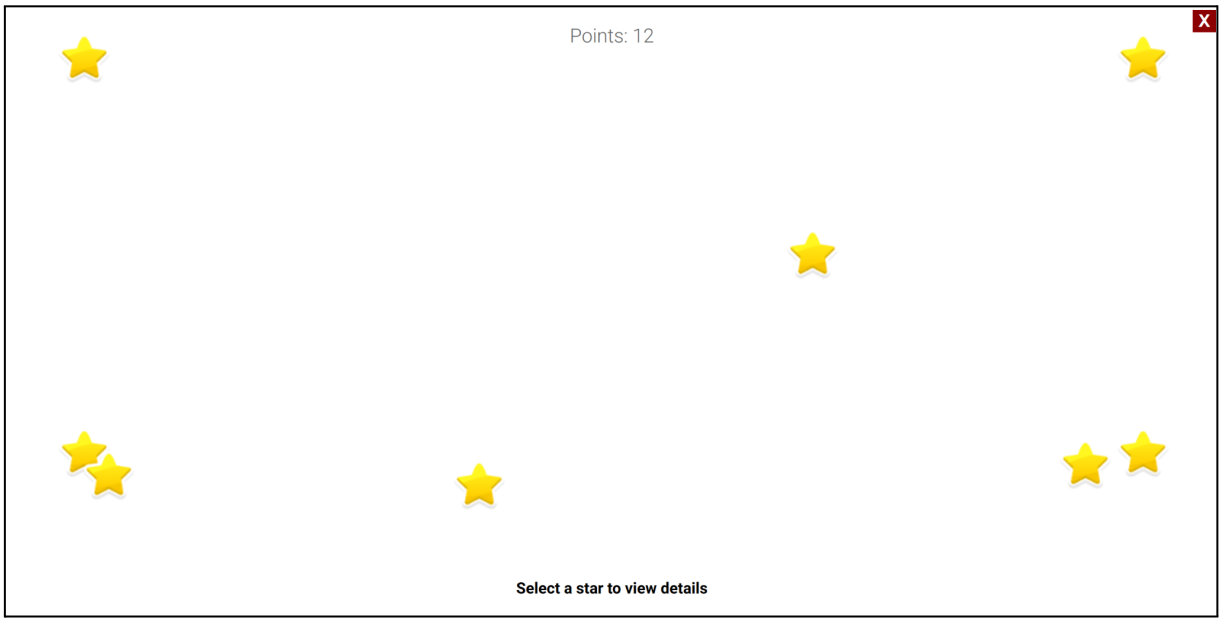


Figure 27 - Bee game score

1.4.5.3.3. Bell game score

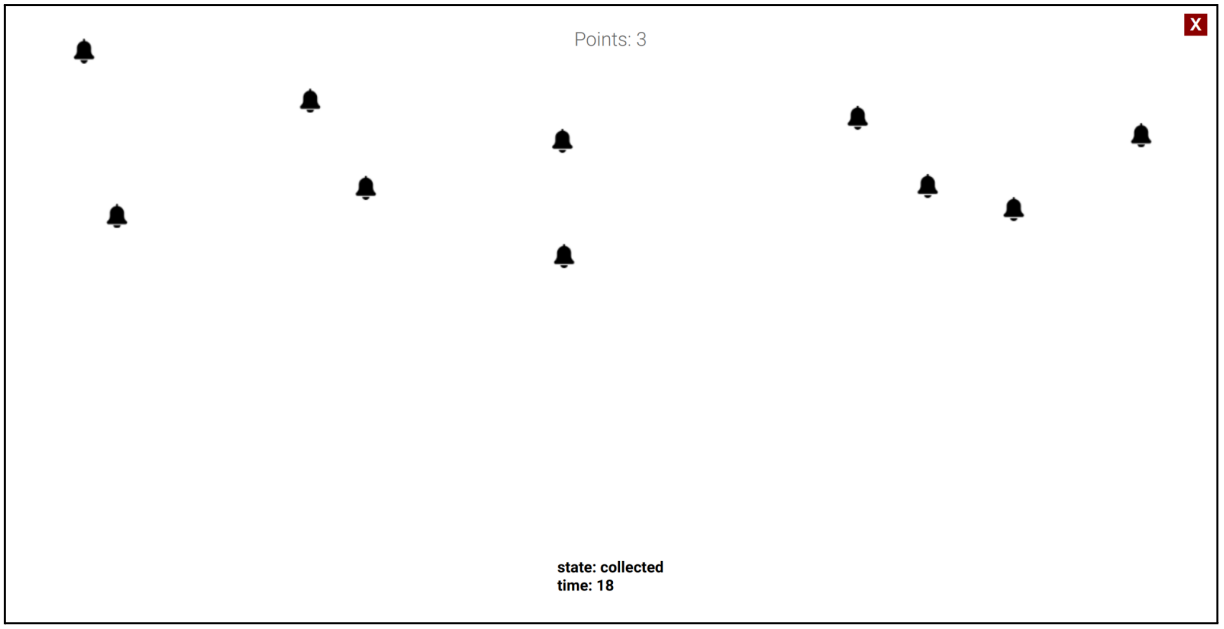


Figure 28 - Bell game score

1.5. Conclusion

This chapter took us through the process of developing the web application based on serious games and most importantly the implementation of the two games for post stroke rehabilitation. As we could see, the game development life cycle doesn't differ much from any software development cycle, but it is more complex as it has to take into consideration patients' limited abilities.

General conclusion

We worked, through this project, on the development of the Web application “SeriousGames” that aims to help post-stroke patients to perform their rehabilitation exercises, especially for arm therapy and cognitive exercises for one-sided spatial neglect. Thanks to the provided tools and the free resources of the game development community that contributed to the achievement of our goal of making a Web application for post-stroke patients rehabilitation.

However the real challenge begins when we see the web application in action. This will help us make improvements if needed on both the patients and therapist side. As for the next steps for the developer side we will add the ability to add new games using the admin site. As for the therapist side we will give better game management such as the game's playing order and the number of times allowed to play the game, all these things were not done because we mainly focused on the games development. As for the patient side which is the most focused on, we hope to be able to create more games.

Finally, we hope this project contributes to serious games development and that it helps post-stroke patients and therapists in the rehabilitation process by planning its possible deployment in the future.

BIBLIOGRAPHY

[1] “Accident vasculaire cérébral (AVC) · Inserm, La science pour la santé.” Inserm, 13 juin 2017, https://www.inserm.fr/dossier/accident-vasculaire-cerebral-avc/. Accessed 11 June 2022.

[2] A.Menon, A.Petzold, A.Kim, T.Ogourtsova, A.McDermott, N.Korner-Bitensky. “Unilateral Spatial Neglect – Strokengine.” Stroke Engine, 04 June 2015, https://strokengine.ca/en/consequences/unilateral-spatial-neglect/. Accessed 11 June 2022.

[3] LOPEZ, Marie. Prise en charge de l'héminégligence sévère d'un patient entrant dans la phase chronique d'une hémiparésie gauche en vue d'un retour à domicile. Travail écrit de Fin d'Études En vue de l'obtention du Diplôme d'État de Masseur-Kinésithérapeute. 2016-2017, pp. 7-8.

[4] Django Software Foundation. Django documentation | Django documentation, https://docs.djangoproject.com/en/3.1/. Accessed 11 June 2022.

[5] Crockford, Douglas. “JSON.” *Wikipedia*, https://en.wikipedia.org/wiki/JSON. Accessed 14 June 2022.

[6] sqlite.org. “About SQLite.” SQLite, https://www.sqlite.org/about.html. Accessed 11 June 2022.

[7] “Gantt chart wiki | TheReaderWiki.” *The Reader View of Wikipedia*, https://thereaderwiki.com/en/Gantt_chart. Accessed 14 June 2022.

[8] ZIANI Wafaa, AMMEUR Mohamed. Personnalisation des Jeux Sérieux dédiés à la remédiation cognitive pour améliorer la concentration chez les enfants et les adolescents. Mini-Project Report, Supervisor: dr. Nadia HOCINE, Faculty of Exact sciences and Computer sciences. 16 December 2019.

[9] Laramee, Francois Dominic, editor. Secrets of the Game Business. Charles River Media, 2003. Accessed 14 June 2022.

[10] “HTML Standard.” *HTML Standard*, 10 June 2022, https://html.spec.whatwg.org/multipage/interaction.html#user-activation-gated-apis. Accessed 14 June 2022.

[11] “Stroke.”*Cedars-Sinai*, Stroke | Cedars-Sinai. Accessed 16 June 2022.

[12] “Stroke | CVA | Cerebrovascular Accident.” *MedlinePlus*, 5 May 2021, https://medlineplus.gov/stroke.html. Accessed 16 June 2022.

[13] Laamarti, Fedwa & Eid, Mohamad & El Saddik, Abdulmotaleb. (2014). An Overview of Serious Games. International Journal of Computer Games Technology. 2014. 10.1155/2014/358152.