

Article

Learning First Aid with a Video Game

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Abstract: Any citizen can be involved in a situation that requires basic first aid knowledge. For this reason, it is important to be trained in this kind of activity. Serious games have been presented as a good option to integrate entertainment into the coaching process. This work presents a video game for mobile platforms which facilitate the formation and training in the PWA (Protect, Warn, Aid) first aid protocol. Users have to overcome a series of challenges to bring theoretical concepts closer to practice. To easily change the point of view of the game play, Augmented Reality technology has been used. In order to make each game looks different, neural networks have been implemented to perform the behavior of the Non-Playable Characters autonomous. Finally, in order to evaluate the quality and playability of the application, as well as the motivation and learning of content, several experiments were carried out with a sample of 50 people aged between 18 and 26. The obtained results confirm the playability and attractiveness of the video game, the increase of interest in learning first aid, as well as the greater fixation of the different concepts dealt with in the video game. The results support that this application facilitates and improves the learning of first aid protocols, making it more enjoyable, attractive, and practical.

Keywords: first aid; video games; serious games; education; augmented reality; artificial intelligence



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1. Introduction

Serious games are defined as video games whose purpose is not only the user's entertainment, although this does not imply that these kinds of games have to be boring [1]. Due to the great popularity of this type of entertainment among the new generations, different fields other than leisure have taken advantage of this circumstance to apply this technology to their field and make their tasks more attractive. A very highlighted area has been education [2]. Some works, such as those presented in [3,4], demonstrate that using games improves the level of motivation and engagement of the learners, since they can combine entertainment with their own training activities [5,6]. Educational video games are developed specifically to help players to understand certain concepts, develop new problem-solving skills, or learn new knowledge through various methods. However, the recreational component is really important, which is what drives most users to use these technologies.

First aid is the initial assistance or treatment given to an accident victim or a person suffering from a sudden illness. In order to be effective in aiding the victim until the arrival of the health care services, it is necessary to have a minimum of essential knowledge [7]. The aim is to save lives, so it is of utmost importance to know how to put previously acquired first aid knowledge into practice [8]. The general behavior in an emergency situation is known as the PWA (Protect, Warn, and Aid) protocol. Learning First Aid requires a series of memorized steps to be performed in a specific order. Since, in real life, the practice of First Aid often takes place in stressful situations, and these steps must be internalized so that there is no need to waste time remembering them, but they come out automatically. For this reason, it is important to learn by doing.

Mobile or wireless devices are currently available to almost everyone because of the great popularity of smartphones in society. As a consequence of this, recent research has used digital devices as platforms for game-based learning [3]. In addition, mobile learning includes the concept of “anytime, anywhere” [9,10], providing the opportunity to learn without being restricted to a set time and place, and allows leisure moments to be used as an opportunity for learning. The replacement of expensive and complicated real simulations with a virtual representation on a mobile device will offer the possibility of practicing an easy and affordable First Aid training to the general population.

There are also different techniques and/or tools that increase engagement in the use of virtual applications, such as the implementation of Augmented Reality (AR) or Artificial Intelligence (AI) algorithms in them. This is an important aspect when this kind of application is applied to the training and education area.

Augmented Reality combines real and virtual objects with a three-dimensional registry, making it possible in some cases to interact in real time [11]. Due to the ability to see physical objects and the overall context, these AR-based solutions also promises less simulator sickness for training [12]. This technique presents itself as a good tool to increase engagement to the use of the applications developed [13,14]. Moreover, AR converts learning situations into contextual situations, which usually improves educational praxis [15]. Applications that include AR in the field of education have reached areas as different as History, English, Environmental Sciences, Technology, Engineering Mathematics, or First Aid [16–19].

Artificial Intelligence is a system that aims to reproduce the characteristics of human thought processes such as decision-making, learning, or thinking without human intervention [20]. Since its beginnings, it has been used in numerous fields such as health, training, and education [21,22]. In the area of AI, there are different machine learning algorithms such as neural networks, which are nowadays being applied in the creation of video games and/or playful experiences [23].

Regarding the application of these disruptive technologies in the education field, Kangas et al. [24] presented the “playful learning environment(s)” (PLE) concept. It denotes an innovative, technology-enriched play and learning environment whose components are located indoors as well as outdoors. In addition, this digital environment does not have either rules or prizes when users play, unlike a video game.

Considering the previously mentioned, this paper proposes a mobile application that allows the acquisition of First Aid knowledge in a practical way, thus making learning about this subject more enjoyable. This video game has been designed that aims to recreate a situation in which First Aid intervention is required, such as the PWA (Protect, Warn, Assist) protocol. It is an application of “a choice of options” in which time is an essential item. If the actions chosen by the player are the right ones and are carried out in the established time, the injured character saves his/her life and the game is won, and in the opposite case, the character loses his life and the game is lost. This video game is visualized with AR technology, so the player can see from different points of view the situation they are facing in the game. Using this technology has demonstrated that it increases the engagement of the applications [25]. The video game has been completed with the use of trained neural networks to control the behavior of the NPCs (Non Playable Character) that randomly appear in the scene. This will make each experience different and more enjoyable the game for the player.

The use of the application is not restricted to an age range. The main objective of this work is that the students internalize the actions to be taken in a situation in which First Aid knowledge is required, and that they do it in a practical and entertaining way to consolidate the acquired knowledge. The mobile application has been designed to encourage the interest of end users. For this purpose, the design principles of learning games have been used in this work, following the indications of a Human-Centered Design (ISO 9241-210: 2019) [26].

The presented application seeks to demonstrate the following hypotheses: on the one hand, learning and training through serious games enhances the memorization of content and, on the other hand, it is assumed that serious games engage the learner and makes learning more enjoyable than traditional methods. In order to be able to evaluate both, the acquisition of the PWA protocol knowledge and the video game engagement, some user tests have been carried out. In terms of training, and with the aim of evaluating whether the use of the created video game is an effective tool in the learning of the P.A.S. protocol, two different ways of teaching these concepts were compared, applying each of them to an independent sample of students. In one of the samples, the video game was used as a learning tool, while, in the other, the content transmission process was carried out by the teacher, using traditional learning. In order to assess the effectiveness of the video game in motivating students to learn, a concept evaluation questionnaire was administered.

The analysis of the results obtained corroborates that the use of this technology has a positive impact on the acquisition of the necessary skills to carry out an intervention in the event of a situation requiring the implementation of a PWA protocol. It is also demonstrated that students learn faster because they are motivated.

The rest of the work is organized as follows: Section 2 briefly reviews works recent works on serious games related to learning and training in First Aid, as well as other research that offers AR-based solutions to complement First Aid training. Section 3 presents the initial research carried out with the aim of providing guidelines for the design and development of this video game. Section 4 analyzes the design and the main contributions of the work. The experiments carried out are analyzed in Section 5. Next, the results obtained are discussed in Section 6. Finally, conclusions and future work are presented in Section 7.

2. Previous Work

Widespread dissemination of first aid can have benefits for injury prevention in traffic accidents and other risk situations [27,28]. Currently, a first aid and basic life support course for learner drivers has become mandatory in many of the countries of the European Union. In addition, organizations such as the Red Cross [29] have defined guidelines that describe how first aid interventions should be safe. The effectiveness of prevention-focused first aid initiatives has also been studied and, in most cases, the general conclusion is that these strategies are effective [30,31]. Adelborg et al. [32] carried out a study on this, concluding that a mandatory course for learner drivers significantly improves participants' knowledge and self-assessed skills in first aid and basic life support.

The popularity of video games makes them an excellent tool to be used for educational purposes [33–35]. Game-based technologies are more effective because the “learning-by-doing” concept is applied. They are able to create personal motivation and satisfaction, in addition to providing an interactive and decision-making context [36,37]. Another advantage of using video game technologies is that they offer the possibility of visualizing realistic scenarios in real time, an aspect of particular relevance when the aim is to reconstruct First Aid scenarios that represent an accident as realistically as possible.

There is much documented evidence of the use of video games in First Aid learning. Countries such as Turkey used educational video games as a basis for teaching units on, among other things, first aid, in primary, secondary, and higher education contexts, respectively [38]. The serious game presented by [39] deals with educating the population on how to proceed in the case of choking. In this game, the player takes on the role of a helper who has to save the choking person by applying the main steps of the protocol. The results showed that the players not only enjoyed the game, but all the indicators of the knowledge of this protocol improved. In the same lines, Ref. [40] proposed a video game for Android in which different First Aid actions are presented to familiarize users with different scenarios, choking being one of them. Other relevant applications to highlight are: Combat Medic [41], a 3D collaborative virtual world for treating hemorrhages, airway management, and tension pneumothorax; HumanSim:Blast [42], in which after an explosion at a train

station, the player must identify and label areas on a map of the area, tag potential hazards, assess patient vitals, perform life-saving procedures, and triage patients. In the field of cardiopulmonary resuscitation (CPR), Ref. [43] proposed a serious game to teach and train automated external defibrillation. In a similar direction, but aimed at familiarizing schoolchildren with this protocol, Ref. [44] developed HeartRun, a mobile simulation game to train resuscitation. In addition, the work aimed at education in first aid for people with Autism spectrum disorder (ASD) is noteworthy [45]. In all of these works, the effectiveness of video games in the field of education was demonstrated.

The use of AR complements traditional teaching methods and materials with some virtual content. The fact that only a smartphone is required to visualize digital objects over real content makes this technology appropriate to be used in education with the aim of improving the learning and motivation of the students [46]. In addition, there are potential benefits such as improving task efficiency [47], improving cost and time of use, and the possibility of large-scale training [48]. There is a variety of research that offers AR-based solutions to complement First Aid training. Most of these works aim to provide a step-by-step guide for training and a potential real-life implementation [49,50].

In recent years, the trend is to combine different technologies in order to make learning first aid easier. In 2020, Ref. [51] explores the feasibility for using a Microsoft HoloLens Head Mounted Display (HMD) with Augmented Reality to complement First Aid trauma training. In 2021, Ying [52] presents an application to help non-expert rescuers to identify the symptoms of the injured person by analyzing machine learning data and to learn First Aid in a clear and concise way using AR as a visual aid. The prototype had the limitation of not being able to detect 3D objects, such as human body parts, with the AR technology used.

After this small analysis of the use and combination of different technological tools in the field of the First Aid Learning, it is concluded that both the use of video games and A.R. visualization technology would improve the acquisition and skills in the learning and training of these abilities. This study has encouraged the design and development of the video game presented in this article. The video game will use AR visualization technology to increase the player's engagement with the application. In addition, neural networks will be used to implement the autonomous behavior of the Non-Playable Characters.

3. Preliminary Study

As it has been previously said, the mobile application has been designed following the indications of a Human Centered Design (ISO 9241-210: 2019), so different meetings and studies have been carried out to adapt the design to the characteristics of the final users.

Firstly, research and analysis of existing applications and tools on the market, focused on training in safety and first aid protocols, were carried out. The next step was to create a group for performing the co-creation and co-design. Some ideas and knowledge with companies and institutions dedicated to the kind of training were shared in order to find the best solution to the presented problem. During these meetings, different market studies that have addressed this topic were considered. Then, as a conclusion, it was determined that designing and developing an application that would show a playful experience for mobile devices would be the most effective and the easiest, as these devices are accessible to everyone.

Taking into account the educational nature of this application and the variety of actions included in first aid (traffic accident, electric shock, serious burns, myocardial infarction...), it was suggested to start with the representation of an action corresponding to a PWA protocol. Although the basic protocol is the same in all of the interventions, each of them requires different actions to be carried out. It was decided that the first experience to be implemented would be the simulation of a traffic accident, one of the most common interventions that citizens can be faced with.

Regarding the discussion about how to address the educational component of the application, the aim was to make learning first aid practical and enjoyable, avoiding the

monotonous theoretical class or the reading of any kind of document. Learners not only have to memorize what to do, but also to internalize the steps to be taken in the event of a specific intervention, so that, even if it is the first time he/she performs it, his/her action is automatic and without having to try to remember the steps to be taken and their correct order.

Finally, to promote the engagement to the application, AR visualisation technology will be incorporated. Some non-playable characters (NPC) will be included in the developed application and their behavior will be implemented by training a neural network, which will make the scene look different every time the playful experience is started.

The game presented in this paper has been designed following the proposed directives.

4. The PWA Video Game

The PWA protocol consists of a series of steps to be carried out in an established order during an emergency situation with injured persons that need of medical assistance. This protocol should be known and internalized by the general public in order to minimize the risks in an emergency situation.

For this purpose, a mobile video game that represents an interactive environment where these actions are required. The application uses AR visualization technology, which will allow users to view the scene from different angles by simply moving the mobile phone. Several options are currently available to work with such technology—for example, the gyroscope and the oscilloscope of the mobile phone—but it was decided to use a simple AR marker to enable this option. The decision was taken because using a marker only requires the mobile phone's camera, which all mobile phones are equipped with. On the other hand, the gyroscope and oscilloscope are not yet included in many mobile phones.

In addition, in order to simulate a different scene every time the game starts, the behavior of the N.P.Cs is obtained as a result of the implementation of neural networks.

4.1. Technology Used for Design and Development of the Video Game

The application has been developed for Android and iOS. All the implementation has been developed in the game engine UNITY 2020.3.6f1 with Vuforia plug-in [53]. The Microsoft Visual Studio 2019 integrated development environment has been used to program the C# scripts.

The assets representing the characters and the city model were obtained from the Unity Asset Store [54,55]. In order to achieve a faster rendering speed enabling the application to run in real time, the chosen models will be made of a small number of polygons, known as low poly models. Animations have been done with the animation software Mixamo [56]. Due to the need to incorporate functionalities into the game, some of the objects, such as the traffic warning triangles or the reflective waistcoat, have been modeled with 3DSMax 2021.3. For the design of the 2D models used in the user interface, Adobe Photoshop 2020 has been used. The original music has been designed with the audio and MIDI sequencer Ableton, and implemented in Unity with the Audiokinetic's software, Wwise [57], and text has been generated with the CoolTexttool [58].

To design, train, and export the neural network, the PyCharm integrated development environment has been used, which is specifically for Python programming. The network will be created and trained using a Tensorflow Keras toolkit [59,60] as it offers more freedom to design neural networks than using Unity's ML-Agents plugin.

4.2. Scene Game Visualization

The game starts with an initial scene presenting the application (Figure 1) in which music and language can be chosen. Once the game play starts, a scene showing an aerial view of a city map is visualized (Figure 2). In the city, various points of interest are highlighted with a yellow exclamation mark. Each point of interest corresponds to a First Aid intervention that makes a mini-game available that represents a particular intervention.

In the case shown in this work, the mini-game represents a traffic accident where a PWA protocol has to be applied.

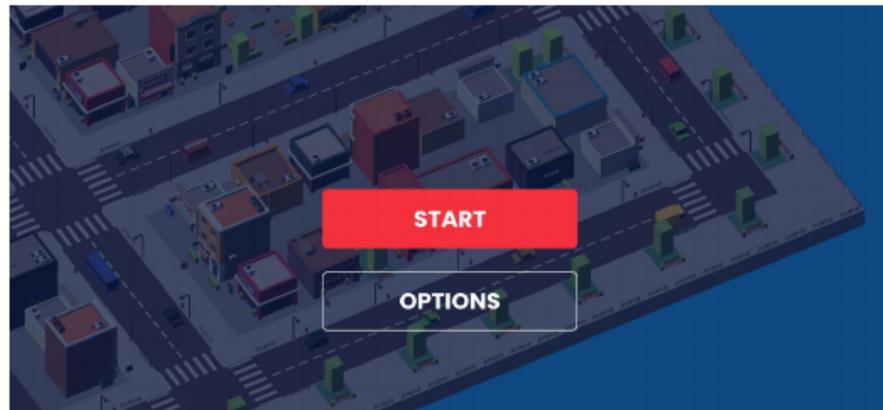


Figure 1. Initial scene presenting the application.



Figure 2. Aerial view of the map of the city.

Then, some information and instructions about the steps to follow are shown to the users (Figure 3). After these scenes, the player will have to focus on an AR marker with the mobile camera to access the main scene of the game. Once the marker is detected, the scene will be shown on the device screen, completely hiding the marker. An example of this case is shown in Figure 4 (right). The character representing the injured person will be positioned just above the marker in the scene. The left image in Figure 4 has been included in the text to clarify how the AR works. There, the AR marker and how the scene and the injured person is placed on it are shown. For this purpose, the image of the road shown in the original scene has been removed. However, during the game play, this AR marker is not visualized. The game scene will be positioned and oriented according to the angle, inclination, and distance to the marker from the point of view of the device. Simply moving the mobile phone can change the point of view of the camera. In addition, every movement of the marker will change this view.

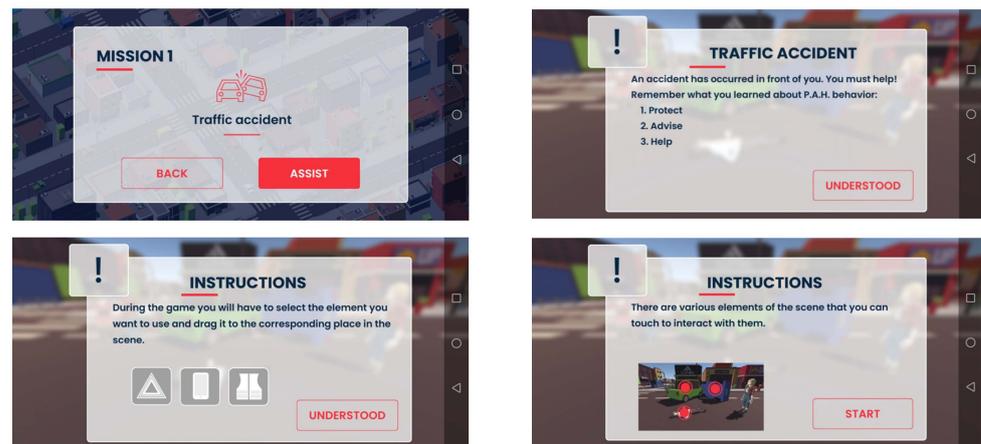


Figure 3. Information scene.

Information concerning the evolution of the game is shown at the top of the main screen (Figure 4). Two bars appear representing the life bar of the injured person (the one on the left), and the one on the right informing about the time spent in the intervention, represented by an image of an approaching ambulance. The time factor is crucial in this type of intervention. Whether the player has not completed the challenges in a maximum time set at 5 min, the life bar of the injured person runs out of time, and the ambulance does not arrive in time, so the game is lost.



Figure 4. Left: Scene with the User Interface of the game play showing the marker. The road has been hidden to clarify how AR works. Right: User Interface of the game play that is presented to the user.

In order to successfully complete the game, the player, in less than the maximum time allowed, must perform correctly and in the right order, a series of steps that will save the life of the injured person. These actions are managed from the icons that appear at the bottom of the game play scene. The actions are:

- Protect phase. Figure 5 illustrates a scene when all the actions to be taken have been developed. These actions are listed below:
 - Putting on the reflective waistcoat. The player shall drag the reflective waistcoat from the button bar to the player's model to put on the waistcoat.
 - Placing a reflective triangle on each side where the accident occurred. As this is a two-way road, the player must drag, from the button bar, a reflective triangle to each side of the accident.
 - Immobilising the accident vehicle. This action allows the player to interact with a static object such as a vehicle. When touching the car, a short description of the situation and several actions appear in the scene. The player must choose the correct one.
- Warn phase. This phase includes the options listed below:
 - Activating the mobile phone. The player must drag the mobile from the button bar to the player's character.

- Dialing Emergency Telephone Number (112). Dial this number on a telephone keypad displayed on the screen (Figure 6 left).
- Talking to emergencies. The screen will show a dialogue between the character player and an emergency operator at his or her switchboard. A text simulating what the emergency operator says is displayed and several possible answers to this situation are shown. The player must choose the correct answer to each of the questions asked by the operator (Figure 6 right).



Figure 5. Protect phase completed.

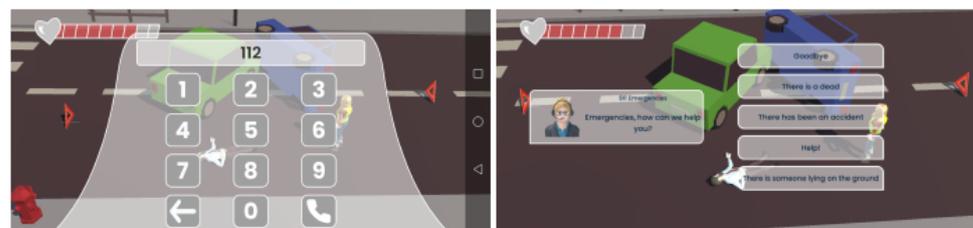


Figure 6. **Left:** Telephone keypad to dial the number 112 on. **Right:** Example of a dialogue between the player and an emergency operator.

- Assist phase. This phase tries to stabilize the injured person. This action allows interaction with the injured person. When touching him/her, the scene displays a short description of the situation and five actions to be performed (Figure 7). They have to be selected in the right order: check consciousness, airway obstruction, and bleeding. The options available for the user are:
 - Check consciousness;
 - Check for bleeding;
 - Check breathing.
 - Left him.



Figure 7. Actions to be ordered.

The flow chart shown graphically in Figure 8 describes the PWA protocol procedure of this video game.

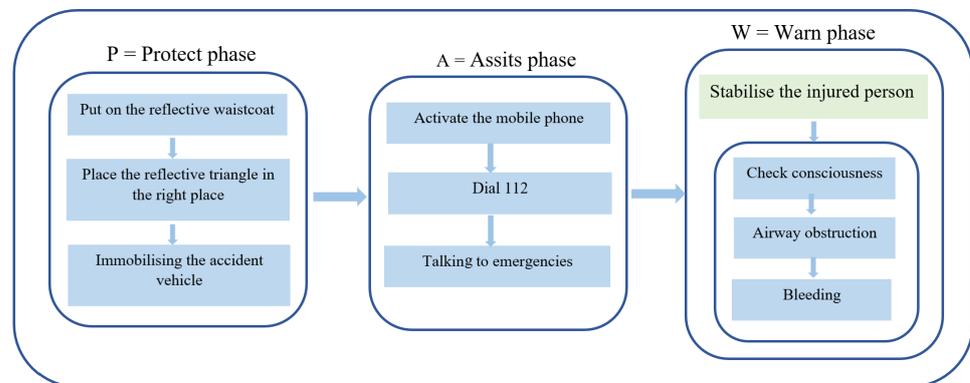


Figure 8. Flow chart describing the PWA protocol procedure.

If the actions have been carried out successfully, the game has been won, and a message will be displayed, allowing you to return to the city if you want to repeat the game or choose a different intervention (Figure 9 left). If the player makes a mistake in any of the steps, the game is lost and the game can be restarted from the beginning or user can access to the game play again. The game is also lost if the time set for completing all the steps and saving the injured person is exceeded (Figure 9 right).



Figure 9. Left: Scene shown when the game is won. Right: Scene shown when the game is lost.

4.3. Intelligent Behavior of the NPCs

This project uses a trained neural network algorithm that is later imported into UNITY. For this purpose, the neural network will be created and trained using TensorFlow's Keras toolkit.

In order to make the player feel that every time he starts the game, even if he is in front of the same intervention, the environment is different, an A.I. based algorithm has been implemented. This algorithm will control the behavior of non-playable characters (NPCs) according to themselves and their environment, making their behavior different from game to game. The characters are spawned randomly, so the input values to the neural network will change in each game, and, therefore, the behaviors of the NPCs, which are loaded from the neural network, will also change.

Regarding the development of the neural network, two phases have to be taken into account:

- Creation, training and export of the model. The flow chart that shows the developed action is included in Figure 10.
- The use of these networks in the AI control of the NPCs. In this case, Figure 11 illustrates the flow chart.

To train this neural network, a training set of 350,000 inputs, 50,000 of each type of output, and a set of 14,000 tests, 2000 of each type of output, were used. Each time the neural network is trained, and due to the scarcity of training situations, the training data will be randomly generated within pre-established ranges in a logical manner.

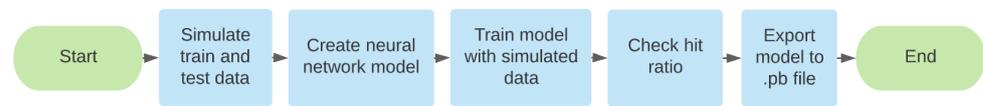


Figure 10. Creating, training, and exporting the model.

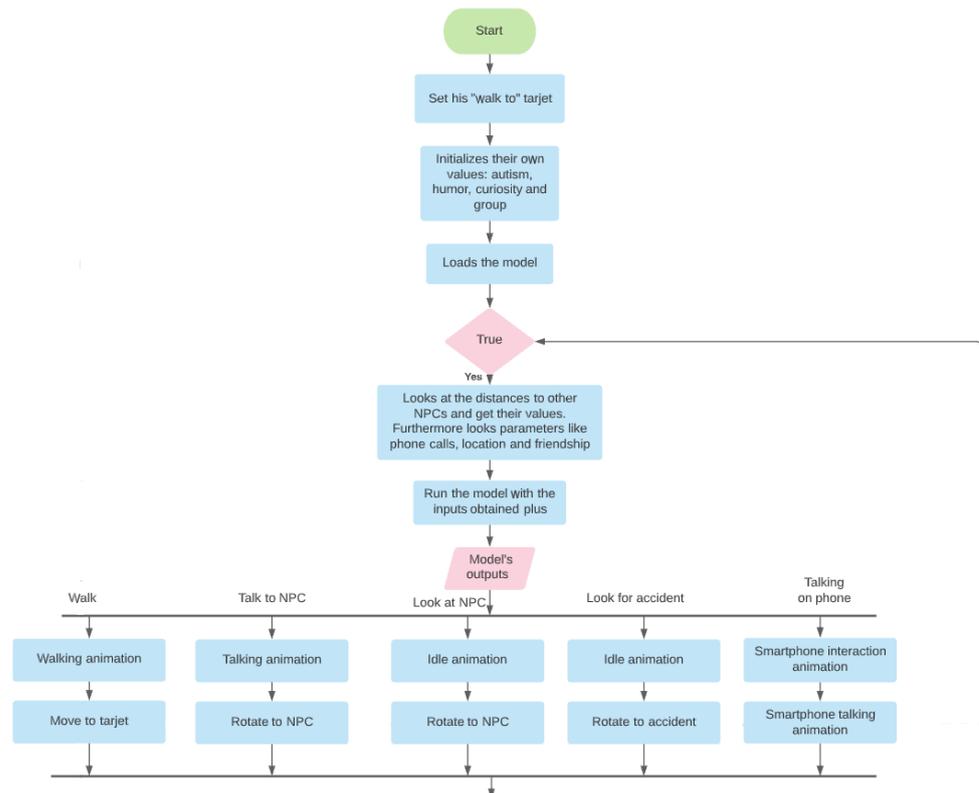


Figure 11. Use of networks in the control of NPCs' AI.

Network inputs are the parameters relating to the environment or to the NPC itself which can affect their behavior. The values of these inputs are set in a range between 0 and 1 and vary according to the actions to be carried out. These values increase or decrease linearly according to the time that goes by in each situation. A 0 means that the NPC is at minimum, and a 1 means that it is at maximum. They can represent:

- Values defining the behavior of an NPC: These values have been three: a curiosity that simulates the curiosity he/she feels to observe the accident; autism that simulates an NPC's desire to talk to another NPC, and motivation that simulates the desire to talk on the phone.
- Values defining distances from one NPC to another depending on whether the other NPC is walking, talking, waiting, watching the accident, or talking on the phone. This is a value relative to the distance from the nearest NPC that meets each of the stated conditions.
- Values defining distances from an NPC to a particular scene element such as the accident or the center of the road. It is a value relative to the distance of the NPC to the reference element.
- Values that represent social situations: the case when two NPC have met before. These data only take two values, 0 or 1 as in the case of knowing another target NPC, where 0 means that he/she does not know him/her and 1 means that he/she does know him/her. Another case that has been considered is about the fact of receiving a phone

call, where 0 means 1 that the NPC is not talking on the phone, while 1 means that he/she is.

The outputs of the network are the actions that the NPC can perform. Seven situations have been defined, listed below:

- Walk to a predefined destination;
- Look at the accident;
- Talking to a nearby NPC;
- Stare at another NPC;
- Talking on the phone;
- Simulate crossing the street;
- Knowing an NPC.

5. Game Evaluation

The study in this experiment has consisted of a usability and acceptance test where the presented application was used in a controlled environment. To carry it out, two groups were defined: the experimental group (EG), composed of 30 users to test the application, and the control group (CG) composed of 20 users.

The used inclusion criteria were, on the one hand, the requirement that all users must have a small amount of knowledge of first aid and the PWA protocol. In this way, it was avoided to have users without the ability to improve their knowledge, and on the other hand, they had to have enough skills to be able to use the application.

The sample consisted of 50 computer science students aged between 18 and 26 years—all of them with a high capacity with the use of Information and Communications Technology (ICTs) and limited knowledge about First Aid. In addition, to avoid problems arising from the device, everyone was provided with a mobile with the application already installed.

5.1. Experiment Design

In order to measure the degree of improvement in knowledge of the PWA protocol, an experimental design study of repeated measures was implemented. The efficacy of this type of study to evaluate performance has already been demonstrated in the literature [61–63]. Using this design, the experiment was divided into three parts: a pre-test, the experiment, and a post-test. Tables 1 and 2 show the type of questions each group received in both tests.

Table 1. Questions in the Pre-Test related to assess the knowledge about the protocol.

| Pre-Test | |
|-----------------|--|
| EC | 1 question about themselves (age) |
| | 2 questions related to their knowledge related to the test |
| | 10 questions about the PWA protocol |
| GC | 1 question about themselves (age) |
| | 2 questions related to their knowledge related to the test |
| | 10 questions about the PWA protocol |

Table 2. Questions in the Post-Test related to assess the knowledge about the protocol.

| Post-Test | |
|------------------|---|
| EC | 10 questions about the PWA protocol |
| | 10 questions about their opinion of the APP |
| GC | 10 questions about the PWA protocol. |

In the pre-test, both groups (EG and CG) received the same questionnaire to assess their knowledge of the PWA protocol prior to the experiment. This questionnaire was composed of 13 questions: 1 to indicate the age of the user, 2 for the self-assessment on the use of augmented reality and the protocol and, finally, the rest of the questions were related to the knowledge of the PWA protocol.

In the post-test, both groups also received the same 10 questions in order to measure the improvement in their knowledge of the PWA protocol. In addition, the experiment group received a questionnaire to assess the application.

5.2. Questionnaires

The questionnaire to assess knowledge was designed to address all sections of the protocol. In addition, to include both simple and complex questions, some of them were given answer options and others were not. The questions used can be seen in Table 3.

Table 3. Questions used to assess protocol knowledge.

| Questions | |
|-----------|--|
| 1 | What does the acronym PWA mean? |
| 2 | What the protect action does not include. <ul style="list-style-type: none"> • Put the triangles • Putting on the reflective vest • Call to emergency |
| 3 | What is the emergency number? |
| 4 | What is the first thing to do if the casualty is not bleeding or breathing? <ul style="list-style-type: none"> • Plugging the wound • Check if something is blocking the airway • CPR |
| 5 | What is the first thing to do if the casualty bleeds and breathes? <ul style="list-style-type: none"> • Plugging the wound • Check if something is blocking the airway • CPR |
| 6 | What comes first when dealing with an accident? <ul style="list-style-type: none"> • Protect the injured • Protect yourself • Call to emergency • Check if the injured person is alive |
| 7 | When do you have to put two triangles in an accident? |
| 8 | Order to help the injured person: <ul style="list-style-type: none"> • Check consciousness, check for bleeding, check for breathing • Check for bleeding, check for breathing, check consciousness • Check consciousness, check for breathing, check for bleeding • Check for breathing, check consciousness, check for bleeding |
| 9 | What should you do if one of the vehicles represents a potential danger? |
| 10 | What should you do if the injured person is apparently dead? |

The questionnaire to evaluate the application was developed following the system usability (SUS) [64,65] adapting the questions to the type of application we needed to evaluate. This type of system uses questionnaires of 10 statements where the level at which the user agrees is assessed by means of a five-level scale (from not agree to very agree). Using this scale, the concepts to be evaluated were: Useful, Necessary and needs covered, intention to use, easy, funny and pleasing. Table 4 informs about the relationship between the questions and the concepts to be evaluated can be appreciated. Along with this questionnaire, a question was also included to know if they managed to finish the app.

Table 4. Questions used to evaluate the application.

| | Questions | Concept |
|----|---|---------------------|
| 1 | I found the game interesting and useful to improve my knowledge of the PWA protocol. | Useful |
| 2 | I think a tool to help you learn about first aid and the PWA protocol is needed. | Necessary |
| 3 | Considering the above statement, I believe this game meets that need. | Need covered |
| 4 | I would use and/or recommend this application as a learning tool for the PWA protocol. | Intention of use |
| 5 | The operation of the game has been easy for me to understand. | Easy |
| 6 | I found the game fun. | Funny |
| 7 | I liked the visual experience. | Pleasing |
| 8 | Augmented reality in this game enhances the experience. | AR evaluation |
| 9 | Every time the game was restarted with the same accident, it seemed to me that the scene changed. | NPC's AI evaluation |
| 10 | I wish there were more games of this kind to learn in other areas. | Overall rating |

5.3. Procedure

To ensure that questionnaires were filled out anonymously, first of all, users received a random code to link the questionnaires. Then, both groups did the pre-test without receiving any information about the protocol.

The groups were then divided into two separate classrooms for 30 min. The control group received the documentation of the PWA protocol to study using the traditional form. The experimental group spent that time using the app. During the experiment, no group received additional help on the PWA protocol.

Once the experiment was finished, they were left three days before passing them the subsequent questionnaire. After that time, the two groups performed the post-test.

6. Results and Discussion

6.1. Learning Effectiveness

Table 5 shows the percentage of correct answers in each question of the pre-test and the post-test for both experiment group and control group.

In the previous tests, both groups obtained similar results, clearly showing that questions were simpler and more intuitive (2 and 3) and which were more complex (9 and 10). When observing the post-test, it can be seen how both groups have answered the simple questions correctly almost completely. They have improved a lot in those of medium difficulty, but on the other hand, it has been the experimental group who has achieved greater improvement in the difficult ones.

As can be seen in Table 5 and in Figure 12, in general, both groups achieved a great improvement in their results. However, the improvement of the experiment group is significantly superior in almost all questions. This result shows that the use of this app allows for understanding and internalizing the concepts of the PWA protocol using less study time than the traditional method.

It must be taken into account that the previous knowledge of the users about the PWA protocol can influence the results. The performance of the pre-test aims to give a starting measure for each user according to their previous knowledge, but, even so, the results have been compared according to the degree indicated by the user. In Table 6, it can see that

half of the users of the experiment do not have any knowledge and the rest are divided between little, something, and enough. In the high grade, there is no user because that was an exclusion criterion.

Table 5. Percentage of correct answers in each question of the pre-test and the post-test.

| Question | Experimental Group (EG) | | Control Group (CG) | |
|----------|-------------------------|-------------|--------------------|-------------|
| | PRE-TEST % | POST-TEST % | PRE-TEST % | POST-TEST % |
| 1 | 40.0 | 83.3 | 35.0 | 70.0 |
| 2 | 73.3 | 96.6 | 75.0 | 90.0 |
| 3 | 86.6 | 100.0 | 70.0 | 90.0 |
| 4 | 30.0 | 60.0 | 45.0 | 65.0 |
| 5 | 36.6 | 70.0 | 35.0 | 60.0 |
| 6 | 53.3 | 83.3 | 40.0 | 65.0 |
| 7 | 36.6 | 66.6 | 55.0 | 60.0 |
| 8 | 56.6 | 86.6 | 55.0 | 60.0 |
| 9 | 0.0 | 60 | 5.0 | 30.0 |
| 10 | 3.3 | 33.3 | 0 | 25 |

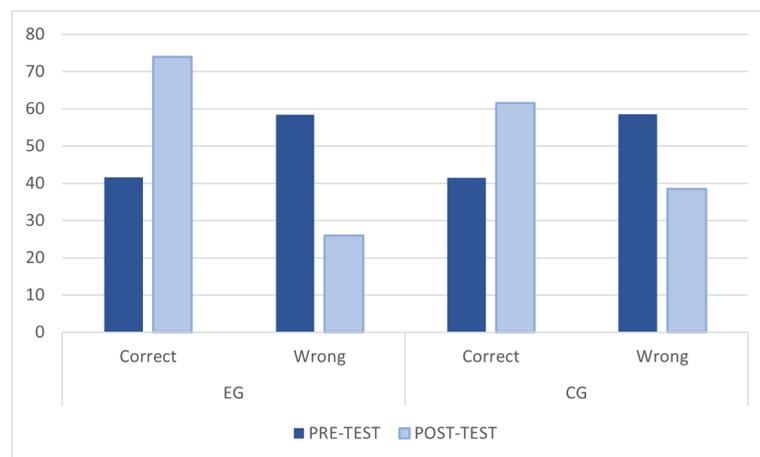


Figure 12. Percentage of correct and wrong answers to exercises in pre-test and post-test.

Table 6. Previous knowledge of the users about the PWA protocol.

| | Experimental Group (EG) | | | Control Group (CG) | | |
|--------|-------------------------|------|------|--------------------|------|------|
| | NUM. | PRE | POST | NUM. | PRE | POST |
| None | 14 | 38.6 | 72.3 | 10 | 40 | 55 |
| Barely | 6 | 31.6 | 68.3 | 4 | 36 | 58.9 |
| Some | 5 | 38 | 72 | 3 | 42 | 65.6 |
| Quite | 5 | 58.2 | 83.4 | 3 | 47.6 | 66.3 |

The results show that there is no relevant difference between the four degrees of knowledge. However, the experiment group continues to improve better than the control group, whether or not they have previous knowledge.

6.2. Usability and Acceptability

Once the application was tested and the protocol questionnaire was completed, the users of the experimental group indicated their degree of acceptance for each point eval-

uated using the System Usability Scale (SUS) with the five-grade scale (from 0 to 4). The results were measured by obtaining the average value of the answers for each question and the standard deviation (SD) that allows for knowing the variation between the answers given. A low SD indicates that data tend to be clustered close to its mean. With this in mind, as it can be seen in Figure 13, the overall general result was very positive. Each point is analyzed separately below.

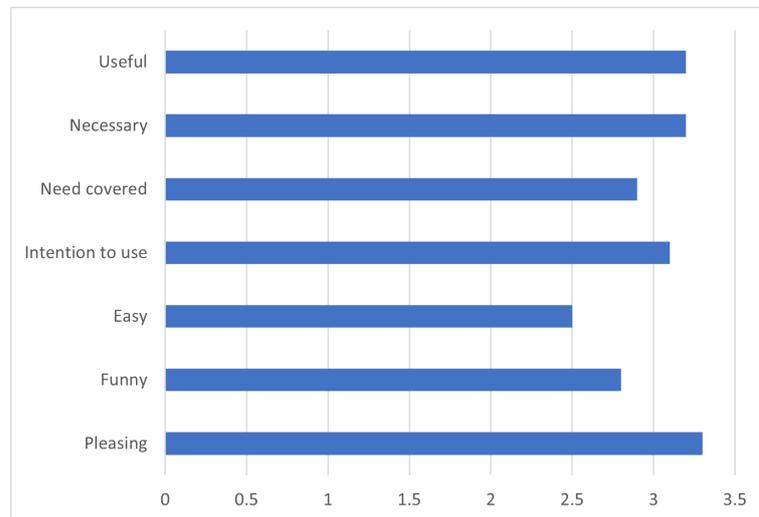


Figure 13. Average of usability variables.

The majority considered that having an application that allows learning about First Aid is necessary (Av: 3.2; SD: 0.79). In addition, they considered that the application they were evaluating covers that need (Av: 2.9; SD: 0.86) and is interesting and useful (Av: 3.2; SD: 0.83). In the question to assess their intent to use, almost all indicated that they would use it to learn about the protocol or to recommend it to others (Av: 3.1; SD: 0.8).

On the other hand, in general, users had fun using it (Av: 2.8; SD: 0.85) and almost everyone liked it visually (Av: 3.3; SD: 0.69). However, in the case of the ease of use of the application, the answers are more disparate, since for some it was not easy to understand (Av: 2.5; SV: 1.02).

Taking into account that the time to use the app during the experiment was limited, they were asked to indicate whether they had managed to win in the app or not. In Table 7, it can see the relevant results, divided between those who did it (16 users) and those who did not (15 users).

Table 7. Results obtained divided between the users who had success with the app and those who have not.

| | Learning % | Useful | Necessary | Need Covered | Intention Use | Funny |
|---------|------------|-------------------|--------------------|-------------------|-------------------|------------------|
| Success | 35.6 | 3.4 (SD: 0.78) | 3.25 (SD: 0.75) | 3 (SD: 0.79) | 3.1 (SD: 0.82) | 2.9 (SD: 1.1) |
| Fail | 29.8 | 2.9 (SD: 0.79) | 3.1 (SD: 0.83) | 2.7 (SD: 0.93) | 3.2 (SD: 0.77) | 2.7 (SD: 0.9) |

Although the group that managed to win has a slightly better opinion of the application, the difference is not significant. The results of both groups remain similar to the overall results. For this reason, it can be deduced that the high difficulty to earn in this application does not influence the opinion of users.

In the case of the percentage of improvement of their knowledge about the protocol, it can be observed that the users who managed to win obtained a greater improvement.

With this, it follows that using the application until winning through the entire protocol correctly will give better results.

6.3. Augmented Reality and Neural Network

One of the items that users were asked to evaluate was their opinion on whether the augmented reality of the game helps or hinders the use of the application. This section has been compared with the previous experience of each user with the RA as it was considered that it may influence the assessment. Figure 14 shows the rating given by users between 0 and 4 (x -axis) and the relationship with their previous experience (y -axis).

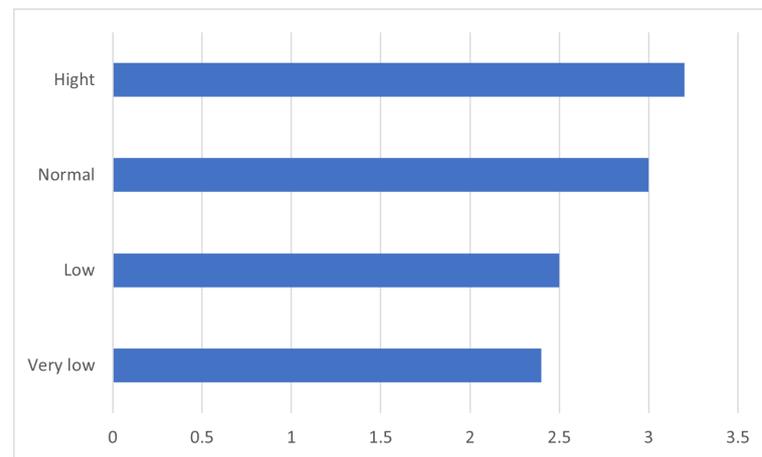


Figure 14. Relationship between previous experience with RA and its assessment.

In general, the AR in the application liked, but as can see in the figure, the rating is higher for those users with more previous experience. This result indicates that those who have not used AR or have used it very little find it difficult to focus their attention on the application itself and can be annoying. In contrast, experience increases when users have experience with AR and know better how it works.

As for the experience with the neural network, one question was the degree to which they had felt that the scenario changed with each execution, even if it was the same accident. Although some thought so, most disagreed (Av: 1.3; SD: 1.1). This result is largely because the importance of the scene is centered on the accident, which does not change. Thus, it is hard to realize that the actions of NPCs are different. Even so, it has been considered that this is a point that requires further study and an important improvement for the future.

6.4. Overall Rating

Finally, they were asked, after having tried this app and evaluated its benefits, to evaluate if they would like to have more applications like this to learn in other areas. Overall, users strongly agreed (Av: 3.3; SD: 0.78). This answer confirms that the previous results are correctly valued. The users of this experiment liked it and found it necessary and useful enough that they would like to be able to use other apps like the one presented, in order to learn in other fields.

7. Conclusions and Future Work

This article presents a video game for mobile platforms which facilitate the formation and training in the PWA First Aid protocol. As hypotheses, it has been supposed that this application will consolidate the acquired knowledge. Users have to overcome a series of challenges to bring theoretical concepts closer to practice. To easily change the point of view of the game play, some Augmented Reality technology has been used. Moreover, neural networks have been implemented and trained for managing the autonomous behavior of the Non-Playable Characters, with the aim that the player has a sense that every game is different.

Finally, in order to evaluate the quality and playability of the application, as well as the motivation and learning of content, several experiments have been carried out with a sample of 50 computer science students aged between 18 and 26 years: the experimental group was composed of 30 users to test the application, and the control group was composed of 20 users. All of them had a low knowledge of first aid and the PWA protocol. The obtained results confirm the playability and attractiveness of the video game, the increase of interest in learning First Aid. In addition, regarding evaluating the acquired knowledge, the results of this study confirm that the use of this app allows one to understand and internalize the concepts of the PWA protocol using less study time than if they were acquired in a masterclass. Thus, it can be said that the use of video games facilitate the learning and internalization of tasks that, once learned theoretically, would be easily forgotten. Once the efficacy of this video game in First Aid training has been demonstrated, as future work, we intend to create a collection of video games where each one of them represents a different action protocol depending on the first aid they are representing. As a pilot, this study is limited by its small size and focus on usability and acceptability. Thus, other more complex studies comparing the AR technology with standard simulation training models will be carried out in the future.

Despite the good results obtained in the study carried out, it is important to recognize other potential limitations of the application. One of them is the possibility of adapting it to people with learning disorders such as Attention Deficit Hyperactivity Disorder (ADHD) because this point of view has not been considered in the study. In future work, it will be investigated how to adapt this application to people with ADHD. A low-cost EEG system, NeuroSky MindWave, will be used to measure attention and concentration while playing [66]. This system will make it possible to identify when the affected person is paying more or less attention. In this way, by analyzing these weaknesses and strengths, it will be possible to reinforce the weak aspects that cause a lack of attention during the application.

On the other hand, due to the lower than expected results on the degree to which the player felt that the scenario changed with each run, this was considered to be a point requiring further study and significant improvement for the future.

With the aim of looking for new scenarios in which this application could be applied, and due to the fact that the size of the AR marker defines the size of the scene, one of the tasks ahead is to evaluate the impact of this feature. The larger the AR marker size, the larger the scene size. This would be an excellent option for use in a First Aid training center, as the scene could be viewed at a real size, allowing for more realistic training.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of the Universitat Jaume I (protocol code CD/94/2021).

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