SeGTE: A Serious Game to Train and Evaluate Basic Life Support

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Keywords: Basic Life Support, Cardiopulmonary Resuscitation, Serious Games, Finite State Machines.

Abstract: Basic life support (BLS) is the level of medical care which is used for victims of life-threatening illnesses or injuries until they can be given full medical care at a hospital. It can be provided by trained medical personnel, including emergency medical technicians, paramedics, and by laypersons who have received BLS training. BLS is generally used in the pre-hospital setting, and can be provided without medical equipment. The ability to respond to an emergency situation can be the difference between life and death. Acknowledging this fact has made decision-makers, governments and Non Government Organizations (NGO) to make a priority to spread this knowledge and skills to the general population. Currently, BLS is taught in a standard course provided by the Red Course or certified entities, where the pedagogical content given to the students is a mix of theoretical and practical training where life-size mannequin are used. In this paper we argue that serious games could help spread this knowledge through the general population and it could also be used to refresh the knowledge of people that have been certified in BLS in the past. In order to test this hypothesis we have developed the SeGTE game and performed an evaluation of its effectiveness on conveying such pedagogical content.

1 INTRODUCTION

In this new millennium, the prevalence of road accidents is so frequent and fatal it is an issue uppermost in the minds of individuals, decision-makers, governments and Non Government Organisations (NGOs) worldwide (Fiander, 2009).

The Statistics of Road Traffic Accidents in Europe and North America contains the basic statistics provided by the Governments States members of the United Nations Economic Commission for Europe (UNECE). In this report is stated that for the ECE region in the decade 1999-2008 there were on average 150 000 persons killed and about 5.5 million persons injured annually in more that 3.8 million road accidents (UNECE, 2011). In the attempt of improving both the consequences and well and the causes for this statistics the International Federation of Red Cross (IFRC) and Red Crescent Societies have issue several reports where recommendations are proposed on how to deal with this critical situation. Namely, one of the central recommendations is to develop greater first aid knowledge amongst the general population be they drivers, car-users or pedestrians involved in, or bystanders to, road accidents (IFRC, 2009; IFRC, 2010).

Although first aid is not a replacement for a emergency services' intervention, it is a vital initial step in intervention that provides an effective and rapid contribution. This both reduces the severity of injuries and improves the chances of survival. In this manner, the IFRC believes that everyone has the potential to save lives. First aid is not just about techniques. It is an act of humanity and therefore is a key responsibility of global citizenship (IFRC, 2009; IFRC, 2010).

The IFRC points out that the solution is not just about making training compulsory. There is also a need to improve the existing training practices and quality. This is why people are called to attend first aid refresher classes. All skills must be practised and upgraded. Refresher classes will bring the performance of most interveners to a higher level than that recorded after initial training (IFRC, 2009; IFRC, 2010). Continuing first aid education is essential to maintain providers' knowledge and skills particularly when they do not use their skills frequently.

An area where training can be improved is by increasing the level of a course's realism. It is one thing to be in a training session but quite another to apply that classroom learning in a real situation. First aid is not just about providing life-saving skills to a manikin; the real situation means dealing with factors that can prevent the provision of efficient first aid, such as coping with the terrifying presence of blood or a person's pale and sweaty appearance when having a cardiac arrest. The person providing first aid can also be influenced by a crowd gathering around an accident. All these are important reasons for preparing all first aid providers for the stress that they will face. Improving this aspect of training will avoid what should never be seen: people trained in first aid running away from an accident scene simply because they are afraid of blood or of the level of exposure.

In this paper we present SeGTE, a serious game designed to train and evaluate Basic Life Support, with the aim to teach the procedures described by the European Resuscitation Council (ERC, 2012). This game exploits video game technology to link in a framework computer-based case with e-learning functionalities. Some computer graphics techniques are used to reproduce different situations where basic life support is required and also the procedures that have to be applied. SEGTE includes two game modes, training mode and evaluation mode. In training mode, the user can train the different medical procedures provided in the ERC's protocol (ERC, 2012). In the evaluation mode the users can assess their knowledge.

The remaining sections of this paper are composed as follows: Section II present the state of the art of serious games for teaching and training of Basic Life Support. Section III presents SeGTE architecture and the main characteristics. Section IV presents Evaluation, how the solution was validated with real users. Section V presents the conclusions and future work.

2 BACKGROUND

Basic life support (BLS) is a sequence of attitudes and procedures aimed at recognizing a patient in cardiac arrest, calling specialized help and meanwhile establishing blood circulation and oxygen supply in order to keep the victim alive. In 2010 The European Resuscitation Council (ERC, 2012) published new guidelines that precisely redefined the algorithm of procedures for BLS. Every citizen should ideally be trained in BLS as most cardiac arrests happen with laypersons as first helpers and brain death usually occurs within 5 minutes of cardiac arrest if no help is provided. Traditionally BLS is taught and trained with dummies in special courses of several hours.

Recently simulation software programmes have been developed where the BLS algorithm can be trained. "Staying Alive" by iLumens[1] creates a 3D environment where the user has to assist a collapsed victim by following the BLS rules. "AedChallange" by Insight Instructional Media[2] is a video game for refreshing already acquired skill. It presents several clinical cases where the player can train BLS. The player scores when he/she proceeds according to the BLS algorithm. At the end there is a debriefing and errors are explained.

3 SeGTE: A SERIOUS GAME TO TRAIN AND EVALUATE BASIC LIFE SUPPORT

SeGTE is a serious game, designed in collaboration with healthcare professionals, to train and evaluate the general public (lay persons) in basic life support. The main objective of the game is to teach the procedures described in the ERC's protocol (ERC, 2012).

The sequence of procedures is determined by the current condition of the patient. Specifically, if a patient is responsive it will not be necessary to execute the procedure that corresponds to preform 2 rescue breaths and 30 compressions. Actually, it would be dangerous to perform such a procedure in a responsive patient. In order to achieve this flexibility both in specifying game cases as well as in game mechanics, we used a finite state machine to guide the simulation underlying the game logic. This finite state machine was defined interactively with the help of healthcare professionals. It was necessary to guaranty that every path through the finite state machine was a valid one and also that the feedback given during game play was correct both in terms of content as well as the simulation execution step. In the next subsections it will be further elaborated how the finite state machine was defined, as well as the game play, clinical cases definition and implementation details.

3.1 SeGTE Finite State Machine

The use of finite state machines in video games is promoted by many developers due to their robust nature as they are easy to test and modify. They are typically used to model the behaviour of computer-controlled game characters, also called no-player characters (NPC), to make NPCs react to game events seem as intelligent and natural as possible, (Hu et al., 2011; Saini et al., 2011).

[1] http://ilumens.fr/numerique/serious-games/
[2] http://aedchallenge.com/

A finite state machine is a system with a set of states and a collection of transitions, which represent some kind of actions for each state. It has a initial state, and one or more final states. In practice, it's a description of how an object can change its state over time in response to the environment and events that occur. Each state represents a behaviour, resulting in the behaviour changing as states change from one to another, (Saini et al., 2011).

In Figure 1, is depicted the Finite State Machine of our serious game.

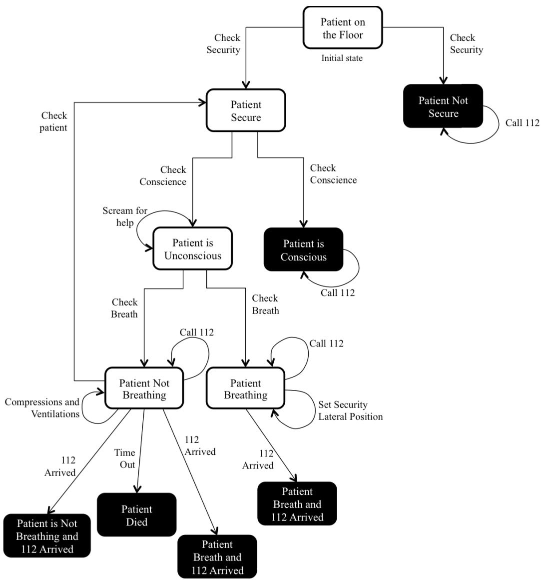

Figure 1: The Finite State Machine representing the procedures of ERC's protocol.

To create this finite state machine, we transform the basic life support algorithm, presented by the European Resuscitation Council 2012 (ERC, 2012), to a set of states and actions, and define how they are connected. The process starts with the transformation of each medical action in a element of the finite state machine. For this purpose, it was necessary to understand what is an action, a state or a transition.

Each state of the finite state machine corresponds to the current state of the patient during a game play. In each state the player can decide which action she/he should take but only the valid transitions of the finite state machine are considered correct. Therefore, every action taken which is outside the set of actions permitted or considered correct will have a negative feedback. Depending on its level of severity, the game can either end, resulting in the death of the patient or a warning is issued to the player. More details about the game play and different elements that make-up the game SeGTE are described in the following subsections.

3.2 SeGTE Game Play

The game play starts with a briefing screen where the player is introduced to the pedagogical goals of the game. Also, in this screen the player can access information concerning the basic life support algorithm and how the user interface works. In this phase a facilitator that has background knowledge of the game and the basic life support algorithm, provides extra information and clarifies any necessary doubts that might be posed by the player.

Once this phase is terminated, the player can choose either to play in training mode or in evaluation mode. In training mode, the player can train the different game cases. If the player chooses the wrong procedure a warning appears. This warning contains information about what procedure should have be done. After this, the player can correct her/his error and continue the game. Furthermore, some information is given on how to make certain actions (e.g. compressions and ventilations). In evaluation mode, the players can assess their knowledge, therefore no type of information or help is provided during the game. If she/he makes a mistake, the patient's life is at risk and some decisions can lead to prematurely ending the game resulting in the patient death.

Independent of the game mode, after each game case the player is presented with the debriefing screen. On this screen the player is given an explanation of what were her/his mistakes and how they can be corrected. This phase of the game play is critical for knowledge retention. By reflecting on the game after playing it, debriefing helps the player make meaningful connections between the game experience and the "real world" (Crookall, 1990; Crookall, 1992), thereby likely enhancing transfer of knowledge and skills. Debriefing can promote active learning by deconstructing the experience, exploring alternatives responses, and linking observations and experiences in the virtual world to those in the real world (Gaba et al., 2001). It is still not clear how debriefing can be most effectively incorporated in serious games (Thompson et al., 2010). Therefore, during the evaluation of different releases of the game informal interviews were made to users in order to better understand if our choices were both aligned with the expectations of the users and, as well as the pedagogical goals of the game.

3.3 Clinical Cases

In SeGTE several game cases were set up in order to allow the player to have the opportunity of exploring the application of the algorithm in patients with different health conditions. Therefore, each game case corresponds to what we have denominate a clinical case. Basically, a clinical case is a description of several attributes that make up the patient's current condition and the environment were he is currently in. Such attributes are for example, if the patient is secure or if the patient is breathing.

Currently the game cases are configured inside the game application, but extending this solution to support adding new clinical cases is trivial and is one of the top priorities of the next release of the SeGTE game. Structuring this information in an XML file would not just facilitate the process of adding new game cases, it would also admit to translate the game into different languages. Apart from this and most important it would allow healthcare professionals to add this information without the intervention of a programmer. This is very relevant, both because it would ideally motivate the use of this game by healthcare professionals but it would also make this game less fragile to new updates of the basic life support algorithm.

3.4 User Interface

The interface was create with the goal of making the player's interaction as simple and efficient as possible. With this purpose we have use a navigation based on point-and-click. This greatly facilitates the navigation inside the virtual world for players that are not used to play games or to navigate inside 3D environments. For the reminder of the user interface, the standard style of interaction such as buttons, boxes and windows were used.

The environment is outside of a hospital. Most of this cases deal with the basic life support, i.e. the primary skills in cardiopulmonary resuscitation and include basic mouth-to-mouth resuscitation and chest compressions to circulate blood. No medical equipment is required and there are no invasive procedures.

The player interface simulates the unexpected emergency incident and allows the player to rescue the victim.

The scene starts with the emergency situation, when a victim falls in the street. The player plays the role of the helper that tries to save the victim. After finishing the clinical case the debriefing menu is shown and the player can assess her/his performance.

Figure 2 shows the sequence of procedures for a cardiopulmonary resuscitation situation from (a) initial state with the patient on the floor; (b) Check is Secure; (c) Check conscience; (d) Check is breathing; (e) Initiate Compressions and Ventilations. Helper choose mouth-to-mouth or mask; (f) Helper starts compressions and Ventilations.

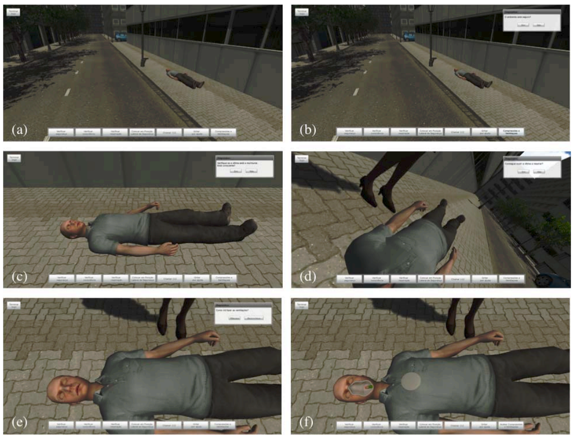

Figure 2: Sequence of Procedures in SeGTE.

Some of the animations and actions lack realism as avatar performance is limited. However, for this first prototype the main objective is that the player learns the order of each procedure.

In the future work, we can improve some of these animations and procedures. The possibility of player collaboration with other characters (e.g. a person for help in compressions and ventilations)will also be included.

3.5 Implementation Details

SeGTE architecture is divided into two main components, the serious game component and the Finite State Machine component. The serious game component is generically responsible for managing the game logic, graphic assets, interfaces and players interactions. It's based on Unity3D [3] game engine and follows a script based architecture, that encapsulates functionality as C# scripts.

In the serious game component there are four main modules, the HUD manager, the Camera Manager, the FiniteStateMachine Manager and the Game Manager. The HUD manager is responsible for managing all the interfaces of the game, namely all the menus, feedback information messages and briefing screen menu. The Camera manager is responsible for managing the navigation inside the game. This is accomplished by methods and routines that dynamically change the camera position in order to allow the player to explore the 3D virtual environment. The FiniteStateMachine manager is responsible for instantiating the finite state machine with the current clinic case and also managing its execution with the

[3] http://unity3d.com/

Finite State Machine component. The game manager is responsible for managing all the game mechanics, interfaces and player interactions. Finally, the Unity3D kernel is responsible for managing the graphical pipeline, graphic asset and scene graph.

4 EVALUATION

One important differentiating factor between serious games and entertainment games is the importance of assessment. Measuring, discussing and reasoning about the game play effectiveness is very important in this domain. This can lead to reflection and therefore improved learning (Lopes and Bidarra, 2011). Chen and Michael have identified some of the main challenges that assessment in serious games is facing, namely effecting and improving player experience. The authors suggest that log information and teachers/instructors knowledge should be fully explored and, in some way, incorporated back in the game, to guide its course (Chen and Michael, 2005).

Pamela Kato (Kato, 2012) has also argued that the few research studies published on the validity and efficacy of health games are often poorly designed and that their conclusions cannot be considered valid evidence to support or refute efficacy. In this respect, she has suggested a set of guidelines for conducting high quality efficacy studies on games for health. These guidelines include grounding the game design in well defined theories, conducting randomized trials that included adequate control groups and number of participants, and also incorporating standardized measures to facilitate comparisons across studies.

The authors agree with the recommendations provided by the previous cited authors and they have been considered both during the development of the game as well as when designing and planning the evaluation of game play effectiveness. During game design, both experts and lay people were involved in defined check-points to validate that both the pedagogical goals as well as the user interactions were according to the expectations of the end-users. Also, the inclusion of pedagogical content in the game had into account previous studies of similar games and approaches such as design patterns (Björk and Holopainen, 2005) and finite state machine diagrams.

It was then important to evaluate if the game actually taught what it had been designed to. This was the hypothesis of our study. In order to confirm or discard this hypothesis, we designed a qualitative study based on pre-experimental design research method (Creswell, 2008), which includes three specific moments: briefing, where the player is introduced to the pedagogical goals of the game; a pre-test, where the user responds to the questionnaire; game experience, where the user plays the different game modes (training mode and evaluation mode); and, a pos-test where the player responds to the questionnaire. The pre-test and pos-test questionnaire are one and the same, and consist of a set of questions related to the ERC's protocol and some demographic information related to the player. In the reminder of this section, we detail how the study was conducted and the achieved results.

4.1 Pre-test and Pos-test

Before each game experience each player was asked to answer the questionnaire in order to have feedback about their knowledge of basic life support. The main goal of the pre-test was to evaluate the previous knowledge the user had about the different procedures provided in ERC's protocol.

The questionnaire was composed by ten questions. The first three questions concern demographic information about the player. According to this information, the participants are between 20-30 years; 23 are male and 8 are female, in a total of 31 participants, without any specific previous knowledge about Basic Life Support.
The remaining questions, were related to the ERC's protocol and they were validated by healthcare professionals.

After playing, each player was asked to answer the questionnaire again in order to evaluate the knowledge the player had acquired during the game session. The pos-test was exactly like the pre-test except for the first three questions concerning demographic information. The main goal of this pos-test was to evaluate if the game teaches the sequence of procedures described in the ERC's protocol. In other words, validated the evolution of the user's knowledge after playing the serious game SeGTE.

After all the participants were evaluated, the data collected were analysed and the results of the pre and pos-test were compared.

5 DISCUSSION

Comparing the results of the pre-test with the pos-test, we obtain better results in all of the questions in the pos-test. This positive trend may show that the serious game has some impact in the user's knowledge, as presented in Figure 3.
These results are very positive which give us a certain confidence that the game fulfils its educational goals. Furthermore, the participants in general demonstrated

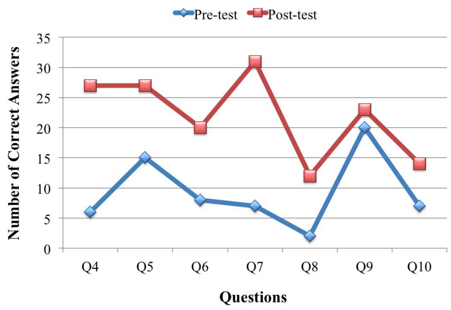

Figure 3: Comparison between Pre-test and Pos-test.

to have enjoyed playing the game and they considered it very interesting. Some participants also got a little sad when the victim died. This is an interesting point, because it demonstrates her/his emotional involvement in the game and their motivation to save the victim.

Nevertheless, there are also some limitations that should be mentioned. Namely, although the game was designed to teach the ERC's protocol procedures it can't be neglected that certain aspects of these procedures can't be entirely simulated in a virtual environment. For example, in a real-world situation performing compressions requires strength and a certain level of physical condition to sustain until assistance arrives. This is why Basic Life Support should ideally be performed by two helpers instead of just one.

Therefore, it is not intended that this game substitutes training with a life-sized doll with replicated airways and anatomy, used in CPR training to simulate the performance of rescue breathing and cardiac compressions. Instead, this game should be used as a complement of this training, as it has proven to help memorize the Basic Life Support procedures and some of its specificities. Also, it can be used as a tool to refresh the knowledge previously acquired in a proper Basic Life Support Course.

6 CONCLUSIONS

In this paper the serious game SeGTE has been described. This game was design to teach the ERC's protocol to laypeople, specifically focusing on the specificities of each procedure and also how it should be applied according to the current condition of an adult victim. SeGTE has been developed in collaboration with healthcare professionals, that participated both in validating the pedagogical content of the game and the correct simulation of the ERC's protocol. To simulate the ERC's protocol we have used Finite State Machines, were the states represent the current state of the patient and the possible actions of the player are the transitions between states. This representation also allowed us to set up different clinical cases by instantiating accordingly different finite state machines. A study based on pre-experimental design was also conducted in order to assess if SeGTE fulfil its pedagogical goals. For that purpose a questionnaire was devised in collaboration with healthcare professionals. This questionnaire was used to evaluate both the previous and prior knowledge regarding the basic life support. In between answering the questionnaire the participant played each clinical case once in training mode and once evaluation mode. This study involved 31 participants and the analysis and comparison of the results was presented in section 4. The number of correct answers increased after the participants played the game which provided us with some confidence that the game could be used as a tools to teach or refresh the procedures of the ERC's protocol. Nevertheless, as future work this study needs to be extended to a bigger and more diverse audience in order to assess its statistical significance. Also, further developments are being included in the current version of the game with the goal of integrating it as a learning tool in the Portuguese Red Cross courses, which have already shown an interest in SeGTE.

ACKNOWLEDGEMENTS

This work was supported by FCT (INESC-ID multiannual funding) under the project PEst-OE/EEI/LA0021/2013. The authors also would like to acknowledge to the European funded Project Games and Learning Alliance (FP7 258169) the Network of Excellence (NoE) on Serious Games.

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