TÉCNICO LISBOA

Sepsis Fast Track: A Simulation Game for Clinical Education based on the Sepsis Fast Track Process

Tiago Miguel Catarino Antunes

Thesis to obtain the Master of Science Degree in

Information Systems and Computer Engineering

Supervisors: Prof. João António Madeiras Pereira
Eng. Cláudia Sofia Sevivas Ribeiro

Examination Committee

Chairperson: Prof. José Manuel da Costa Alves Marques
Supervisor: Prof. João António Madeiras Pereira
Member of the Committee: Prof. Miguel Leitão Bignolas Mira da Silva

May 2014

Acknowledgments

I would like to start thanking to my advisor, Prof. João Madeiras Pereira, and co-advisor, Eng. Cláudia Ribeiro, for the possibility of working in VIMMI at INESC-ID. A special thanks to Eng. Cláudia Ribeiro for the given support, guidance, patience, and friendship during this work.

I would also like to thank to the Emergency Department team of Hospital São Francisco Xavier without whom this project would not have been possible. In particular, to Dr. Micaela Monteiro, Dr. Ana Sofia Corredoura and Dr. Pedro Santos for the support and collaboration in this project.

I wish to thank my IST colleagues and friends whom was a pleasure to work with during the graduation and master's degree.

Finally but not least, I would like to thank all my friends and family for the support, motivation and encouragement to get this work done.

Thank you very much!

Tiago Antunes

Resumo

Sépsis é uma inflamação sistémica causada por uma infecção grave e é responsável por uma elevada taxa de mortalidade. A taxa de sobrevivência de um paciente infectado com sépsis diminui 7,6% a cada hora que passa, implicando que os pacientes sejam diagnosticados e tratados em tempo útil.

Em 2010, a Direcção-Geral da Saúde portuguesa emitiu uma circular normativa, baseada nas directerizes da Surviving Sepsis Campaign, que visa a implementação do protocolo da Via Verde Sépsis. O objectivo deste protocolo é permitir a rápida identificação de um caso de sépsis e o seu tratamento. Cada profissional de saúde do serviço de urgências deve receber formação da Via Verde Sépsis, a fim de saber os procedimentos necessários para a triagem de um paciente e como o tratamento deve ser realizado. A actual formação é baseada em métodos tradicionais de aprendizagem, que são mencionados como ultrapassados para as novas gerações, os chamados ”nativos digitais” .

Os jogos sérios são uma tendência recente que tem sido tida em consideração quando se discute sobre as novas ferramentas para ensino e formação em diversas áreas devido às suas características. Embora a aplicação de jogos sérios para a educação médica esteja a ser explorada, a literatura carece de estudos quanto à sua eficácia.

Nesta tese será apresentado o jogo sério Via Verde Sépsis, um jogo desenvolvido para ensinar o protocolo da Via Verde Sépsis e treinar enfermeiros e médicos dos serviços de urgências. Também será apresentado um estudo conduzido com profissionais de saúde cujo objetivo de avaliar os impactos do jogo sério nas suas práticas de trabalho.

Palavras-chave: Jogos sérios, sépsis, educação médica, formação médica

Abstract

Sepsis is a serious medical condition responsible for high levels of in-hospital mortality. It requires fast diagnosis and treatment, since the survival rate decreases 7.6% for each hour without treatment.

In order to facilitate this process of diagnosis and medical therapy, the Portuguese Directorate-General of Health issued a document regulating the implementation of a Sepsis Fast Track protocol based on the Surviving Sepsis Campaign guidelines. Therefore, training of emergency department healthcare professionals is essential, and should be attended often in order to refresh knowledge and to be made aware of updates to any changes of the protocol. Currently, this training is conducted through traditional learning methods that are mentioned as outdated for the current generation, the so-called ”digital natives”.

Serious games are a recent trend that has been taken into consideration when discussing new tools for teaching and training in several fields, including healthcare. In the last decade, several research works have been developed that studied the impact of the application of such technologies in healthcare, stating that serious games could provide new approaches and opportunities.

In this paper, a Sepsis Fast Track serious game is presented, which is a serious game developed to teach and train nurses and physicians working in hospital emergency departments about the Sepsis Fast Track protocol. An evaluation study done with the healthcare professionals will also be presented, the main goal of which was to evaluate the impact of serious games on professional working practices.

Keywords: Serious games, sepsis, medical education, training

Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Introduction

Sepsis is defined as a whole-body inflammation caused by a severe infection that is responsible for a high level of in-hospital mortality and morbidity. The treatment for this inflammatory condition must be administered in a timely manner, because for each hour that passes without the appropriate antibiotherapy, the survival rate reduces by 7.6%.

In 2010, the Portuguese Directorate-General of Health issued a *Circular Normativa* for the implementation of a Sepsis Fast Track program in Portuguese hospitals' emergency departments Direcção-Geral da Saude (2010) based on the Surviving Sepsis Campaign guidelines Dellinger et al. (2008). This Sepsis Fast Track would enable rapid identification of a possible sepsis case in order to begin treatment of a patient in a timely manner.

For healthcare professionals to know how the Sepsis Fast Track works, including its procedures and when they have to be performed, professionals are required to have a training session. This training should be given recurrently to the professionals, not only to refresh their knowledge, but also to teach them any changes that may occur in the Sepsis Fast Track protocol. Presently, a Sepsis Fast Track training program uses traditional learning methods.

Serious games are gaining interest as a powerful tool for learning and teaching people Durkin (2010). Namely, instead of plain explanations, serious games focus on actions creating motivation and satisfaction. The application of serious games to the healthcare field is also being recognized. Several authors Graafland et al. (2012); de Wit-Zuurendonk and Oei (2011); Kato (2010) have conducted systematic reviews regarding the usage of serious games for clinical education. Serious games are also expanding; in the last decade, several research works have been developed that studied the impact of the application of such technologies in healthcare, stating that serious games could provide new approaches and opportunities.

This thesis describes a serious game developed for teaching and training healthcare professionals, namely nurses and physicians, about the Sepsis Fast Track protocol. We also explain the evaluation study, which included 43 nurses and 15 physicians of a hospital emergency department. It was carried

out in order to understand if the application of Sepsis Fast Track serious game has any impact on professional working practices.

1.2 Context

The thesis work and research were done in the Visualization and Intelligent MultiModal Interfaces Group (VIMMI) at INESC-ID, during the second semester of the 2012/2013 academic year and the first semester of the 2013/2014 academic year.

During the VIMMI Summer Internships of 2012, a serious game for training healthcare professionals on the transport of critically ill patients protocol (Ribeiro et al. (2013)) was developed together with the Emergency Department (ED) of Hospital S. Francisco Xavier, Centro Hospitalar de Lisboa Ocidental, E.P.E.. Due to the positive results of that serious game, we proposed to develop a new one regarding another topic - Sepsis Fast Track protocol.

Moreover, in order to contribute to the scientific research and since there are very few examples of the application of serious games for medical education in a working context, an evaluation was carried out on the impacts on healthcare professionals working practices.

In this context, a serious game entitled 'Sepsis Fast Track' was created and the research, development and evaluations are reflected in this thesis.

1.3 Problem Statement

Sepsis is a serious public health problem with a high in-hospital mortality and morbidity. Portuguese data shows that 22% of admissions to intensive care units are due to community-acquired sepsis (Sociedade Portuguesa de Cuidados Intensivos and Ordem dos Médicos (2010)). These cases result in an overall hospital mortality of 38%, which is almost three times the mortality of cerebrovascular accident (CVA) in 2007. Also in Europe and the United States of America, sepsis represents a serious public health problem comparable to cerebrovascular accident (CVA) and acute myocardial infarction (AMI). The United States of America estimates 780,000 CVA cases per year and 920,000 AMI cases per year. The incidence of sepsis is estimated at 751,000 cases per year with associated annual costs higher than 16.7 billion dollars.

Not only are sepsis cases increasing by more than 1.5% per year (Angus et al., 2001), but also the severity of the sepsis. For each hour that passes without the appropriate antibiotherapy given, the survival rate decreases 7.6%. Therefore, its treatment in a timely manner is a very important aspect that can save lives.

In January 2010, the Portuguese Directorate-General of Health issued a *Circular Normativa* regulating the creation and implementation of the Sepsis Fast Track in all units of National Health Service.

Sepsis Fast Track aims to identify early the cases of severe sepsis or septic shock in a hospital emergency department, and establish, in a timely manner, a set of measures with recognised impact on the prognosis of sepsis cases.

The *Circular Normativa* states that it is required to receive training on the Sepsis Fast Track. The training program must include three types of courses:

- Sepsis Fast Track course for nurses, focused on the triage process and in the identification of a suspicion of sepsis, providing information about the entire treatment algorithm.
- Sepsis Fast Track course for physicians of ED level 1[1], focused on steps 1, 2, 3a, and 3b, for providing information about the entire treatment algorithm.
- Sepsis Fast Track course for physicians of ED level 2[2], focused on the entire treatment algorithm and on the relationship with the Intermediate and Intensive Care Units.

This training program should be done by each healthcare professional that starts working in an Emergency Department. Nevertheless, every professional should also refresh and update (in case of protocol changes) his or her knowledge about the Sepsis Fast Track protocol.

Currently, this training program is being given using a traditional learning method in a class room. This requires the presence of every healthcare professional of a particular hospital emergency department, which is nearly impossible since an emergency department is a non-stop service. Therefore, this training is not being given to the professionals with an optimal attendance.

Moreover, the traditional learning methods that are being proved are not the most efficient for the current generation, the so-called ”digital natives” (Prensky (2001)). Serious games are a recent trend and are being used as teaching and training tools in several fields, including healthcare. However, there are very few examples in the literature describing evaluation studies of serious game applied to medical education, namely healthcare professionals.

The main challenges of this thesis:

- The serious game requirements regarding the medical area.
- The development of the game in order to be played by, in general, a non-gamer population.
- Implement an efficient way to provide players the learning outcomes.
- The serious game evaluation with the emergency department healthcare professionals.

1.4 Contributions

In this thesis we described the Sepsis Fast Track serious game aimed at teaching and training healthcare professionals of hospitals' emergency departments about the Sepsis Fast Track protocol. This thesis introduces the following contributions:

- A serious game to teach and train healthcare professionals about the Sepsis Fast Track protocol.
- An evaluation of the impacts in working practices of a serious game targeted to healthcare professionals.

[1] Emergency Department without Intensive Care Unit
[2] Emergency Department with Intensive Care Unit

1.5 Thesis Structure

The remainder of this document is divided into four chapters.

In Chapter 2, Background, the *Serious Game* concept and several serious games for medical education are analysed. In addition, the several serious game design models and frameworks are explored.

In Chapter 3, Sepsis Fast Track Serious Game, the developed serious game is described in detail including the description of the Sepsis Fast Track algorithm, the game phases, the game environment and GUI, and the implementation details.

In Chapter 4, Evaluation, the serious game evaluation study that was carried out is presented. It is divided into two parts, one with nurses and another with physicians.

Finally, the conclusions of this thesis are presented in Chapter 5.

Chapter 2

Background

2.1 Serious Games

The use of games as a way of enhance learning date back 3.000 BC where games where applied mainly to battle planning, trade accounting, fortune telling and religious deviation. Although it may seem strange to look at fortune telling and religious deviation as learning areas they were the equivalent to the use o mathematics and science in that era, they help people to rationalize a complex universe and to make intelligent decisions.

With the clear expansion of video-games market, it emerged the concept of Serious Games that was introduced in Abt (1987) as:

> *"games that have an explicit and carefully thought-out education purpose and are not intended to be player primarily for amusement".*

Today, the term Serious Game is becoming more and more popular showing that is established, nevertheless there is not yet a current singleton definition of the concept.

The difficulty of defining Serious Games may arise from the contradiction between the word "serious" and the word "game" that seem to be mutually exclusive. "serious" as Sawyer (2007) argues, intended to reflect the purpose of the game, why it was created and has no bearing on the content of the game itself. Regarding the "game", Wittgenstein (1953) showed that there are difficulties in defining the concept of a game, nevertheless as Michael and Chen (2006) states games may be described as:

> *"a voluntary activity, obviously separate from real life, creating an imaginary world that may or may not have relation to real life and that absorbs the player's full attention. Games are played out within a specific time and place, are played according to established rules and created social groups out of their players."*

Since Abt many definition were established, for example according to Corti (Corti, 2002) game-based learning/serious games can be defined as leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to developed new knowledge and skill. Zyda on the other hand, propose in (Zyda, 2005) a more formal definition:

a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy and strategic communication objectives.

When comparing serious games with commercial computer games, Zyda argues that serious games have more that just a story, art and software. It is the addition of *pedagogy* that make the games serious. In (Susi et al., 2007) a literature review was carried on and the following definition was proposed:

A Serious Game is defined as games that engage the user, and contribute to the achievement of a defined purpose other than pure entertainment (whether or not the user is consciously aware of it).

In the same year, Alvarez (2007) proposed a more complete definition:

"A software application which initial purpose is to combine in a coherent way serious subjects such as teaching, learning, communication and information (this list being non exhaustive nor exclusive), with the entertainment resources of video games. This association, achieved with the implementation of a "pedagogical scenario" and which at IT level corresponds to implementing a sound and graphic skinning, a history and appropriate rules, has therefore as goal to diverge from simple entertainment. This gap seems to be based on the salience of the "pedagogical scenario"."

In (Djaouti, 2011) another definition was proposed:

"computer application, for which the original intention is to combine with consistency, both serious (serious) aspects such as non-exhaustive and non-exclusive, teaching, learning, communication, or the information, with playful springs from the video game (game). Such an association, which operates by implementing an utility script, which, in computer terms is to implement a package (sound and graphics), a history and the same rules, is therefore intended to depart from the simple entertainment."

Also several authors (Corti, 2002; Kiili, 2005) point out the game-based learning and serious games as more a less the same thing.

As described above, there isn't an agreement on the definition of what is a serious games. Also, the application of serious games covers a wide range of areas. Having into account the intersection of definitions and the range of applications we proposed the following definition:

"a gaming activity, played within a specific time and place, according to established rules, with an explicit and carefully thought-out purpose. This purpose can be the development of new knowledge, improvement of skills, create awareness of socio-political or healthcare factors and to explore/understand social behaviours in specific contexts, such as activities, social organizations, etc."

The project described in this thesis specifically explores the application of serious games to teach and train emergency department healthcare professionals about the Sepsis Fast Track protocol.

In the following subsection several serious games developed for clinical education are reviewed, including a sepsis serious game.

2.1.1 Serious Games for clinical education

Serious games for clinical education are a recent trend that is developing significant interest (Graafland et al., 2012; de Wit-Zuurendonk and Oei, 2011; Kato, 2010). Some examples of serious games developed for clinical education are presented below.

Figure 2.1: Critical Transport Serious Game

Critical Transport serious game was designed to teach healthcare students the recommendations for critically ill patients (Ribeiro et al., 2013). It is composed of two main scenes, one where the player must evaluate ten parameters regarding the patient's condition, and another one where the player must choose the correct team and equipment for the transport of the patient. An evaluation study was carried out, resulting in a positive impact on player's knowledge.

Pulse!! is a serious game designed for training healthcare professionals in clinical skills (BreakAway, 2007). It uses a 3D immersive virtual space as presented in Figure 2.2. Cutting-edge graphics recreate a lifelike, interactive, virtual environment in which civilian and military heath care professionals can practice clinical skills in order to better respond to injuries sustained during catastrophic incidents, such as combat or bioterrorism.

Figure 2.2: Pulse!! Serious Game

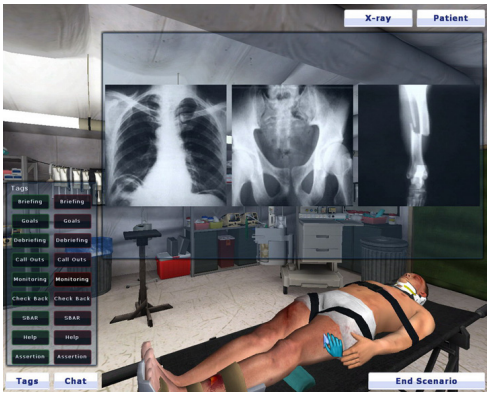


Figure 2.3: 3DiTeams Serious Game

3DiTeams is a multiplayer serious game for clinical education and team training (VirtualHeroes, 2007). It is a first-person game developed using the Unreal Engine (Figure 2.3). The training is based on the DoD Patient Safety Program and Agency for Healthcare Research and Quality's (AHRQ) Team-STEPPS curriculum. 3DiTeams is composed by three phases:

- *Independent learning phase*, where the players are introduced to the teamwork and communication skills
- *Collaboration & team coordination phase*, which takes place in a virtual hospital where the players (up to 32) will assess and the the patients.
- *Debriefing phase*, in which a video of the *Collaboration & team coordination phase* is played back, allowing the players to observe and reflect on their behaviors as well as those of the team.

Clinispace serious game (in Learning Inc., 2010) was developed using Unity3D and takes place in a 3D virtual hospital where several rooms are represented, namely a reception area, an intensive care room, a conference room, an emergency care room, a ward, a medical clinic, and an urgent care room (Figure 2.4). It is targeted to medical students, how can train follow procedures just like they would in real life, such as washing their hands, performing tests, talking to patients.

Pivotal Decision serious game was created for mass casualty triage training (HumanSim, 2011). It is a first-person serious game and takes place in a virtual environment where the player has to navigate

Figure 2.4: Clinispace Serious Game

Figure 2.5: Pivotal Decision Serious Game

through the landscape, locate casualties, and preform triage (Figure 2.5). Players receive feedback detailing both game achievements and casualty details. The learning objectives of Pivotal Decision are:

- Describe the principles of triage and when it should be performed
- Describe the difference between the psychological and medical footprint of a disaster
- List and describe the START and JumpSTART systems for casualty triage
- List the roles and responsibilities of a triage officer
- Describe common errors during triage

Figure 2.6: Triage Trainer Serious Game

Triage Trainer is a serious game developed to train first responders on catastrophe protocols and prioritization of casualties (TruSim, 2008). It takes place in a busy high street where occurred an explosion and the player have to take care of the multiple casualties (Figure 2.6). This serious game was evaluated across the UK in comparison to a traditional learning method. Statistically, it was significantly

better at developing accuracy in prioritising casualties and in enabling students to follow the correct protocol to make their decisions (Knight et al., 2010).

Figure 2.7: Zero Hour Serious Game

Zero Hour: America's Medic is a serious game designed to train and exercise first responders to respond to mass casualty incidents such as earthquakes and terrorist attacks (HumanSim, 2009). It is a 3D first-person game and was development using Unreal Engine 3 (Figure 2.7). It takes place in a fictional city where the player must choose which equipment will need and the act according with the requirements of a particular situation. The main goal of this serious game is train and exercise emergency medical service (EMS) professional, but it is also used as recruiting tool for EMS community.

2.1.1.1 Sepsis Serious Games

In regard to sepsis, a serious game by Stanford University - School of Medicine was developed in 2011 entitled Septris (Stanford University, 2011). Septris serious game was developed to provide a practical approach to the identification and application of evidence-based management and evidence-based guidelines. It was developed to target healthcare students.

The learning objectives designed for the game are:

- Classify epidemiology of sepsis syndrome and differentiate between the different forms of sepsis syndromes (simple, severe and septic shock).
- Integrate best evidence practices, clinical expertise and diagnostic test results for early identification and optimal management of septic states using evidence-based guidelines and clinical decision support tools (eg. ordersets, best practice alerts etc.)
- Demonstrate specific best practice strategies such as fluid resuscitation, early identification with laboratory markers and screening and transfer of patient to higher care with sepsis.
- Describe priority actions for establishing and implementing early goal directed therapies for the septic patients along the continuum of care.
- Develop and apply communication skills related to identification and management of sepsis when working among healthcare teams. (eg. Calling for help early)

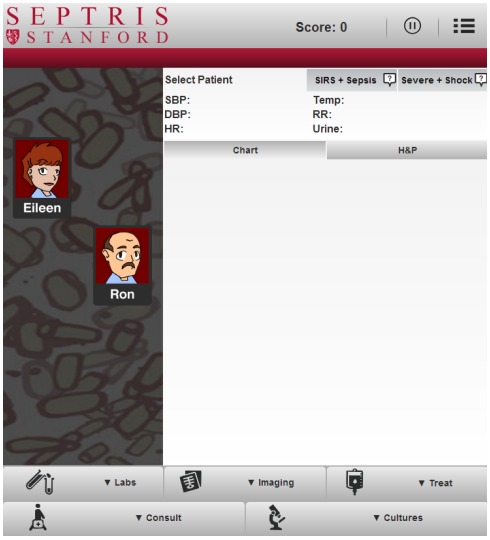


Figure 2.8: Septris Serious Game

Figure 2.8 presents a screenshot of the Septris serious game which runs in a web browser. It is composed of eight patients (clinical cases) who may have a sepsis infection and need medical treatment. If a patient has a confirmed case of sepsis and he or she is not treated in time, he or she dies, resulting in the loss of points. The player has several options available for diagnosis, namely lab exams, imaging, and cultures, as well as options for treatment, namely antibiotics, fluids, and pressors, among others.

2.2 Serious Games Models and Frameworks

Serious game models and frameworks allow developers to combine the engagement and fun element of traditional games in order to achieve specific learning outcomes. In this section several models and frameworks for serious game development are described.

2.2.1 Experiential Gaming Model

The Experiential Gaming Model (Kiili, 2005) is based on experiential learning theory, flow theory, and game design Figure 2.10. Based on this model is expected that a serious game provides the player with immediate feedback, clear goals and challenges for different player's skill level. The usage of flow theory as a framework facilitates positive user experience, maximising the impact of educational games.

Flow theory was presented by Csikszentmihaly (1990) and describes flow as a state of complete engagement in an activity and refers to it as the optimal experience (Csikszentmihalyi, 2000). This flow state has positive impact on a person's learning, since during optimal experience he or she is so involved with the driven goal that nothing else seems to matter. Kiili refers that the flow state should be taken into account when designing learning games.

According to Finneran and Zhang (2003), to accomplish an activity performed in a computer-mediated environment it must be broken into the main task and the artifact. Artifact term cover both tools and toys. So, the authors proposed a person-artifact-task (PAT) model that conceptualizes the major components

of a person working on a computer-related activity. PAT model contributed to the flow theory providing a means to consider what influences experiencing flow: the task itself, the use of artifacts or individual differences.

Other computer-mediated flow studies (Chen et al., 1999; Hoffman and Novak, 1996) distinguish the flow in the following stages: flow antecedents, flow experience and flow consequences. The flow antecedents include focused attention, potential control, a perception of challenges, playfulness, speed, and ease to use. The flow experience comprises a merging of action and awareness, concentration , a sense of control over activity, time distortion, and telepresence. From the flow experience, come the flow consequences which may be an increased learning, increased exploratory behaviour, positive effect, an acceptance of information technology, and perceived behavioral control.

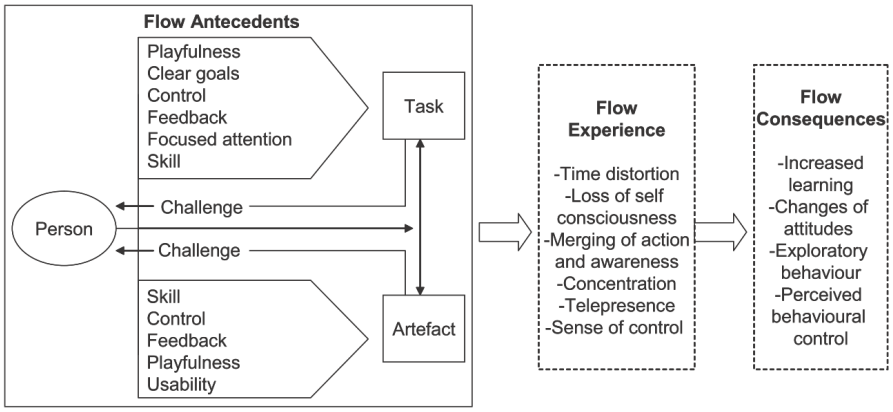


Figure 2.9: Framework of flow (Kiili, 2005)

Figure 2.9 presents a flow framework in computer-mediated environments which includes each flow stage and the components of the PAT model.

The experiential learning is based on direct experience and reflective observation. According to experiential learning model (Kolb et al., 1984), learning begins with a concrete experience followed by collection of data and reflective observations about the experience. Generalizations, conclusions and hypothesis formation about the experience are made by learners in the abstract conceptualization stage. The mentioned hypothesis are tested in the final stage through active experimentation. This model stresses the continuous nature of learning and the appropriate feedback, providing the basis for a continuous process of goal-directed action.

Experiential gaming model was created because of the need of a model that could be used in designing and analysing educational games.

The main purpose of the model is to link gameplay with experiential learning in order to facilitate the flow experience. In this model, learning is described as a cyclic process through direct experience in the game world and is defined as a construction of cognitive structures through action or practice in the game world.

Figure 2.10 presents the experiential gaming model, which consist of an ideation loop, an experience loop and a challenge bank. Its operation is based on the human blood-vascular system, where the challenges form the heart of the model. The task of the heart is to pump challenges, based on

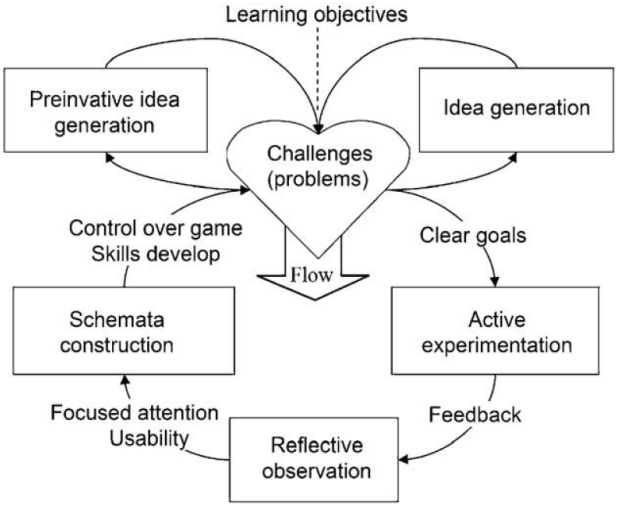


Figure 2.10: Experiential Gaming Model (Kiili, 2005)

educational objectives, in order to sustain the engagement and motivation of the players. To overcome the challenges, a player creates solutions in the ideation loop reflecting lesser circulation. Generation of solutions is divided into a preinvative idea generation, which refers to primary creativity (Maslow, 1963), and idea generation, when a player develops solutions by considering constraints and available resources of the game world.

After the ideation phase the player tests solutions in the experience loop and observes the outcomes of actions. In order to facilitate flow experience, games must provide clear goals and appropriate feedback to the player. The reflective observation of the feedback may lead to the construction of schemata and enable the discovery of new and better solutions to problems. The solutions test also increases the player's skill level and he or she may achieve control over the game and its subject.

2.2.2 Problem-based Gaming Model

The Problem-based Gaming (PBG) Model (Kiili, 2007) is founded on the same principles as Problem-based Learning (PBL).

PBL is a student-centred learning approach helping learners to acquire and develop the knowledge, skills, and capabilities needed to solve problems effectively (Engel, 1997). The PBL approach aims to prepare students to encounter ill-structured problems normally encountered in real life. The main principles of PBL are contextuality, collaboration, and experimentalism.

PBG is an approach that emphasises the meaning of learning tasks, experiential learning, and collaboration. Usually, games allow players to creatively test hypotheses and reflect on outcomes in the game world, so experiential learning theory provides an appropriate basis for PBG. The basic idea is to anchor the acquisition of knowledge and skills into meaningful problem-solving situations encountered in everyday life. This sort of approach supports the transferability of learned knowledge and skills into practice. In games, the storyline and the game world can be used to contextualise the relevant problems.

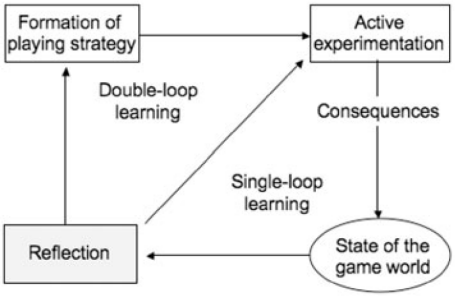


Figure 2.11: Problem-based Gaming Model (Kiili, 2007)

In Figure (2.11), the PBG model is illustrated as a learning process divided into modules. The model describes learning, which is a construction of cognitive structures, as a cyclic process conducted through direct experience in the game world.

The PBG process starts with strategy formation, when the player tries to form a playing strategy in order to solve the problems that are provided by the game. This playing strategy is formed by the player according to his prior experiences, which must be adequate to the games subject, although the player may start the gaming process by exploring the game world. After the strategy formation, the player tests his game strategy, as an active experimentation, in the game world and observes the consequences of his actions. Afterwards, occurs the reflection phase in which the player recapture their experience, think about it, mull it over and evaluate it. For this, is important that the game provide player's actions feedback that support reflective thinking and knowledge construction. The outcome of the reflection phase may be personal synthesis or appropriation of knowledge, validation of hypothesis laid during strategy formation, or a new strategy to be tested.

2.2.3 Input-Process-Outcome Game Model

The Input-Process-Outcome Game Model (Garris et al., 2002) has the goal of developing learners who are self-directed and self-motivated, both because the activity is interesting in itself and because achieving the outcome is important, as represented in Figure 2.12.

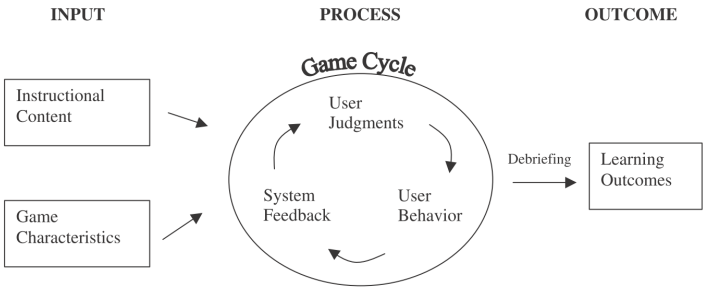


Figure 2.12: Input-Process-Outcome Game Model (Garris et al., 2002)

The objective was to design an instructional program that incorporates features or characteristics of games that trigger a cycle including user judgements and further system feedback. This allows the engagement of players leading to the achievement of training objectives and specific learning outcomes.

In input-process-outcome model, the key component is the game cycle that is triggered by specific game features. The game cycle is an iterative process, such that the game play involves repeated judgement-behaviour-feedback loops. That is, game play can lead to certain user judgements or reactions such as increased interest, enjoyment, involvement, or confidence; these reactions lead to behaviours such as greater persistence or intensity of effort; and these behaviours result in system feedback on performance in the game context. Thus, the game cycle is a defining characteristic of computer game play - that users engage in repetitive play and continually return to the game activity over time.

The authors intend the learner to actively construct knowledge from experience. Although the model is represented as a cyclical training model, the authors do not imply that all learners necessarily learn in the same way, or that all learners proceed through these stages in a sequential or linear manner. Therefore, emphasis is placed on the idea that (i) people learn from active engagement with their environment and (ii) this experience, coupled with instructional support (i.e., debriefing, scaffolding), can provide an effective learning environment.

2.2.3.1 Game Cycle

The game cycle focuses attention to a critical chain of dependencies: (a) To elicit desirable behaviours from learners, (b) they first need to experience desirable emotional or cognitive reactions, (c) which result from interaction with and feedback generated from game play.

2.2.3.2 User judgements

Judgements are made by players when they initiate the game play. These judgements regard whether the game is fun, interesting, and engaging. Judgements are usually represented by self-reports of interest and engagement, enjoyment, and feelings of mastery.

Regarding *interest*, games are consistently perceived as more interesting than traditional instruction (Randel et al., 1992).

Enjoyment is a sense of achievement that occurs when one's skills are matched with the task's challenges (Czikszentmihalyi, 1990). And a main characteristic of games is that they are fun and a source of enjoyment.

Task involvement is a degree to which individuals concentrate on and become absorbed in an activity (Elliot and Harackiewicz, 1994). The degree of immersion experienced in a computer game may be determined by several factors, namely control, sensory, distraction and realism factors (Witmer and Singer, 1994).

Regarding *confidence*, games can provide a training environment in which users can perform tasks without facing the real-world consequences of failure. Games can serve to enhance trainee confidence, especially important when training for complex, stressful, or dangerous tasks (Driskell and Johnston, 1998).

2.2.3.3 User behaviour

The affective judgements that are formed from initial and ongoing game play determine the direction, intensity, and quality of further behaviour. Motivated learners more readily choose to engage in target activities, they pursue those activities more vigorously, and they persist longer at those activities than do less motivated learners.

The players who form positive user judgements more actively engage in game play, exert intense effort and concentration, and return to game play unprompted.

2.2.3.4 System feedback

Feedback or knowledge of results is critical to support performance and motivation (Wexley and Latham, 2001).

Authors state that feedback is a critical component of the judgement-behaviour-feedback cycle, since individual judgements and behaviour are regulated by comparisons of feedback to standards or goals.

Feedback provides an assessment of progress toward goals that drives the motivated performer to expend more effort, to persist, and to focus attention on the task.

2.2.3.5 Debriefing

In input-process-outcome game model debriefing provides a link between the game cycle and the achievement of learning outcomes. Debriefing is the review and analysis of events that occurred in the game itself. Which many authors consider as the most critical part of the gaming experience (Crookall, 1995; Crookall and Saunders, 1989; Lederman, 1992; Lederman and Fumitoshi, 1995).

Debriefing provides a link between what is represented in the simulation/gaming experience and the real world. It allows the participant to draw parallels between game events and real-world events. The debriefing process allows us to transform game events into learning experiences. It may include a description of events that occurred in the game, analysis of why they occurred, and the discussion of mistakes and corrective actions.

2.2.3.6 Learning Outcomes

The authors classified the learning outcomes in three types, namely skill-based, cognitive, and affective outcomes. Skill-based learning outcomes can be the development of technical or motor skills. Cognitive learning outcomes are divided into three types, namely declarative knowledge which refers to knowledge of facts and data regarding the task performance, procedural knowledge which refers to knowledge about how to perform a task, and strategic knowledge which requires the application of learned principles to different contexts deriving new principles for general situations. Affective learning outcomes is related to affective reactions which include feelings of confidence, self-efficacy, attitudes, preferences, and dispositions.

2.2.4 Four-dimensional Framework

Four-dimensional framework (De Freitas and Oliver, 2006), presented in Figure 2.13 was created for helping tutors evaluate the potential of using game- and simulation-based learning in their practice, as well as to support more critical approaches to this form of games and simulations. This framework requires the practitioner to consider four main dimensions before using games and simulations in their practice.

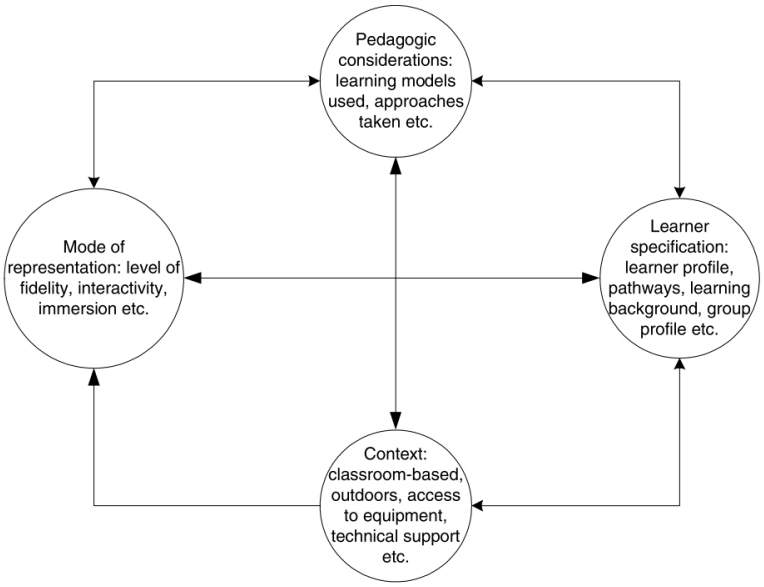


Figure 2.13: Four-dimensional Framework (De Freitas and Oliver, 2006)

This framework requires the practitioner to consider four main dimensions in advance of using games and simulations in their practice. It should be regarded as iterative and reflect the process of evaluation.

The Four-Dimensional framework allows researchers and evaluators to develop metrics for supporting effective analysis of existing educational games and simulations; and allowing educational designers to consider a more user-based and specialised set of educationally specific factors.

The first dimension focuses upon the particular context where play/learning takes place, including macro-level historical, political and economic factors as well as micro-level factors such as the availability of specific resources and tools.

The second dimension focuses upon attributes of the particular learner, this may may include the age and level of the group, and how they learn including their learning background, styles and preferences. Games can support formal as well as informal learning and may become an effective way of linking between formal and informal learning processes to accelerate learning outcomes.

The third dimension focuses upon the internal representational world – or diegesis – of the game, this is, the mode of presentation, the interactivity, the levels of immersion and fidelity used in the game or simulation. It highlights the difference between being immersed within the game and the process of critical reflection that takes place outside the game. This may serve as a method for supporting the teaching aims and learner objectives by defining the 'learning activity as play' and highlighting the

potential of briefing/debriefed which take place before and after 'serious play' to reinforce the learning outcomes.

The fourth dimension focuses upon the processes of learning both during the course of formal curricula based learning time and during informal learning. This dimension promotes the practitioners' reflection upon methods, theories, models and frameworks used to support learning practice. This dimension therefore also includes the consideration of how learning content is embedded and personalised to support the more differentiated learning approaches.

The authors refer that the four dimensions should not be considered as separate but rather reveal the significance of how each dimension relates and maps to each other to produce, support or inhibit the particular learner or learner group's experience.

2.3 Summary

In this chapter we started by introducing the *serious game* concept and presented several serious game developed for clinical education, namely:

- **Critical Transport** designed to teach healthcare students the recommendations for the critically ill patients.
- **Pulse!!** designed for training healthcare professionals in clinical skills.
- **3DiTeams**, a multiplayer serious game for medical education and team training.
- **Clinispace serious game** for training healthcare professionals.
- **Pivotal Decision** serious game was created for mass casualty triage.
- **Triage Trainer** developed to train first responders on catastrophe protocols and prioritization of casualties.
- **Zero Hour: America's Medic** is a serious game designed to train and exercise first responders to respond to mass casualty incidents.

We also described several serious game gaming models and frameworks, namely:

- **Experiential Gaming Model** based on experiential learning theory, flow theory, and game design.
- **Problem-based Gaming model** founded in the very same principles of Problem based Learning.
- **Input-Process-Outcome Game Model** designed to develop learners who are self-directed and self-motivated, both because the activity is interesting in itself and because achieving the outcome is important.
- **Four-dimensional Framework** created for helping tutors to evaluate the potential of using games- and simulation-based learning in their practice, and to support more critical approaches to this form of games and simulations.

Chapter 3

Sepsis Fast Track Serious Game

3.1 Introduction

This chapter describes the Sepsis Fast Track serious game. The main goal of this serious game is to teach and train healthcare professionals of hospital emergency departments, namely nurses and physicians, about the Sepsis Fast Track protocol. This serious game was developed together with emergency department healthcare professionals in order to ensure that all the information present in the game are correct resulting in better learning outcomes. We started describing the context, followed by a description of the protocol, the stages that composes the serious game, the game environment and user interface, and the implementation details.

3.2 Learners and Context

Sepsis Fast Track Serious Game is intended to be used as an on-the-job training tool and to be played by Emergency Department (ED) professionals, namely nurses and physicians. The main objective of this serious game is to teach, train and refresh the healthcare professionals knowledge about the Sepsis Fast track protocol.

This serious game is divided into two main phases, one for nurses (*Identification of a Possible Sepsis Case*) and other for physicians (*Sepsis Case Confirmation and Therapy*).

Regarding the nurses phase, this serious game focused on teaching:

- How a patient should be evaluated during the triage in order to identify a possible sepsis infection.
- The medical procedures available for the evaluation and its correct sequence.
- The interactions that should be done with the patient while evaluating him or her.
- How to contact a physician responsible for the Sepsis Fast Track to refer the patient (in case he or she has been identified with a sepsis infection).

- How the patient's data regarding to the Sepsis Fast Track should be registered on the hospital IT system (including its activation).

In respect to the physicians phase, this serious game focused in teaching:

- How a patient should be evaluated in order to confirm his or her sepsis infection.
- The medical procedures available for the diagnose and its correct sequence.
- The available medical therapies that should be applied to a sepsis patient with a confirmed sepsis case, how they should be applied and in which order.
- The interactions with the patient, a nurse (to request medical procedures), and the intensive care unit.
- How to interact with the hospital IT system, namely to request complementary exams and to register patient's data regarding to the Sepsis Fast Track.

Due to the importance of a treatment in a timely manner, this serious game took into account the time within some procedures should be done (e.g. the antibiotic administration). Therefore, it is presented in both game's phases a clock showing the in-game time and several warnings are shown in order to the player achieve the main goals successfully.

Since Sepsis Fast Track protocol is constantly evolving (Campaign, 2006; Dellinger et al., 2008; Marshall et al., 2010; Dellinger et al., 2013), this serious game was designed to be easily modified and updated. In addition, Sepsis Fast Track protocol is used worldwide, this serious game was also designed to be translated and adaptable to other hospitals and countries.

3.3 Sepsis Fast Track Protocol

Sepsis Fast Track protocol is part of the *Circular Normativa* issued by Portuguese Directorate-General of Health in January 2010 (Direcção-Geral da Saude, 2010) based on the guidelines of Dellinger et al. (2008). presents the required steps, and its sequence, to a healthcare professional in order to identify a possible case of sepsis, as well as the consequent medical procedures to treat the patient. The protocol is presented in Figure 3.1.

Sepsis Fast Track protocol is divided into two main phases, the *Identification of a Possible Sepsis Case*, performed by a triage nurse, and the *Sepsis Case Confirmation and Therapy*, performed by an emergency department physician. These phases are subdivided into four steps. The following subsections explain how the protocol should be applied.

3.3.1 Identification of a Possible Sepsis Case

The first step occurs during the triage of a patient, made by a nurse. The main goal of this step is to identify a suspected sepsis case in the patient. It consists in the systematic evaluation of all patients that

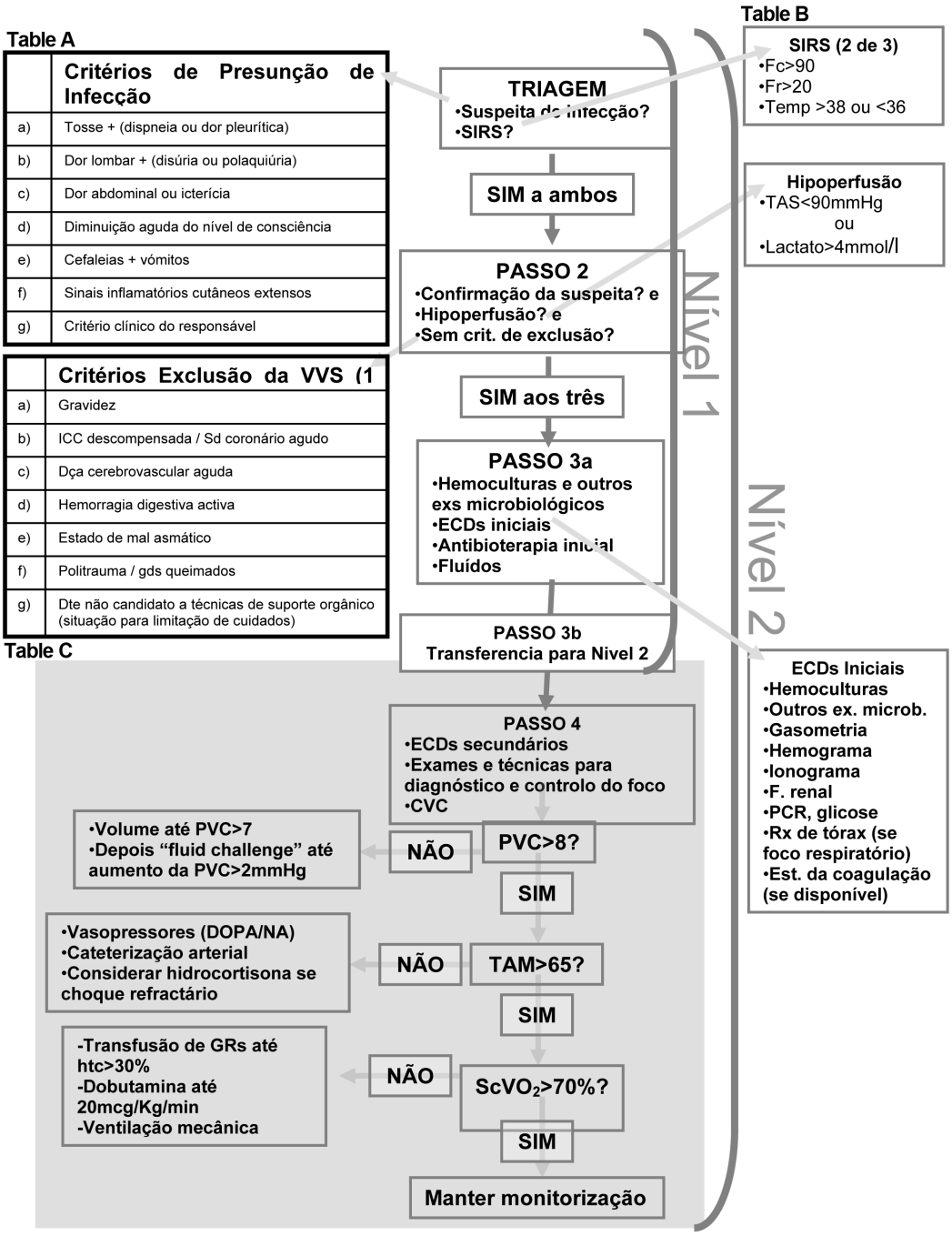


Figure 3.1: Sepsis Fast Track Protocol

go to the emergency department (ED) at the time of the initial general triage, namely the Manchester Triage System, as potential candidates of Sepsis Fast Track.

The nurse responsible for the patient's triage must analyse the patient's symptoms. A presence of a clinical suspicious infection, presented in Table A of Figure 3.1, should motivate to a mandatory assessment of heart rate, respiratory rate, and body temperature, this is, the criteria for systemic inflammatory response syndrome (SIRS) presented in Table B of Figure 3.1. Patients with a complaint suggestive of infection and at least two criteria of SIRS, namely heart rate greater than 90 beat per minute, respiratory

rate greater than 20 breaths per minute, or body temperature below 36º Celsius degrees or above 38º Celsius degrees, must advance to the second step of the algorithm.

Before the second step, the nurse that identified a suspicious sepsis case, must register all the data about the patient and the SIRS criteria, in the information technology (IT) system. This data must include the patient's personal data, his or her complaints, heart rate, respiratory rate, and body temperature. Also in the IT system, the nurse must activate a Sepsis Fast Track alert that identifies the patient with a suspicious sepsis infection. After the IT system data registration, the nurse must contact by phone the physician responsible for the Sepsis Fast Track.

3.3.2 Sepsis Case Confirmation and Therapy

Following the patient referral, the second step starts and is conducted by a physician. The main goal of this step is to medically confirm the suspicious sepsis case, the existence of hypoperfusion, and the absence of exclusion criteria. For this, a physician of the ED must reassess the patient and confirm the presence of clinical suspicious infection (Table A of Figure 3.1), assess whether there is a severe hypoperfusion, namely the patient have hypotension (mean arterial pressure greater than 90mmHg), or hyperlactacidemia (lactacte greater than 4mmol/l), and if there are not Sepsis Fast Track exclusion criteria presented in Table C of Figure 3.1.

Only the patients with a confirmed clinical suspicious infection and hypoperfusion, without any exclusion criteria, must advance to the third step of the algorithm.

Before the third step, the physician must validate (or do not validate, in case the patient does not meet the mentioned criteria) the Sepsis Fast Track in the IT system. For this, the physician must create a document where he or she should take note of the patient's suspicious infection, if there is any exclusion criteria, the patient's systolic and diastolic arterial pressure, the lactate value, the patient's conscious state, and the Sepsis Fast Track validation.

The third step is conducted by the same physician that performed the second one. The main objective of this step is the administration of appropriated antibiotherapy. The appropriated antibiotherapy lies in the use of active drugs against the causative microorganism in maximized doses, with good penetration into the focus of infection, and must be administered within the first hour after the recognition of the patient's clinical condition.

In addition to the antibiotherapy, other important clinical procedures must be done in this step. Namely, a blood culture collection, request of complementary diagnosis exams, and the initiation of fluid therapy.

As in the previous step, the physician must use the IT system to register the procedures that were performed and at what time. Namely, the hemocultures, the antibiotherapy and which drug was used, and the fluid therapy.

Also, before proceeding to the forth step, the physician must contact the hospital's intensive care unit (ICU). If the ICU has availability to receive the patient, he or she must be transferred to the ICU and the algorithm reaches its end, if not the algorithm continues to the next step.

The forth and final step must be conducted by the same physician that preformed the previous two steps. The main goal of this step is to optimize the oxygen delivery to the peripheral tissues. This is done with an objective oriented therapy that rely on obtaining, in sequential order, three clearly defined hemodynamic parameters. Namely, the central venous pressure, mean arterial pressure, and the central venous oxygen saturation.

Before performing the mentioned procedures, the physician should reassess the patient's conditions. If the condition remains the same, or there is not any improvement of the patient's condition, the physician must place a central venous catheter in the patient. Then, the physician needs to check the patient's central venous pressure, if it is lesser than 8 mmHg new fluid therapy must be performed. The mean arterial pressure must also be verified, and if it is lesser than 65 mmHg the physician must administer vasopressors to the patient, dopamine is the recommended vasopressor. The last procedure that the physician should do is verify the patient's central venous oxygen saturation, for getting its value a venous blood gas test must be preformed, if the result of central venous oxygen saturation is lesser than 70% the physician must administer dobutamine to the patient.

Concluding the forth step, the Sepsis Fast Track algorithm reaches its end, and the physician must contact the ICU again. The patient's monitoring should be maintained.

3.4 Game Stages

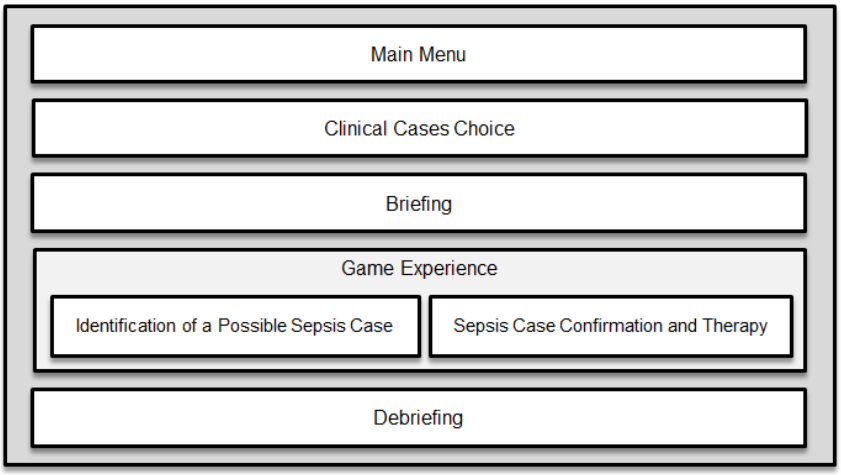


Figure 3.2: Sepsis Fast Track serious game stages.

In Figure 3.2 the stages that compose this serious game are presented. Namely, *Main Menu*, *Clinical Cases Choice*, *Briefing*, *Game Experience* composed by *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation and Therapy*, and *Debriefing*.

When a player starts the Sepsis Fast Track serious game, he or she is prompted with the *Main Menu* (Figure 3.3), where he or she must identify him or herself using his or her name and personnel number. The player must also select if he or she is a nurse or a physician, which will allow him or her to play the respective serious game phase (both roles can be chosen if the player wants to play both game phases).

Figure 3.3: Sepsis Fast Track serious game main menu.

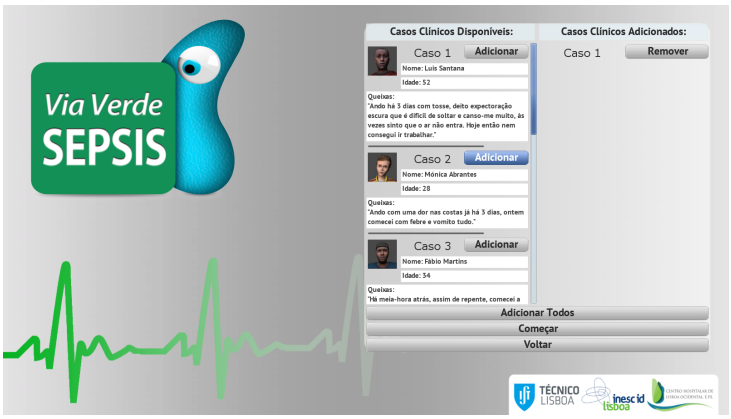


Figure 3.4: Clinical Cases Choice.

Afterwards, the player is presented with a menu for the *Clinical Cases Choice*.

The gameplay of Sepsis Fast Track serious game is divided into three phases: Briefing, Game Experience, and Debriefing.

3.4.1 Briefing

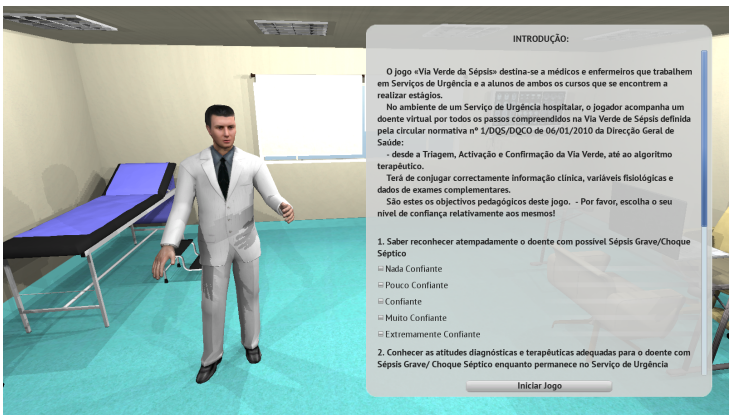


Figure 3.5: Briefing.

Briefing is the first phase that composes the gameplay. It consists in a reference point for the main

target users (players) to explain the Sepsis Fast Track serious game, as well as the Sepsis Fast Track protocol. The main objectives are described in detail, allowing the player to understand what the serious game is all about.

Also, the pedagogical goals are explained. There are four pedagogical goals; for each one, the player must choose his or her confidence level concerning their knowledge in that area. Every answered question is logged by the game, allowing further data analysis (3.7.3).

To increase the player's engagement, a 3D avatar impersonating a physician was used to present the briefing. The briefing content was provided by physicians and is in accordance with the Sepsis Fast Track protocol. This ensures that the information and pedagogical goals given are the most accurate in order to obtain the best results.

3.4.2 Game Experience

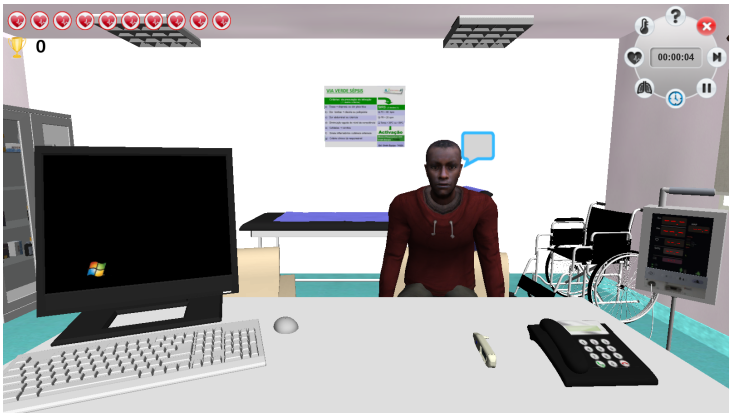


Figure 3.6: Identification of a Possible Sepsis Case Game Experience.

Figure 3.7: Sepsis Case Confirmation and Therapy Game Experience.

After the briefing, the game experience begins. According to the role chosen on the main menu, a specified game's phase begins, either *Identification of a Possible Sepsis Case* for nurses (Figure 3.6) or *Sepsis Case Confirmation and Therapy* for physicians (Figure 3.7). If both roles were chosen, *Identification of a Possible Sepsis Case* is the first phase to be played.

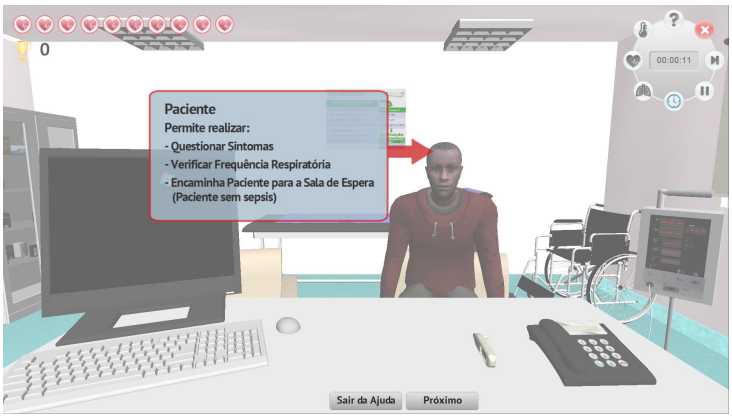


Figure 3.8: Help Screen - Identification of a Possible Sepsis Case Game Experience.

When the game experience begins, the player is prompted with a help dialogue message asking if he or she wants to see the help screens (this is recommended for first-time players). If the player chooses to see the help screens, the available options that a player has during the game are explained, as in Figure 3.8. This help option is also available during the game by clicking on the help button as explained in 3.6.1.

During the game experience, the player will apply his or her knowledge about the Sepsis Fast Track protocol described in 3.3. The goals of the game experience are not only to test the player's knowledge, but more importantly to teach and refresh his or her knowledge of the standard protocol. The game experience consists of evaluating a patient who was admitted to the hospital emergency department and may or may not have a sepsis infection.

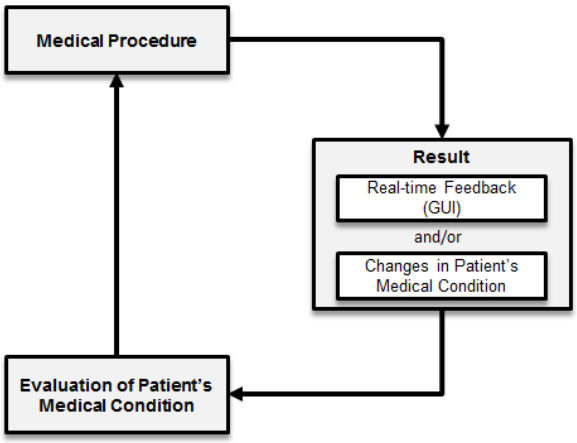


Figure 3.9: Game Experience.

The development of the game experience phase was based on both *Problem-based Gaming Model* (Kiili (2007)) and *Input-Process-Outcome Game Model* (Garris et al. (2002)), as shown in Figure 3.9. It consists of three main modules, namely *Medical Procedures*, *Result* (composed by *Real-time Feedback* and/or *Changes in Patient's Medical Condition*), and *Evaluation of Patient's Medical Condition*, that form a cyclic process. that form a cyclic process. During gameplay, the player interacts with the game environment, executing medical procedures that may have impacts on the environment and/or on the

medical condition of the patient. Depending on the procedure and when it is conducted, the impacts can be positive or negative. This information is provided by the *Real-time Feedback* on the user interface, letting the player know if the procedure was correctly performed, and if not, what he or she should have done instead. If a procedure is correctly performed, it may have an impact on the patient's condition. Therefore, the player must re-evaluate the patient in order to identify the next appropriate medical procedure.

In order to increase the player's immersion, the game environment was developed using a three-dimensional virtual world, described into more detail in 3.6.

To bridge the gap between how healthcare professionals perform their tasks (medical procedures) in the real world and how they should be performed in the virtual world, several specific game mechanics were designed, as described below.

3.4.2.1 Game Mechanics

Game mechanics are the rules, processes, and data at the heart of a game Adams and Dormans (2012). In this serious game, several game mechanics were designed and are based on the real interactions of healthcare professionals concerning the Sepsis Fast Track protocol described in the previous section (3.3). These mechanics are divided by interaction type, namely, how or what a player interacts with.

As was described in Section 3.3, Sepsis Fast Track protocol is divided into two main phases. Therefore, Sepsis Fast Track Serious game experience is also divided into the same phases, namely the *Identification of a Possible Sepsis Case* phase (3.3.1) played as a nurse and the *Sepsis Case Confirmation and Therapy* phase (3.3.2) played as a physician. Each phase has its own game mechanics.

The following subsections present several mechanics diagrams corresponding to each interaction type. Each diagram is composed by the in-game player action that triggers a particular mechanics, a mechanics itself, its outputs, and the in-game visual changes.

3.4.2.1.1 Identification of a Possible Sepsis Case Mechanics

In the game's first phase, the player, playing as a nurse, can interact with a patient, with the IT system, and with the physician responsible for the Sepsis Fast Track. Each of these interactions were defined according to the following mechanics.

Nurse-Patient Mechanics

There are two main mechanics available in the relation Nurse-Patient, the *Communicate* and the *Acts* (Figure 3.10).

Communicate mechanics allow a player to question or request something from the patient who is being evaluated. *Communicate* options are available when a player clicks on the patient avatar (Figure 3.11), then a menu is shown, allowing the player to choose which type of communication he or she wants (Figure 3.12).

For *Communicate*, two mechanics were defined, the *Symptoms Check* and *Send to Waiting Room*.

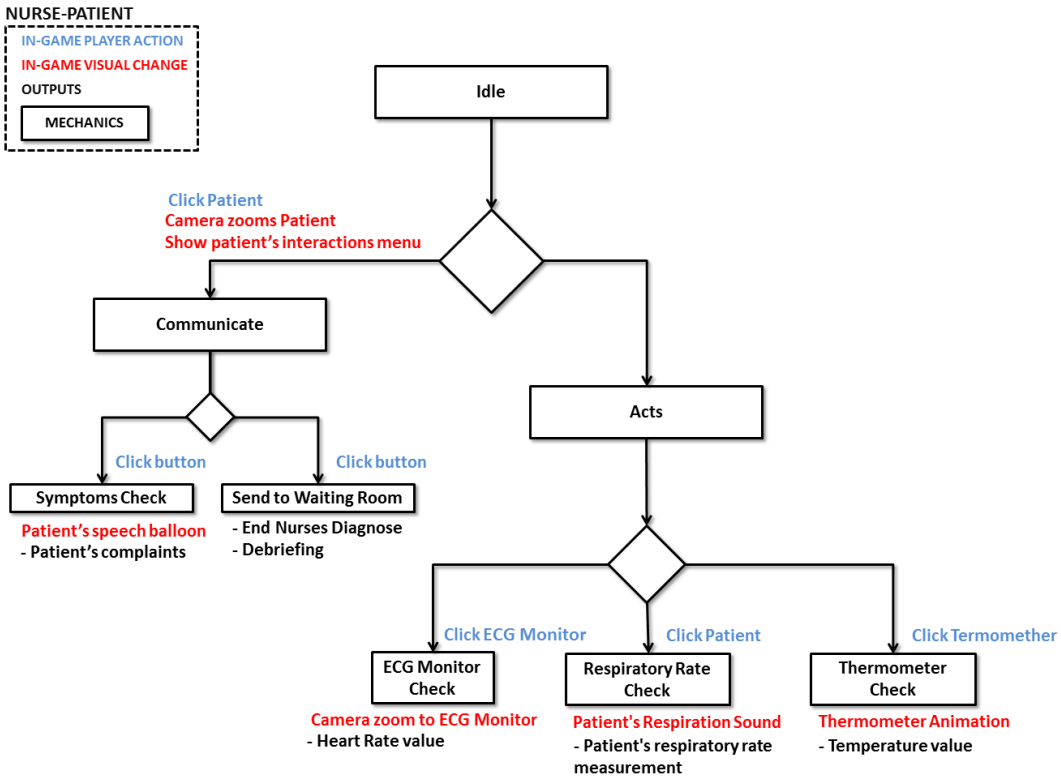


Figure 3.10: Nurse-Patient Mechanics.

Figure 3.11: Patient Avatar.

Symptoms Check allows the player to ask about the patient's complaints that made the patient visit the emergency department in the first place. With this, a suspected infection can be analysed comparing the complaints with the symptoms presented in Table A in Figure 3.1 (described in 3.3). The patient's complaints (output) are presented in a speech balloon using a *common patient speech* (Figure 3.13), so the player must interpret what the patient is saying in order to conclude if any of his complaints matches with the ones presented in Table A in Figure 3.1.

Send to Waiting Room, as the name suggests, allows a player to send the patient to the waiting room if the player concludes that the patient does not have a suspected sepsis infection. This mechanics ends the *Identification of a Possible Sepsis Case* game phase, and is followed by a Debriefing (3.4.3).

Acts mechanics allows the player to perform a diagnostic or therapeutic action, which can be invasive or non-invasive.

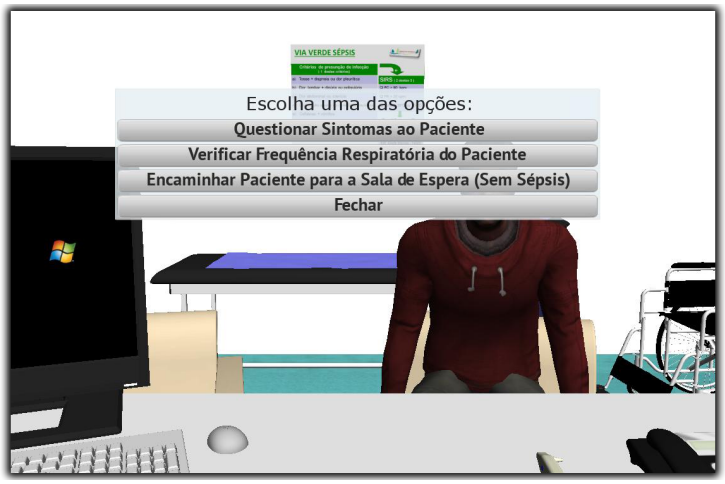


Figure 3.12: Patient Options Menu.

Figure 3.13: Patient Speech Balloon.

Regarding the *Identification of a Possible Sepsis Case* game's phase, three *Acts* mechanics were defined, namely the *ECG Monitor Check*, *Respiratory Rate Check* and *Thermometer Check*. All of them are non-invasive and for diagnose. They correspond to the evaluation of Systemic Inflammatory Response Syndrome (SIRS) that are an inflammatory state affecting the whole body, frequently a response of the immune system to infection. If a patient meets criteria for SIRS the Sepsis Fast Track must be activated.

ECG Monitor Check allows the measurement of the patient's heart rate (according to SIRS, it is positive if it is greater than 90 beats per minute). To trigger this mechanics, the player must click on the ECG Monitor available in the triage room, then the game's camera zooms to it, showing the patient's heart rate value (Figure 3.12).

Respiratory Rate Check, as the name suggests, allows the measurement of the patient's respiratory rate (according to SIRS, it is positive if it is greater than 20 breaths per minute). For this measurement, the player must choose the respective option in patient's options menu (Figure 3.12), afterwards the player is prompted with a clock on-screen and the patient's breathing sound will start playing. The measurement is made as in real life, the player must count how much breaths the patient has in 15 seconds, then multiply that value by 4 to get the respiratory rate in breaths per minute.

Thermometer Check allows the player to measure the patient's body temperature (to be positive,

Figure 3.14: ECG Monitor in Triage Room.

according to SIRS, temperature must be less than 36 °C or greater than 38 °C). To measure the patient's body temperature the player needs to click on the thermometer placed on the table of the triage room. After the click, an animation is shown, ending with the temperature value displayed on the thermometer (Figure 3.15).

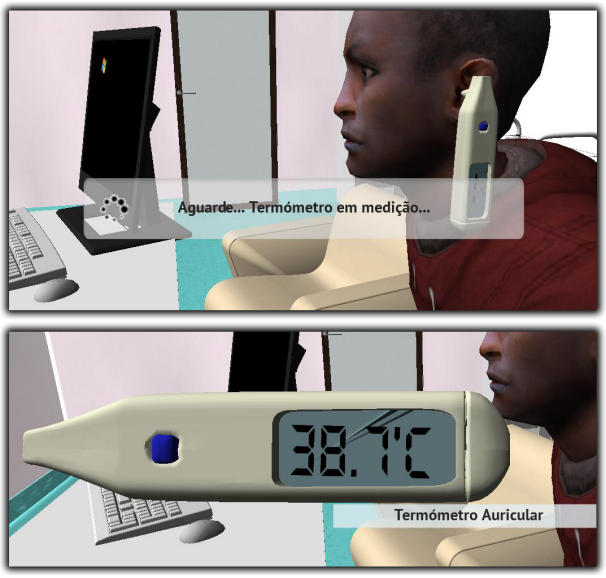


Figure 3.15: Temperature Check.

Nurse-IT System Mechanics

IT System represents the hospital's information technology system that records and manages all the information regarding the patients, medical acts, and so on. Each hospital has its own IT system, Sepsis Fast Track Serious Game IT system is based on the São Francisco Xavier hospital system. It is described in detail in 3.5.3.

There are three main mechanics in the relation Nurse-IT, *Check Patient Data*, *Register Patient Data*, and *Activate Sepsis Fast Track* (Figure 3.16). To use these mechanics a player must click on the computer present in the triage room, then the camera will zoom to it and the IT system will be shown.

Check Patient Data allows a player to check a patient's information given in the hospital's reception area, such as name, age, gender, and identification number (Figure 3.17).

Register Patient Data is used to register patient's data related to the sepsis infection (Figure 3.18).

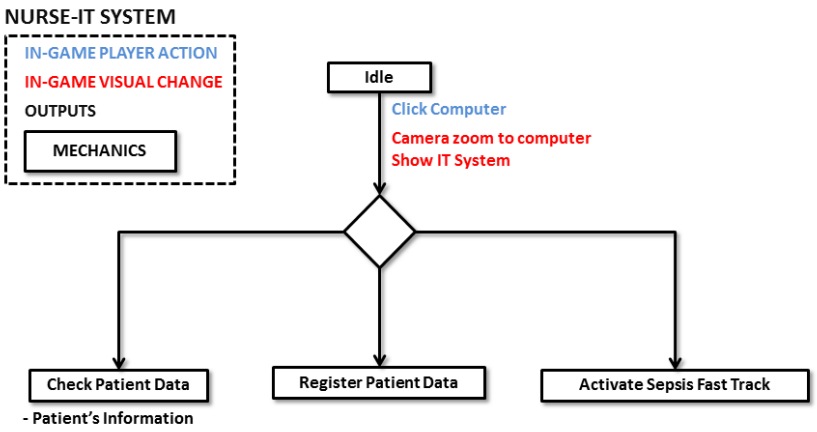


Figure 3.16: Nurse-IT System Mechanics.

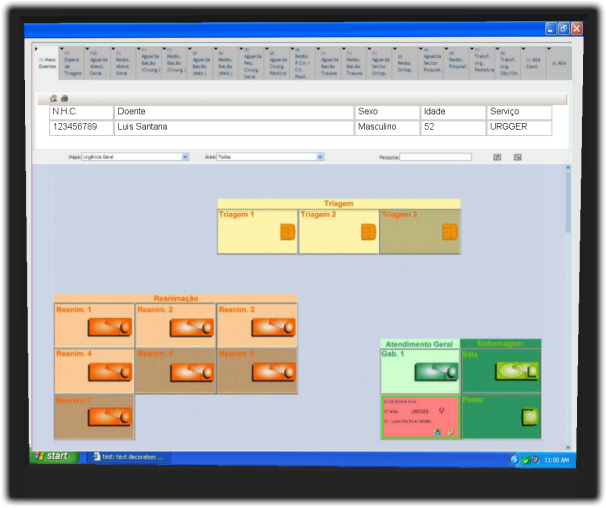


Figure 3.17: Patient's data in IT system

Namely, symptoms, heart rate, respiratory rate, and body's temperature. The fields where it is possible to add new data are explicitly represented, so the player can disregard the irrelevant information and fields.

Activate Sepsis Fast Track allows the player to activate the Sepsis Fast Track alert in the IT system (Figure 3.19).

Nurse-Physician Mechanics

When the patient's evaluation is completed and a possible sepsis case is detected, the player must contact the physician responsible for the Sepsis Fast Track. This contact is made by phone, so there are two mechanics present in Nurse-Physician relation, *Pick Up Phone* and *Call Physician responsible for Sepsis Fast Track* (Figure 3.20).

Pick Up Phone brings up a phone interface that should be used to dial the physician contact (Figure 3.21). To trigger it, the player should click on the phone placed in the triage room.

To trigger *Call Physician responsible for Sepsis Fast Track* the player must dial the correct physician's contact number. If the player doesn't know the physician contact, it is the same used in hospital São

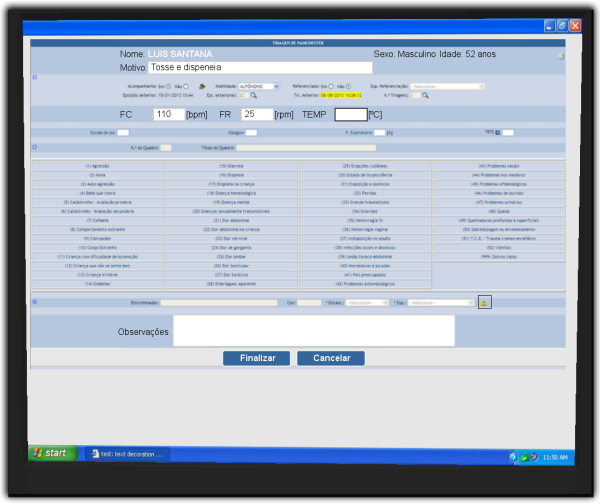


Figure 3.18: Patient's evaluation data registration in IT system

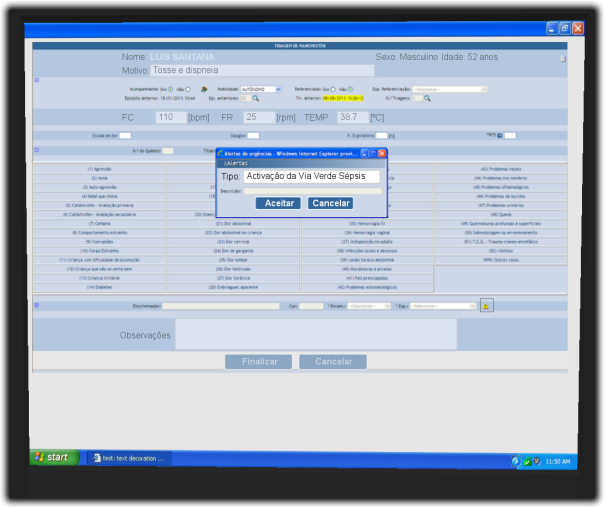


Figure 3.19: Sepsis Fast Track alert activation in IT system

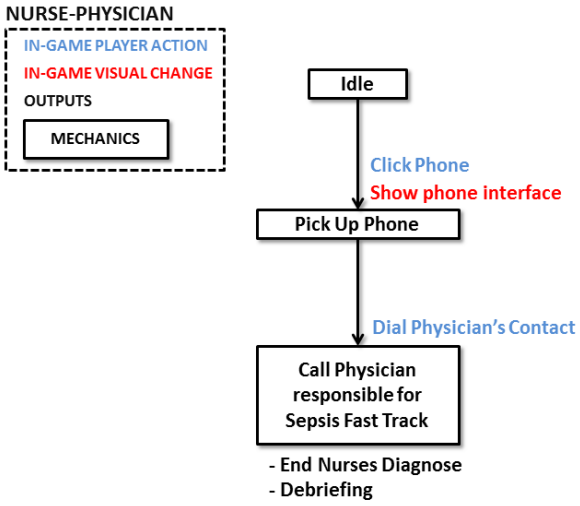


Figure 3.20: Nurse-Physician Mechanics.

Figure 3.21: Phone Interface.

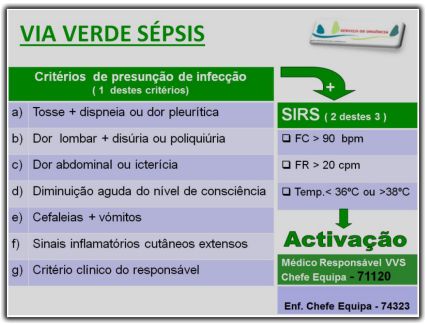


Figure 3.22: Sepsis Fast Track poster present in triage room.

Francisco Xavier, it is present on the Sepsis Poster (Figure 3.22). This mechanics ends the *Identification of a Possible Sepsis Case* game phase, and is followed by a Debriefing (3.4.3).

Summary

In Table 3.1 is presented a summary of every game mechanics used in *Identification of a Possible Sepsis Case* game's phase. Each game mechanics may have pre-conditions, this is, it is impossible to execute it before other mechanics has been performed. If a player tries to execute a particular mechanics that has a not done pre-condition, it will affect his or her lives in the game (3.6.2). In this table is also presented which new mechanics are available after a particular have been performed.

ID	Mechanics	Pre-conditions	New Mechanics
GM01	Symptoms Check	None	GM02, GM03, GM4
GM02	Temperature Check	GM01	GM06, GM09
GM03	Respiratory Rate Check	GM01	GM07, GM09
GM04	Heart Rate Check	GM01	GM08, GM09
GM05	Symptoms Register	GM01	None
GM06	Temperature Resgister (IT)	GM02	None
GM07	Respiratory Rate Resgister (IT)	GM03	None
GM08	Heart Rate Resgister (IT)	GM04	None
GM09	Sepsis Alert Activation (IT)	GM02, GM03, GM04	GM11
GM10	Send Patient to Waiting Room	GM01	None
GM11	Call Physcian	GM09	None

Table 3.1: *Identification of a Possible Sepsis Case* Mechanics Overview

3.4.2.1.2 Sepsis Case Confirmation and Therapy

The *Sepsis Case Confirmation and Therapy* game phase is composed of two main steps that match the

last two main steps of Sepsis Fast Track protocol (3.3). In this phase, the player, playing as a physician, can interact with the patient, a nurse, and with the IT system, the respective mechanics of which are described below. Furthermore, there are interactions between the nurse and the patient, as well as between the nurse and the physician (player), which are also described in the following subsections.

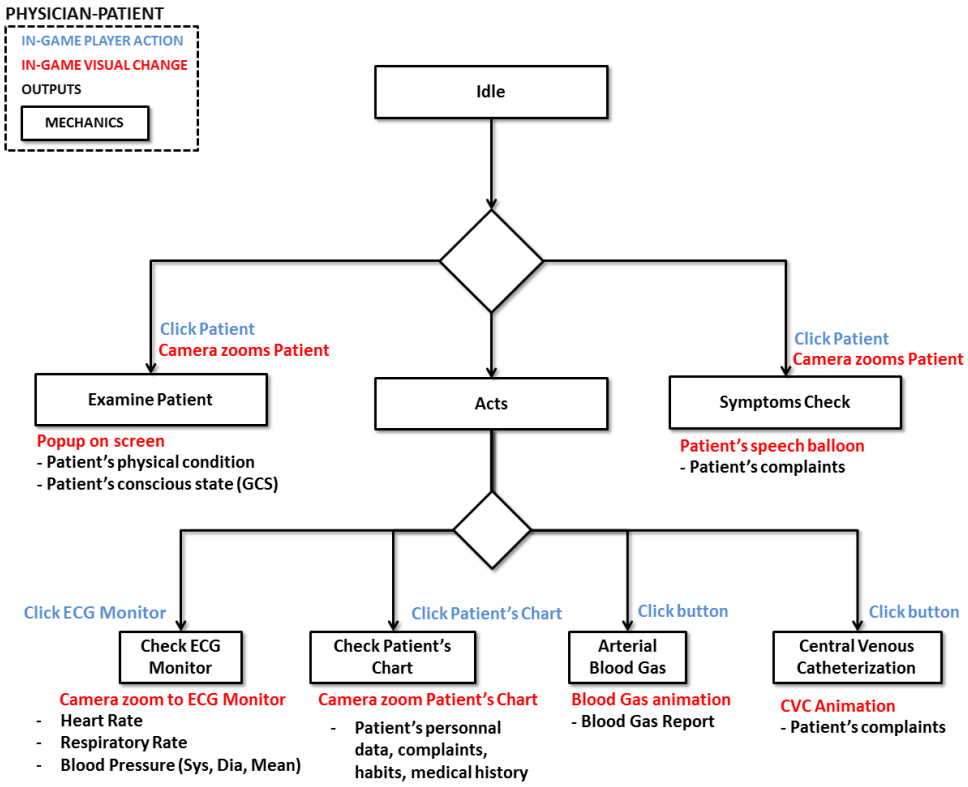


Figure 3.23: Physician-Patient Mechanics.

Physician-Patient Mechanics

There are three main mechanics available in the Physician-Patient relation, namely *Examine Patient*, *Acts* and *Symptoms Check* (Figure 3.23).

Examine Patient allows the player to perform a physical exam on the patient and also to evaluate his neurological state. To trigger this, the player must click on the patient and then on a button from the presented menu (Figure 3.24). The information is then presented in a popup message, with all the information needed for an accurate patient evaluation.

As in the *Identification of Possible Sepsis Case* game phase, *Acts* mechanics allow the player to make diagnostic or therapeutic actions, that can be invasive or non-invasive.

Regarding *Acts*, four mechanics were defined, namely the *Check ECG Monitor*, *Check Patient's Chart*, *Arterial Blood Gas*, and *Central Venous Catheterization*.

Check ECG Monitor allows for measurement of the patient's heart rate, respiratory rate, and blood pressure (systolic, diastolic and mean). To trigger this mechanics, the player must click on the ECG Monitor available in the examination room (Figure 3.25), then the game's camera zooms to it showing the referred data. Evaluating the systolic blood pressure allows the player to evaluate the patient's state

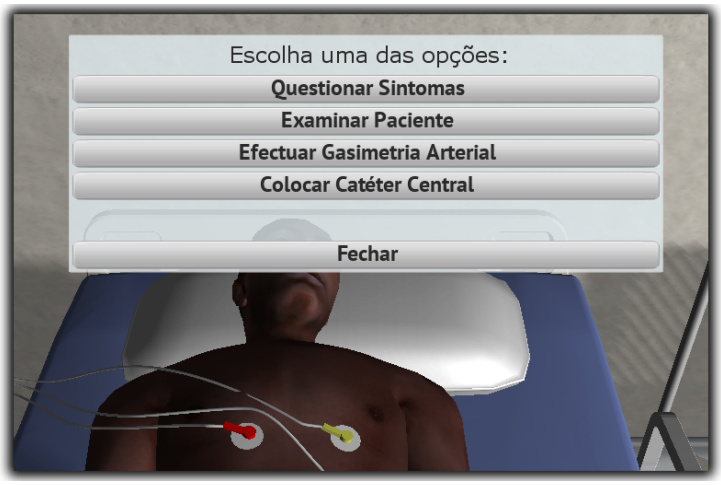


Figure 3.24: Patient's options menu.

of hypoperfusion, which is a condition for confirming the sepsis case (there are signals of hypoperfusion if the systolic blood pressure is less than 90mmHg).

Figure 3.25: ECG monitor of examination room.

Check Patient's Chart allows a player to check the patient's personal and medical information, such as, his name, age, his or her complaints registered during the triage, habits and medical history. With this information, the player can conclude if the patient has any exclusion criteria presented in Table C of Figure 3.1. It is mandatory that the patient does not have any exclusion criteria. Even if a patient has a confirmed sepsis infection and hypoperfusion, if he or she has any exclusion criteria the antibiotherapy cannot be done, so the Sepsis Fast Track must not be validated and the evaluation must end. Patient's chart is represented by a clipboard on the patient's bed (Figure 3.26), the game's camera will zoom to it on-click.

Arterial Blood Gas allows the player to make a blood gas exam to the patient. Arterial blood gas is a blood test that in sepsis evaluation is used to analyse the blood lactate. For use this mechanics the player must click on patient and then choose the Blood Gas option on the patient's menu (Figure 3.24). Then, an animation representing the blood gas exam will start, ending with a report created by the blood gas analyser (Figure 3.27). This blood gas report uses the same layout as the real one with all the information regarding to the patient's current condition (the player must then analyse its values, namely the lactate that must be greater than 4mmol/L, which represent patient's hypoperfusion).

Central Venous Catheterization allows the player to apply a central venous catheter to the patient.

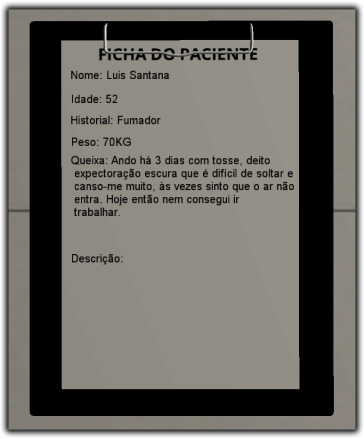


Figure 3.26: Patient's Chart.

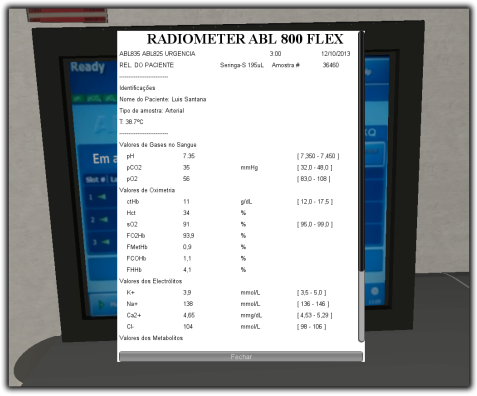


Figure 3.27: Blood Gas Report.

This must be done on Step 4 of Sepsis Fast Track protocol (Reference 3.3). To trigger this mechanics the player must click on patient and then choose the Blood Gas option on the patient's menu (Figure 3.24). This will show an animation representing the central venous catheter application, the fluidtherapy and antibioteraphy tubes, that were connected to a peripheral catheter, are reconnected to the central catheter. Afterwards, it is possible to evaluate the central venous pressure, using the respective mechanics.

As in the *Identification of Possible Sepsis Case* phase, *Symptoms Check* allows the player to ask the patient which are his or her complaints. The patient's complaints (output) are presented in a speech balloon using a *common patient speech*, so the player must interpret them (Figure 3.28).

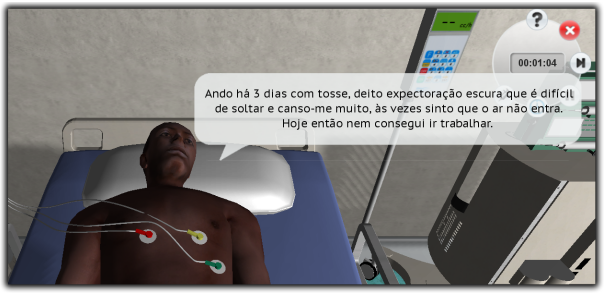


Figure 3.28: Patient's Speech Balloon.

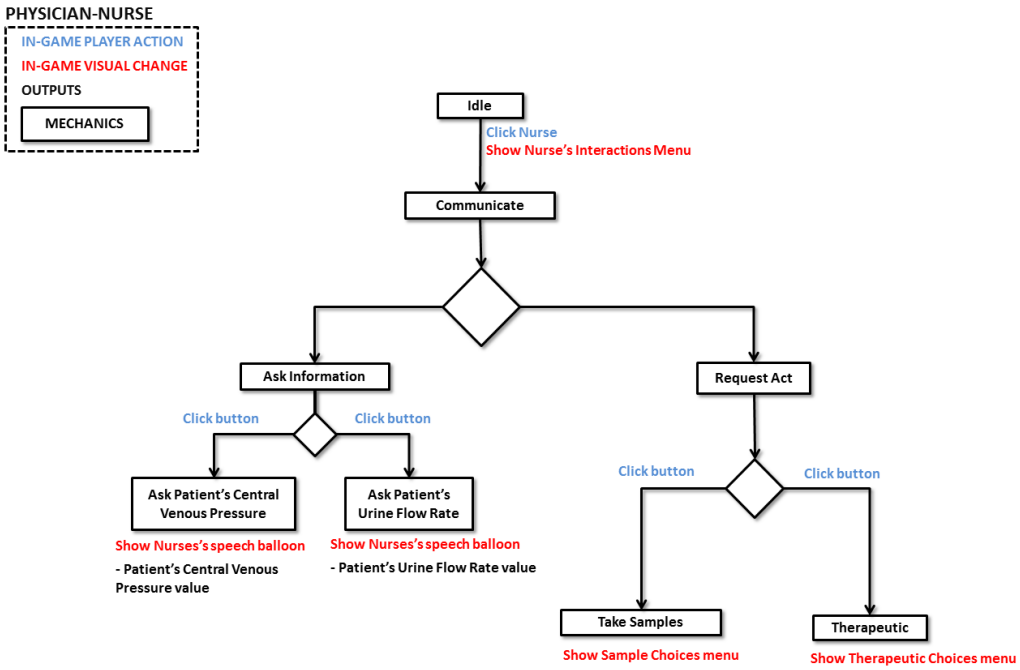


Figure 3.29: Physician-Nurse Mechanics.

Physician-Nurse Mechanics

There are two main mechanics available in the relation Physician-Nurse, *Ask Information* and *Request Act*, which are specializations of *Communicate* mechanics (Figure 3.29). Both mechanics become available upon a click on the nurse present in the examination room, then a menu with the options will be displayed.

Ask Information is a mechanics that allows the player to question the nurse about the patient's medical condition. There are defined two types of *Ask Information*, *Ask Patient's Central Venous Pressure* and *Ask Patient's Urine Flow Rate*.

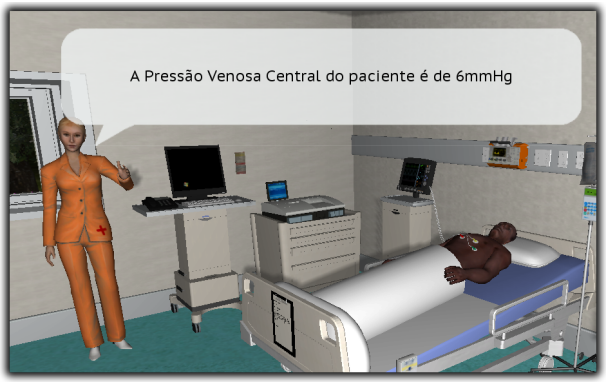


Figure 3.30: Nurse's Speech Balloon.

Ask Patient's Central Venous Pressure allows the player to know which is the patient's central venous

pressure (CVP) value represented in mmHg. This mechanics can only be used if a central venous catheter was applied to the patient. CVP is used in Step 4 of protocol (3.3) in order to know is the patient needs to make a fluid challenge or not (which must be made if the CVP is less than 8mmHg). After triggering *Ask Patient's Central Venous Pressure* mechanics in nurse's options menu, the information is given in a nurse's speech balloon (Figure 3.30).

Ask Patient's Urine Flow Rate allows the player to know the patient's urine flow rate, which is an indicator to the effectiveness of the fluid therapy. As the *Ask Patient's Central Venous Pressure* mechanics, the information is given in a nurse's speech balloon (Figure 3.30).

Request Act mechanics allows the player to request the nurse to execute medical acts. These acts can be for diagnose, *Take Samples* mechanics, and for therapy, *Therapeutic* mechanics. When one of these mechanics are triggered, the correspondent mechanics is executed as a Nurse-Patient relation, which are explained in next subsection.

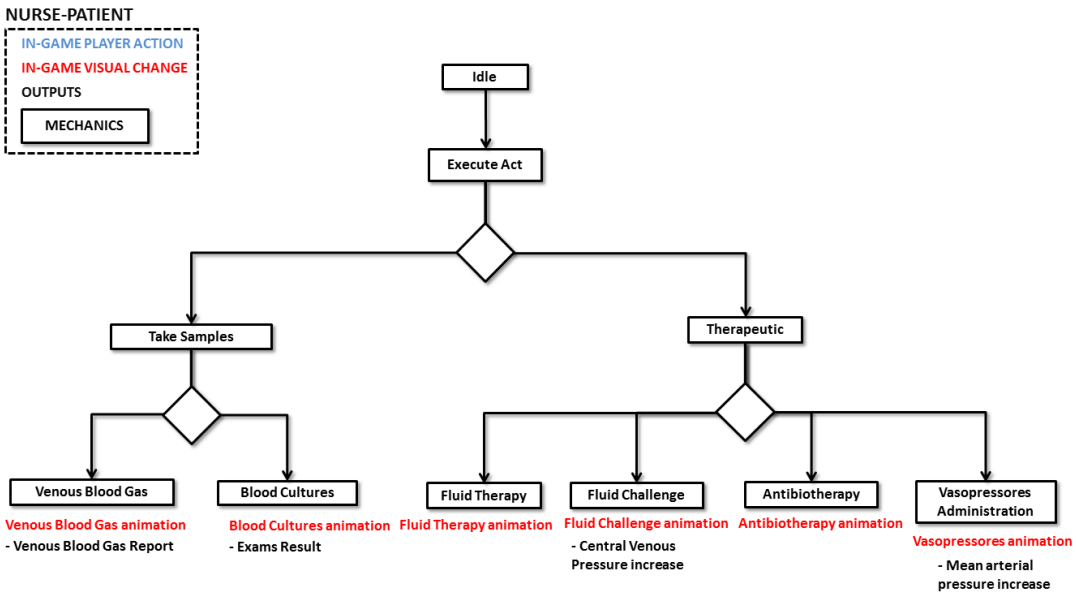


Figure 3.31: Nurse-Patient Mechanics.

Nurse-Patient Mechanics

Relation Nurse-Patient is composed by two main mechanics, *Take Samples* and *Therapeutic* that specialization of the mechanics *Execute Act* (Figure 3.31). These mechanics are responsible for the diagnose and therapy of the patient. Are triggered by the player in the relation Physician-Nurse, described in the previous subsection.

Take Samples is a mechanics for diagnose the patient's medical condition. It is composed by two mechanics, the *Venous Blood Gas* and the *Blood Cultures*.

Similarly to the mechanics *Arterial Blood Gas* present in the relation Physician-Patient, *Venous Blood Gas* allows the player to make a blood gas exam to the patient, in this case, using the venous access. This mechanics must be used in the Step 4 of Sepsis Fast Track protocol (3.3) to analyse the ScVO2 and to monitor the lactate value. When triggered, this mechanics shows an animation of the nurse making

the test with the patient, afterwards a blood gas report is shown as in *Arterial Blood Gas* mechanics.

Blood Cultures allows the player to take blood cultures from the patient for complementary exams. This is a requirement in the Step 3a of Sepsis Fast Track Protocol (3.3). When triggered, this mechanics is presented with an animation of the nurse taking the blood cultures and leaving them for analysis. Afterwards, the exams results are shown. These exams allow the player to take an appropriated therapeutic.

Therapeutic is a mechanics to execute the therapies needed by the patient. These therapies are dependent on the diagnose made using the previous referred mechanics, namely *Take Samples* in Nurse-Patient relation, *Check ECG Monitor* and *Check Patient's Chart* in Physician-Patient relation, and *Ask Information* in Physician-Nurse relation. *Therapeutic* is composed by four mechanics, namely *Fluid Therapy*, *Fluid Challenge*, *Antibiotherapy*, and *Vasopressores Administration*.

Fluid Therapy allows the player to administer fluids to a patient as a treatment. When this mechanism is triggered the player is presented with a menu where he must choose which type of fluids and their quantity must be administered (Figure 3.32). Afterwards, an animation is shown presenting the nurse administering the fluids to the patient. This mechanics must be used in Step 3a of Sepsis Fast Track protocol (3.3).

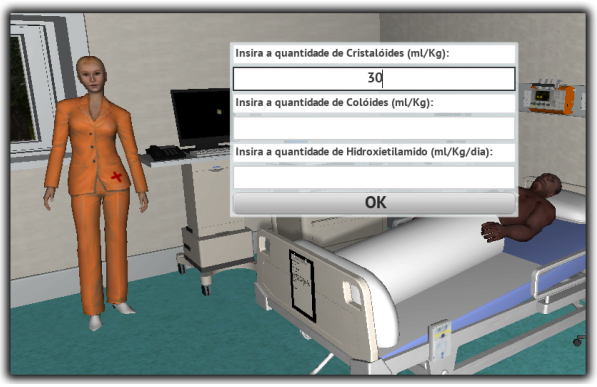


Figure 3.32: Fluids options menu.

Fluid Challenge is a mechanics that must be used depending on the value of central venous pressure (CVP) given by the mechanics *Ask Patient's Central Venous Pressure* in Physician-Nurse relation. As stated before, a fluid challenge must be required when the patient's CVP is less than 8mmHg. The fluid challenge consists in increasing the fluids that are being administered to the patient. When this mechanics is triggered, an animation of the execution of the fluid challenge performed by the nurse is presented to the player. This mechanics must be used in the Step 4 of Sepsis Fast Track protocol (3.3) and results in the increased CVP, allowing the continuation of the algorithm.

Once a suspected sepsis case is confirmed, *Antibiotherapy* is the most important mechanics of Sepsis Fast Track. It allows the administration of an antibiotic to the patient, which must be made within one hour, since the patient's admission in the Emergency Department. This is critical and if it is not done in time, the patient dies, resulting in a game-over for the player. This mechanics must be made in the Step 3a of Sepsis Fast Track protocol (3.3). This mechanics is represented with an animation of the nurse administering the antibiotic to the patient.

As *Fluid Challenge* mechanics, *Vasopressores Administration* must be used in the Step 4 of Sepsis Fast Track protocol (3.3). Its execution is dependent on the value of the patient's mean arterial blood pressure, which can be seen using the mechanics *Check ECG Monitor* presented in the Patient-Physician relation (*Vasopressores Administration* should only be used when the patient's mean arterial blood pressure is greater than 65mmHg).

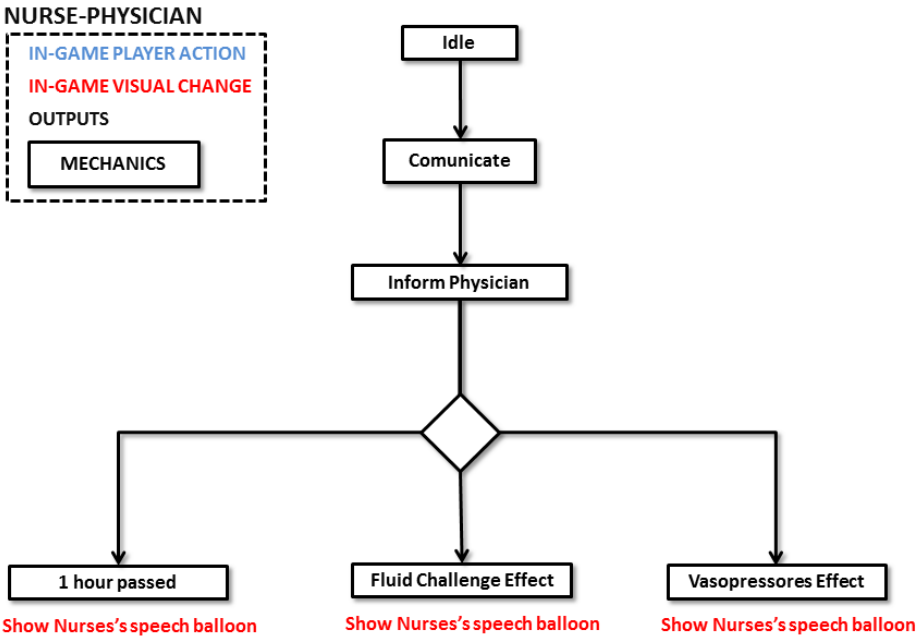


Figure 3.33: Nurse-Physician Mechanics.

Nurse-Physician Mechanics

It were also defined mechanics in the relation Nurse-Physician, which are triggered automatically without the player intervention. The main mechanics is *Inform Physician*, which is a specialization of *Communicate*, once all the interactions between the nurse and the physician are communications to inform the player about some event of the game. There are three mechanics, *1 hour passed*, *Fluid Challenge Effect*, and *Vasopressores Effect* (Figure 3.33). When triggered, the information of each mechanics is presented in a nurse's speech balloon (Figure 3.30).

1 hour passed is triggered when an hour (in game's time) passes, which are counted since the patient was admitted in the emergency department. As stated before, if a sepsis case is confirmed the antibiotherapy must be done within one hour, or else the patient dies. This mechanics is used to verify if the *Antibiotherapy* mechanics was already done, if not the nurse informs the player that the patient died and the game ends, if it was done the nurse recommends the player to re-evaluate the patient's condition in order to proceed with the algorithm.

Fluid Challenge Effect and *Vasopressores Effect* are triggered 30 minutes (in game's time) after the application of the mechanics *Fluid Challenge* and *Vasopressores Administration*, respectively. The nurse recommends the player to re-evaluate the patient's condition due to the last therapeutic act.

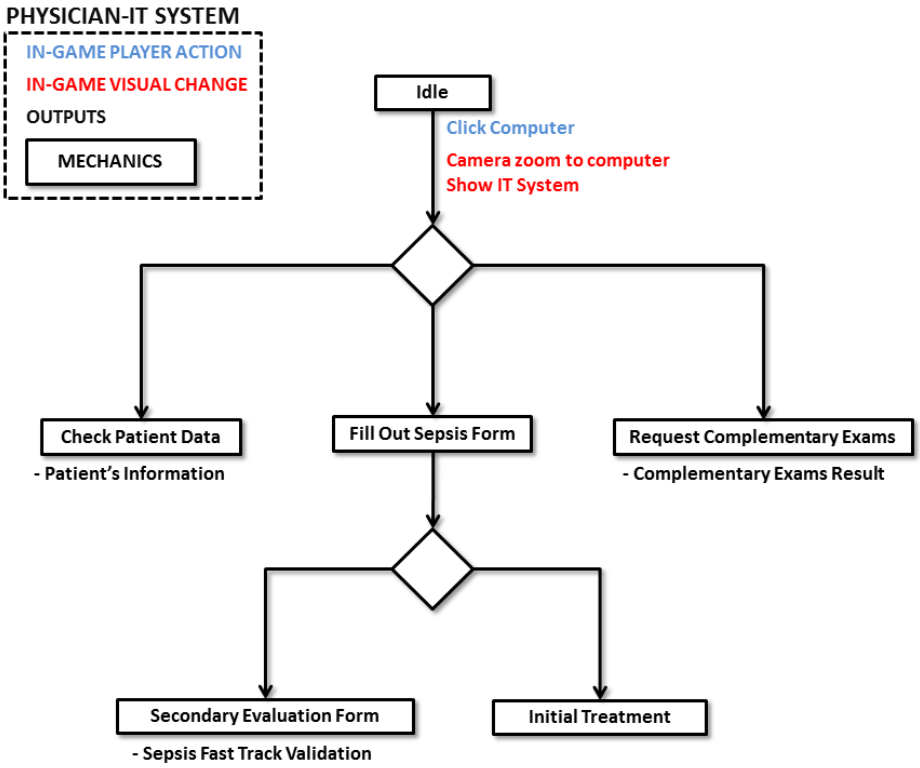


Figure 3.34: Physician-IT System Mechanics.

Physician-IT System Mechanics

As in *Identification of a Possible Sepsis Case* (3.4.2.1.1), there is an integration of IT System mechanics in *Sepsis Case Confirmation and Therapy* game's phase. The IT system is similar to the one used in the first phase, however it is now used by the physician and it includes other mechanics, namely *Check Patient Data*, *Fill Out Sepsis Form*, and *Request Complementary Exams* (Figure 3.34).

Check Patient Data allows the player to check patient's information, given at hospital's reception, such as name, age, gender, and identification number and also the information registered by the nurse during the triage (Figure 3.35).

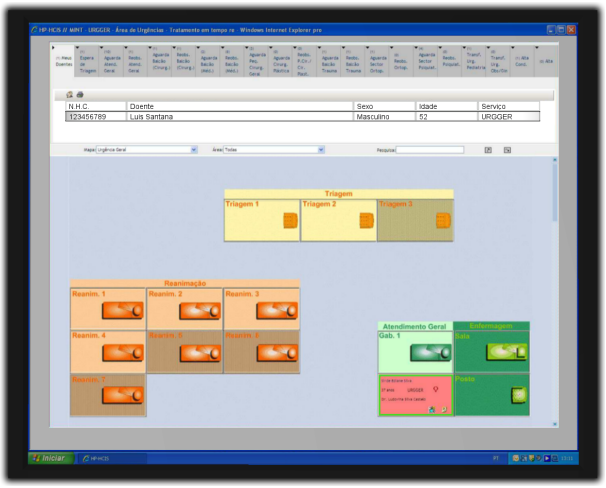


Figure 3.35: Patient Data in IT system.

Fill Out Sepsis Form is used to register all the information about the patient's Sepsis Fast Track (Figure 3.36). This registration is made through a form that contains data registered in the triage regarding the SIRS (body temperature, heart rate, and respiratory rate) and other fields which need to be completed represented by the mechanics *Secondary Evaluation Form* and *Initial Treatment*.

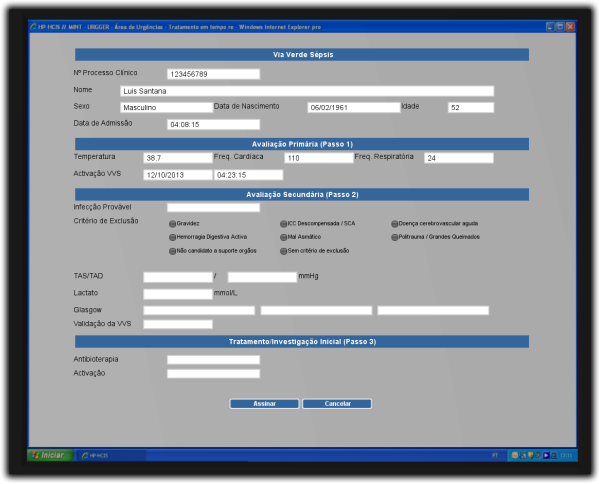


Figure 3.36: Sepsis Form in IT system.

Secondary Evaluation Form is the part of the form where are registered the information about the confirmation, or not, of the sepsis case suspicious. It includes the registration of the arterial blood pressure, checked using the mechanics *Check ECG Monitor*, the exclusion criteria, checked using the mechanics *Check Patient's Chart*, the glasgow comma scale, checked using the mechanics *Examine Patient*, and the lactate value, checked using the mechanics *Arterial Blood Gas*. In this part it is also registered the validation, or not, of the Sepsis Fast Track.

Initial Treatment regards to the information about the therapy made to the patient. This may be only used if a sepsis case is confirmed, and validated using the previous mechanics. In *Initial Treatment* is registered the time when the patient had the therapies, such as hemocultures, antibiotherapy and fluid therapy.

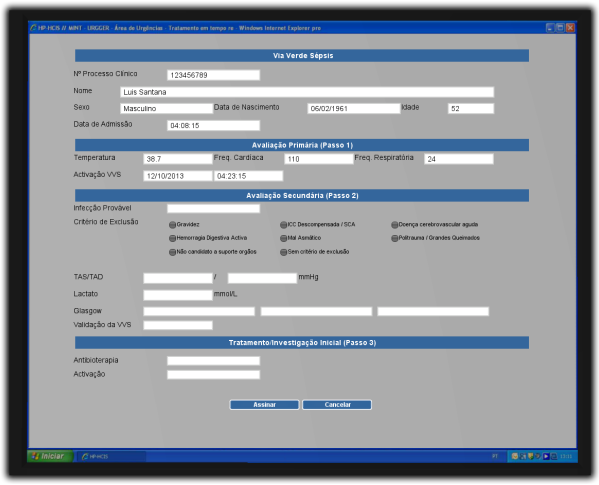


Figure 3.37: Complementary Exams Request in IT system.

Request Complementary Exams allows the player to request complementary exams that should be needed for a proper patient's evaluation (Figure 3.37). A set of exams for sepsis diagnose is provided by default, however the player must choose other ones specific for the current patient's condition, such as x-ray computed tomography, medical ultrasonographies, and radiographies. After the request, the exams results are presented to the player as a pop-up.

Summary

In Table 3.2 is presented a summary of every game mechanics used in *Sepsis Case Confirmation and Therapy* game's phase. Each game mechanics may have pre-conditions, this is, it is impossible to execute it before other mechanics has been performed. If a player tries to execute a particular mechanics which pre-condition was not done yet, it will affect his or her lives in the game (3.6.2). In this table is also presented which new mechanics are available after a particular have been performed.

ID	Mechanics	Pre-conditions	New Mechanics
GM01	Symptoms Check	None	GM03, GM05
GM02	Patient's Chart Check	None	GM03, GM06
GM03	ECG Monitor Check	GM01 or GM02	GM04
GM04	Arterial Blood Gas	GM03	GM06
GM05	Examine Patient	GM01	GM06
GM06	Sepsis Fast Track Validation	GM02, GM04	GM07
GM07	Hemocultures	GM06	GM08
GM08	Fluidtherapy	GM07	GM11
GM09	Antibiotherapy	GM08	GM11
GM10	Request Complementary Exams	GM06	GM11
GM11	Call Intensive Care Unit	GM09	GM12
GM12	Central Venous Catheterization	GM11	GM13
GM13	Central Venous Pressure Check	GM12	GM14
GM14	Mean Arterial Pressure Check	GM13	GM15
GM15	Uninary Flow Rate Check	None	None
GM16	Venous Blood Gas	GM14	GM17
GM17	Fluid Challenge	GM16	GM18
GM18	Vasopressores Administration	GM17	None
GM19	Blood Pressure Registration (IT)	GM03	None
GM20	Lactate Registration (IT)	GM04	None
GM21	Antibiotic Registration (IT)	GM09	None

Table 3.2: *Sepsis Case Confirmation and Therapy* Mechanics Overview

3.4.3 Debriefing

Debriefing is the last phase of the gameplay and is a very important part of this serious game, as it functions as a final link between the game experience and the achievement of learning outcomes Garris et al. (2002). Figure 3.38 explains this link between the game itself and the learning outcomes through the debriefing.

At the debriefing, the players have the opportunity to analyse the procedures that they performed during the game. If a player performed a procedure incorrectly, it is mentioned in the debriefing, along with what the right procedural choice should have been and an explanation for it. All the procedures

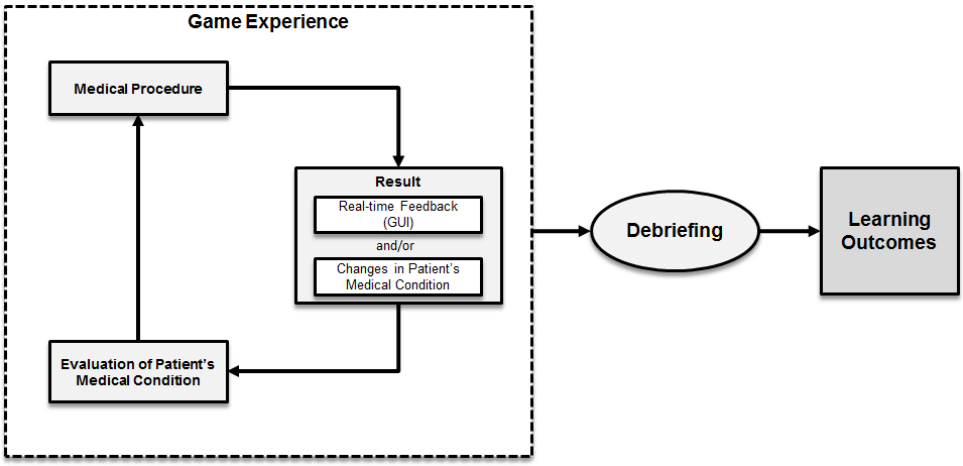


Figure 3.38: From Game Experience to Learning Outcomes - Debriefing.

performed during the game experience were reviewed in a sequential manner, starting with the first procedure.

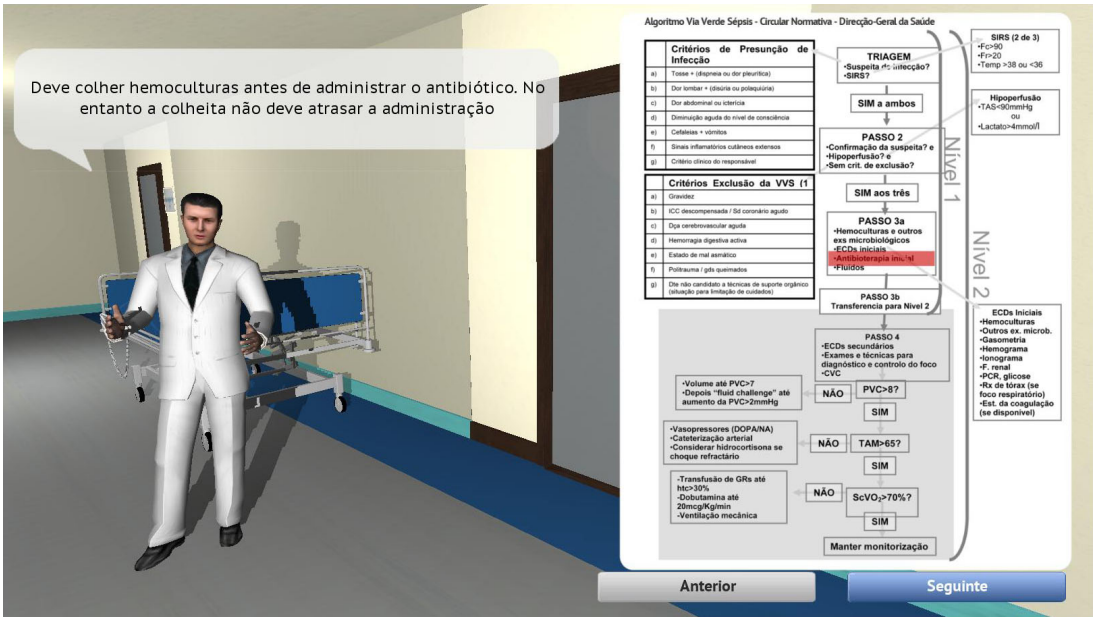


Figure 3.39: Debriefing.

Figure 3.39 presents how the debriefing is shown to the player. It consists of an avatar representing a physician that reviews each procedure that was performed, and a figure of the Sepsis Fast Track protocol. Each time a procedure was reviewed, a box was shown on the protocol diagram, overlaying the procedure. If the procedure was correctly performed the box is green, otherwise it is red. This allows the player to frame the performed procedure in the protocol, resulting in better comprehension of it.

3.5 Game Environment

The Sepsis Fast Track serious game environment was designed with the goal of increasing the player's immersion, thereby allowing the players to have in-game experiences that are as similar as possible to the real world. The underlying idea was to facilitate the player's interactions with the virtual environment and also to transfer the game world learning to real working practices. Therefore, at the beginning of this project's development, several observation sessions were conducted, along with photography reports in the hospital's Emergency Department facilities. Also, the medical equipment brand and model needed for sepsis diagnose and therapy was identified in order to match the equipment present in the game to the real one. This allowed us to design a 3D game environment the most similar to the reality, with all the elements that players, namely nurses and physicians, need for a proper patient's evaluation and therapy.

This serious game is divided into two main phases, the *Identification of a Possible Sepsis* and the *Sepsis Case Confirmation and Therapy* game's phases, as presented in the previous sections. Each game phase occurs in a particular part of the Emergency Department. Therefore, each phase has its own game environment. The following subsections describe the elements that compose each environment and how they were designed.

3.5.1 Identification of a Possible Sepsis Case Phase

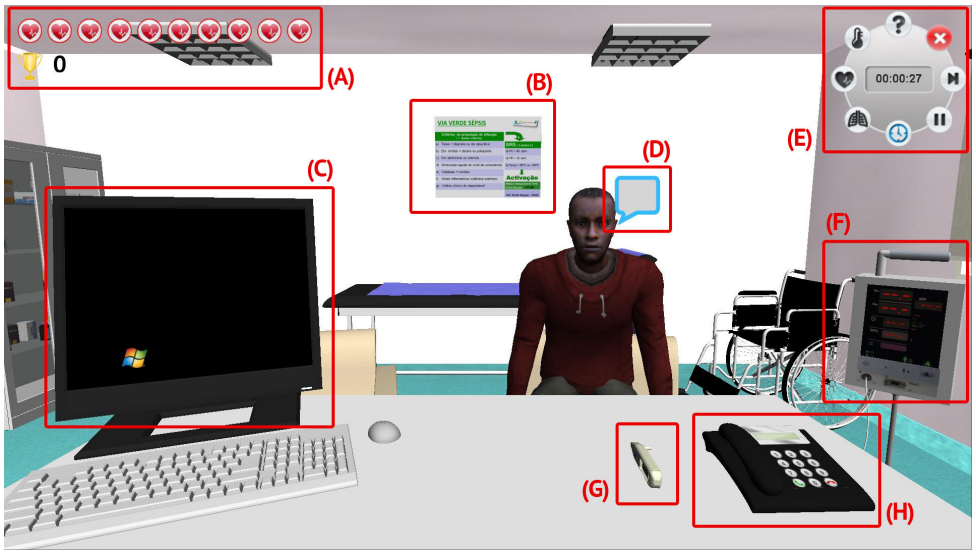


Figure 3.40: User Interface - Identification of a Possible Sepsis Case phase.

The *Identification of a Possible Sepsis Case* phase takes place during the patient's triage and is performed by a nurse in a triage room. Along with the Manchester triage protocol, the nurse must evaluate the patient's SIRS and complaints in order to identify a possible sepsis case. Therefore, the nurse needs to see the patient's complaints, measure patient's respiratory rate, heart rate and temperature.

Figure 3.40 presents the elements that the player have available for the patient's evaluation. The following list explain the goals of each element:

(A) Score and Lives HUD (Detailed in 3.6.2)

(B) Sepsis Poster Presents a poster containing the Sepsis Fast Track procedures. This poster is the same as the one presented in the real hospital Emergency Department.

(C) IT System Allows the player to access to the hospital IT system regarding to the patient's data and the Sepsis Fast Track form. The IT system user interface is presented in more detail in 3.5.3.

(E) Information/Options HUD (Detailed in 3.6.1)

(F) Vital Signs Monitor Allows the measurement of the patient's heart rate.

(G) Thermometer Allows the measurement of the patient's temperature.

(H) Phone Allows the contact of Sepsis Fast Track responsible physician, in order to refer the patient as a possible sepsis case. When the player makes the call, this game's phase ends.

3.5.2 Sepsis Case Confirmation and Therapy Phase

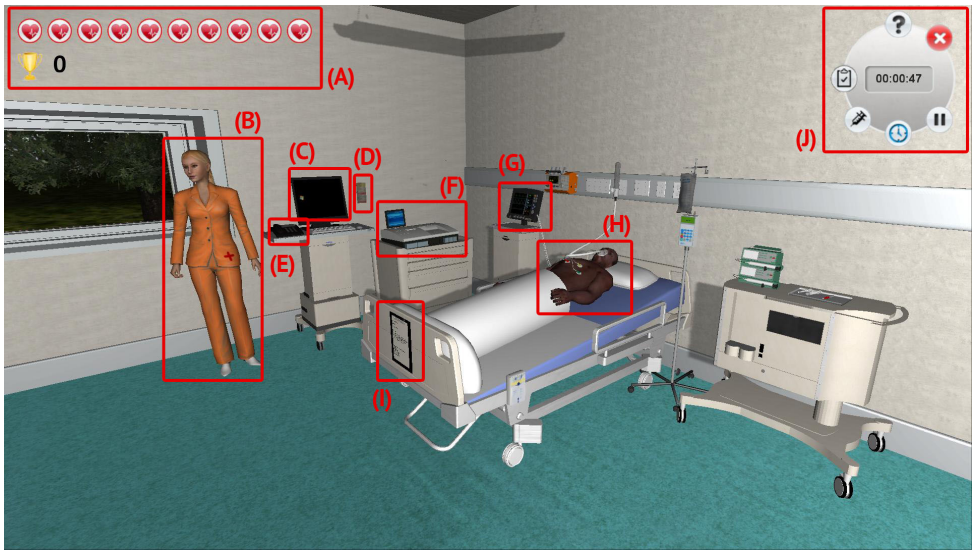


Figure 3.41: User Interface - Sepsis Case Confirmation and Therapy Phase.

The *Sepsis Case Confirmation and Therapy* phase takes place after the triage and is performed by a physician in an observation room. During this phase the physician must evaluate if the patient has a confirmed sepsis case and perform medical acts for patient's therapy if needed.

Sepsis Case Confirmation and Therapy game's phase occurs in an hospital observation room, which, like the triage room described in the previous subsection, was designed after visiting the a real one along with a photography report.

Figure 3.41 presents all the elements that the player has available during this phase to interact with. The following list explain the goals of each element:

(A) Score and Lives HUD (Detailed in 3.6.2)

(B) Nurse Allows the player to ask the nurse for patient medical condition and to request medical acts.

(C) IT System Allows the player to access to the hospital IT system regarding to the patient's data and the Sepsis Fast Track form. The IT system user interface is presented in more detail in 3.5.3.

(D) Phonebook Allows the player to check phone numbers, namely the phone number of the Intensive Care Unit.

(E) Phone Allows the player to contact the Intensive Care Unit, in order to refer the patient when a sepsis case is confirmed.

(F) Blood Gas Analyser Allows the player to view the arterial or venous blood gas report. This report is only available after the player performed a blood gas exam.

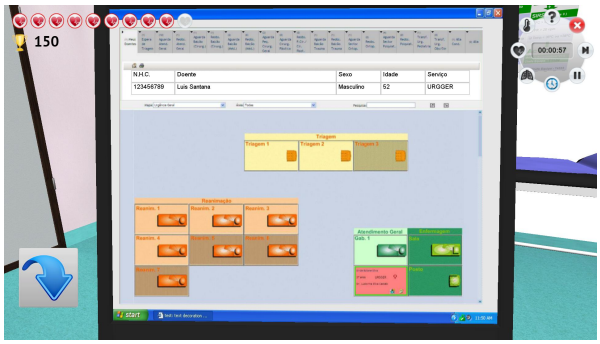
(G) Vital Signs Monitor Allows the player to check the patient's vital signs, namely blood pressure, oxygen saturation, and heart rate.

(H) Patient Prompts the possible interactions with the patient, namely, ask for symptoms, perform a physical exam, and execute a blood gas exam.

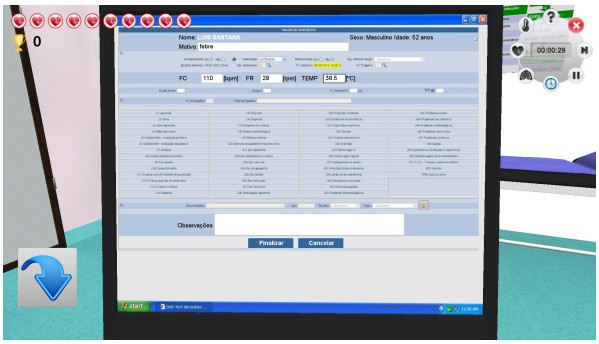
(I) Patient's chart Shows the medical and personal informal about the patient, such as, name, age, medical history, among others.

(J) Information/Options HUD (Detailed in 3.6.1)

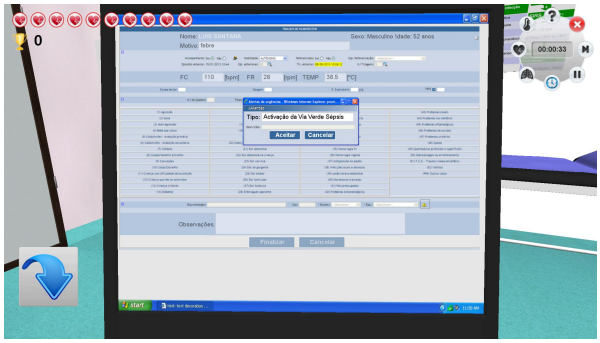
3.5.3 IT System



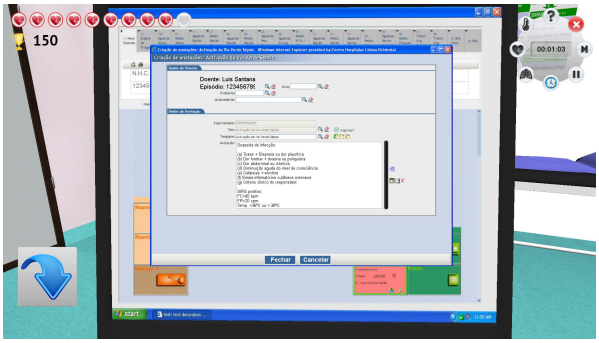
(a) Main Screen



(b) Patient Triage Data



(c) Sepsis Fast Track Alert



(d) Sepsis Fast Track Annotation

Figure 3.42: IT System of Identification of a Possible Sepsis Case game's phase.

(a) Main Screen

(b) Options Available

(c) Sepsis Fast Track Form

(d) Complementary Exams Request

Figure 3.43: IT System of Sepsis Case Confirmation and Therapy game's phase.

One important part of the game's environment is the IT system. Which is where nurses and physicians must register every patient's data, in this case, regarding the Sepsis Fast Track. Namely, registration of patient's SIRS and complaints, Sepsis Fast Track activation, fill of Sepsis Fast Track form, request of complementary exams, among others.

One goal of this serious game is to increase the usage of the current IT system regarding the registration of the Sepsis Fast Track cases, both by nurses and physicians. Although there are identified and confirmed sepsis cases, sometimes the healthcare professionals despise the IT system, not registering all the medicals acts that were carried on. In order to fight the lack of IT system utilization by healthcare professionals, every element of the real IT system regarding to the Sepsis Fast Track are present in the game.

The development of the in-game IT system is made using screen-shots of the real IT system, which facilitated the identification of several elements. Namely buttons, dynamic text boxes, editable text boxes, drop-down menus, among others. This development, based on the real IT system, allows the players to know exactly where are the needed options and to learn and train how to fulfil and register the needed data into the real Sepsis Fast Track form.

Figure 3.42 present four screens of the *Identification of a Possible Sepsis Case* game's phase, and figure 3.43 presents four screens of the *Sepsis Case Confirmation and Therapy* game's phase.

3.6 User Interface

During the requirements identification sessions with the healthcare professionals, it was told that most of nurses and physicians are *non-gamers*. Which was confirmed during the evaluation sessions, according to the sample characterization survey as presented in 4.2.2 and 4.3.2. Therefore, the graphical user interface was idealised to be the most simplistic as possible.

Another fact that contributed for the GUI design was that in Portuguese healthcare education and training serious games are still not used. This was also confirmed with the sample characterization survey, where most of the healthcare professionals did not used a single serious game for their training.

It was decided that the game should be the most user-friendly as possible, contrarily to some commercial game which require complex interactions and coordination.

The interaction with the elements of the game, in both *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation and Therapy* game's phases, is made in a point-and-click manner. Which elements that a player can interact with were described in previous section.

Also in both game's phases, is presented a *Health and Score* head-up display (HUD) and a *Information/Options* HUD. The *Health and Score*, presented in (A) of Figures 3.40 and 3.41, shows player's remaining lives and the player's score, how the player's health and score is calculated are explained in more detail in 3.6.2. The following subsection details in which consists the *Information/Options* HUD.

3.6.1 Information/Options Head-up Display (HUD)

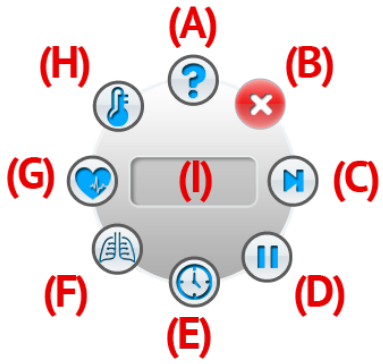


Figure 3.44: HUD - Identification of a Possible Sepsis Case Phase.

Figure 3.44 presents the HUD available during the *Identification of a Possible Sepsis Case* game's phase. It is composed by eight buttons, the following list refers to each one and its options:

(A) Help Opens the Help dialogue and further help screens

(B) Exit Player is prompted with a pop-up, allowing him or her to quit the game.

(C) Advance to Physician's Diagnose Allows the player to advance to the *Sepsis Case Confirmation and Therapy* game's phase, skipping the *Identification of a Possible Sepsis Case* phase. This options is only available if the player chose both nurse and physician roles in the main menu.

(D) Pause Allows the player to pause the game, pausing also the time counting which is an important aspect of the sepsis diagnosis.

(E) Clock This option shows the clock, a time counter, in (I) Information Panel.

(F) Respiratory Rate This option shows the patient's respiratory rate in (I) Information Panel. This information is visible only after the player make the respiratory rate measurement.

(G) Heart Rate This option shows the patient's heart rate in (I) Information Panel. This information is visible only after the player make the heart rate measurement.

(H) Temperature This option shows the patient's temperature in (I) Information Panel. This information is visible only after the player make the temperature measurement.

(I) Information Panel Displays information to the player, such as, clock, patient's temperature, respiratory rate, and heart rate.

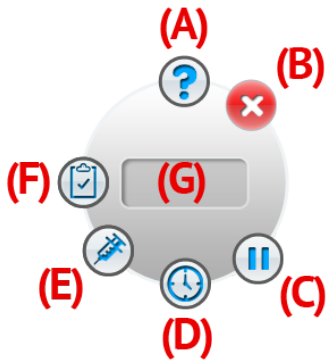


Figure 3.45: HUD - Sepsis Case Confirmation and Therapy Phase.

Figure 3.45 presents the HUD available during the *Sepsis Case Confirmation and Therapy* game's phase. It is composed by six buttons, the following list refers to each one and its options:

(A) Help Opens the Help dialogue and further help screens

(B) Exit Player is prompted with a pop-up, allowing him or her to quit the game.

(C) Pause Allows the player to pause the game, pausing also the time counting which is an important aspect of the sepsis diagnosis.

(D) Clock This option shows the clock, a time counter, in (I) Information Panel.

(E) Blood Gas Report Shows the patient's arterial or venous blood gas report. This report is only available after the player performed a blood gas exam.

(F) Previous Acts This option shows the previous acts performed by the player.

(G) Information Panel Displays a clock to the player.

3.6.2 Score, Lives and Real-time Feedback

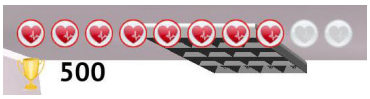


Figure 3.46: Score and Lives.

In order to make this serious game more challenging, the designers decided to measure the player's performance and present it in a *Score and Lives* HUD as shown in Figure 3.46.

The number of available *Lives* was decreased whenever a player made an error, either *major* or *minor*, depending on which procedure the mistake occurred in. Tables 3.3 and 3.4 present, for each game's phase, the error type of each procedure. Therefore, the error type is reflected in the number of lives, this is, if a major error is committed one full life is removed, on the other hand if the error is minor only half of a life is withdrawn.

ID	Action	Score	Error Type
GM01	Symptoms Check	100	Major
GM02	Temperature Check	100	Major
GM03	Respiratory Rate Check	100	Major
GM04	Heart Rate Check	100	Major
GM05	Symptoms Register	25	Minor
GM06	Temperature Resgister (IT)	25	Minor
GM07	Respiratory Rate Resgister (IT)	25	Minor
GM08	Heart Rate Resgister (IT)	25	Minor
GM09	Sepsis Alert Activation (IT)	100	Major
GM10	Send Patient to Waiting Room	100	Major
GM11	Call Physcian responsible for Sepsis Fast Track	100	Major

Table 3.3: *Identification of a Possible Sepsis Case Phase* Score and Errors

The *Score* is incremented whenever a player executes a procedure correctly. According to the importance of the procedure, different scores values are added to the total score. This score feature increases the challenging in the game, and can be used for a global highscore table increasing.

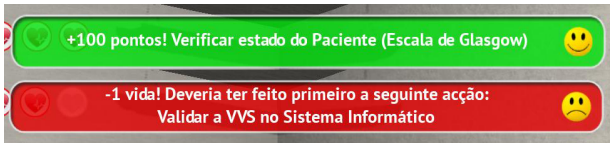


Figure 3.47: Real-time Feedback.

Real-time Feedback is an important game feature and is also presented to the player as shown in Figure 3.47. This feedback allows the player to know if the procedure that he or she executed was done right or wrong. If a procedure is correctly done, the player is presented with that information and the corresponding points that he or she won. If a procedure is incorrectly done, in addition to that information, the player is advised on the correct procedure and is informed about the lives that he or she lost.

ID	Action	Score	Error Type
GM01	Symptoms Check	100	Major
GM02	Patient's Chart Check	100	Major
GM03	ECG Monitor Check	100	Major
GM04	Arterial Blood Gas	100	Major
GM05	Examine Patient	100	Major
GM06	Sepsis Fast Track Validation	100	Major
GM07	Hemocultures	100	Major
GM08	Fluidtherapy	100	Major
GM09	Antibiotherapy	100	Major
GM10	Request Complementary Exams	100	Major
GM11	Call Intensive Care Unit	100	Major
GM12	Central Venous Catheterization	100	Major
GM13	Central Venous Pressure Check	100	Major
GM14	Mean Arterial Pressure Check	100	Major
GM15	Uninary Flow Rate Check	100	Major
GM16	Venous Blood Gas	100	Major
GM17	Fluid Challenge	100	Major
GM18	Vasopressores Administration	100	Major
GM19	Blood Pressure Registration (IT)	25	Minor
GM20	Lactate Registration (IT)	25	Minor
GM21	Antibiotic Registration (IT)	25	Minor

Table 3.4: *Sepsis Case Confirmation and Therapy* Score and Errors

3.7 Implementation

Sepsis Fast Track Serious Game was developed using Unity3D[1] and a C# script based architecture. In the following subsections we describe the serious game architecture, the modifiability and extensibility properties, the data logging system, and how multiple clinical cases was implemented.

3.7.1 Architecture

Figure 3.48 presents a layer view diagram where the main layers, as the communication among the several modules and submodules, of the architecture of *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation* are represented, which are the two serious game's phases. Each layer is composed of several modules that are presented below, from top to bottom.

The first layer is the *Presentation Layer*, which is intended to introduce the player to the serious game world, the head-up displays (HUD), and to record the player's actions within the game world.

The *HUD* main module is part of the game's user interface and the main goal of this module is to present relevant information to the player. It is composed by three submodules, namely the *Main HUD*, the *Score and Lives*, and the *Real-time Feedback*. The *Main HUD* objective is to display relevant information about the patient's condition and giving the player's option, such as pause, exit, and so on, it is described in 3.6.1. *Score and Lives* module is responsible for displaying the players current score and lives available, it is described in more detail in 3.6.2. The *Real-time Feedback* responsibility is to present a pop-up to the player with a positive or negative feedback regarding to a procedure that he or

[1] http://www.unity3d.com

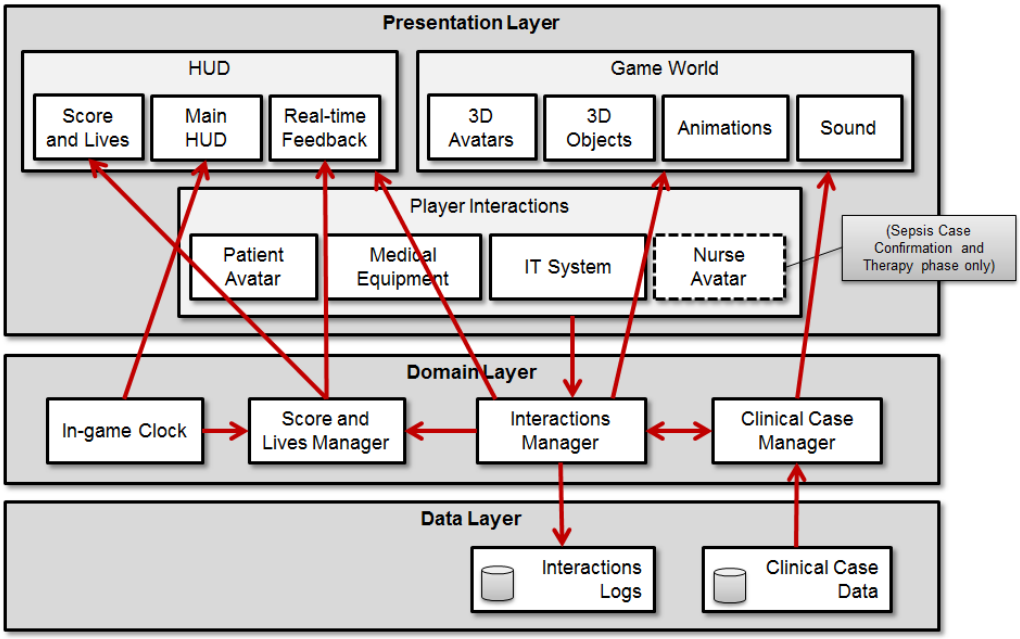


Figure 3.48: Layer View with communication among modules and submodules.

she made, it is describe in more detail in 3.6.2.

The *Game World* main module is responsible for representing the virtual emergency department world to the player. This virtual world is composed by two main scenes corresponding to each game's phase. Therefore, each game scene is composed by its own *3D Avatars*, *3D Objects*, *Animations*, and *Sounds*. The *Game World* module, its contents, and how its environment was designed is fully describe in 3.6.

Player Interactions is the main module responsible for the interactions between the player and the game world. In both game's phases the player can interact and execute medical and non-medical procedures, which are managed by the *Patient Avatar*, *Medical Equipment*, and *IT System* interactions modules. The interactions with a nurse, managed by the *Nurse Avatar* module, only occur in the *Sepsis Sepsis Case Confirmation* game's phase. These interactions are handled by the *Interactions Interpretation and Feedback* module presented in the following layer.

The second layer is the *Domain Layer*, which is responsible for managing the in-game actions relating them to the real-world rules. It is composed by three main modules, namely the *In-game Clock*, the *Score and Lives Manager*, the *Interactions Manager*, and the *Clinical Case Manager*.

The *In-game Clock* is a module that deals with the in-game time and it is responsible for managing the time, alerting the player for important timed events that may require his or her attention regarding the patient's evaluation.

Score and Lives Manager is the module responsible for updating the player's score and lives according to the player's interactions. It receives the information from the *Interactions Manager* module, processes the information and updates the module *Score and Lives* of the *HUD* in the upper layer, *Presentation Layer*.

The *Interactions Manager* handles the player's interactions and gives the player the output of the

performed procedures. The output of the procedures done by the player are dependent on the clinical case, so this module operates together with *Clinical Case Manager*. It also notifies the *Score and Lives Manager* in order to update its information. Every time a player interacts with the game, the *Interactions Manager* logs it in the *Interactions Logs*.

The *Clinical Case Manager* responsibility is to handle all of the data from each clinical case (from *Clinical Case Data*), and to generate the *Game World* according it. Each clinical case includes several data about the patient and its condition, which is described into more detail in 3.7.4.

The bottom layer is the *Data Layer* which includes all the data of the serious game. It is composed by the *Interactions Logs* and the *Clinical Case Data*.

Interactions Logs records all the interactions that a player has with this serious game. This was implemented for further evaluation, essential to evaluate the players performance, but also to evaluate the game itself. It is explained in more detail in 3.7.3.

Clinical Case Data includes the data for every clinical case, mainly relating to patients' personal information and medical conditions. In 3.7.4 is explained which data each case contains. XML notation was used to define each clinical case, increasing the serious game modifiability and extensibility as referred in 3.7.2.

The *Game Mechanics* presented in 3.4.2.1 are managed by *Player Interactions* and *Interactions Interpretation and Feedback* modules.

3.7.2 Modifiability and Extensibility

Sepsis Fast Track Serious Game modifiability and extensibility were important features that were taken into consideration.

Each clinical case was defined using XML notation in order to add, remove, and edit them easily. In order to achieve the extensibility and modifiability of this game, each element of mechanics, its data, and its pre-conditions were represented in an XML file.

Medicine is a field that is constantly evolving, therefore Sepsis Fast Track algorithm is also changing over the time. The last Surviving Sepsis Campaign Guidelines (Dellinger et al., 2013) published is from 2012 and it is the third edition, the second one was published in 2008 and the first edition was published in 2004. Therefore, it was important to think about this evolution while developing this serious game.

In order to achieve the extensibility and modifiability of this game, each mechanics (3.4.2.1), its data and its pre-conditions were represented in an XML file (Figure 3.49). Using XML as a notation for the mechanics allows the easy modifiability of the game, namely, it is easy to add, remove, and modify a mechanics, and to change their sequence. Being it designed in XML, easy to read, it does not require a programmer to make the changes, allowing healthcare professionals to make the changes themselves. Although, not every one is able to understand XML, therefore in order to facilitate the modifiability of the algorithm present in the game, a web-interface for modify the XML file is thought for future work.

Also, considering the game's extensibility, each clinical case (3.7.4) is defined using XML notation. This allows add new clinical cases, and edit or remove the existing ones in an easy way.

```
<mechanics_all>
  <nurse>
    <is-sepsis>
      <mechanics>
        <id>SymptomsCheck</id>
        <description>Questionar Sintomas ao Paciente</description>
        <preconds>
        </preconds>
        <score>100</score>
        <is-major>true</is-major>
      </mechanics>
      [...]
      <mechanics>
        <id>AlertActivated</id>
        <description>Activar o Alerta no Sistema Informático</description>
        <preconds>
          <precond>SymptomsCheck</precond>
          <precond>HeartRateCheck</precond>
          <precond>RespiratoryRateCheck</precond>
          <precond>TemperatureCheck</precond>
        </preconds>
        <score>100</score>
        <is-major>true</is-major>
      </mechanics>
      [...]
```

Figure 3.49: XML notation used for Game Mechanics description.

```
<menu>
  <text>
    <name>Nome:</name>
    <id>Número Mecanográfico:</id>
  </text>
  <buttons>
    <start>Começar</start>
    <quit>Sair</quit>
  </buttons>
</menu>
```

Figure 3.50: XML notation used for game translation (Main Menu).

Since Sepsis Fast Track is based on a worldwide algorithm, globalisation through translation was discussed ever since the beginning of the game development. Therefore, each string present in the game is defined in an XML file (Figure 3.50). The translation of the game can be made without any major difficulties, and can also be done by a non-programmer, if necessary.

3.7.3 Data Logging

```
Player Name: Test Player, Id: 12345
Nível de Confiança:
goal1: little
goal2: normal
goal3: very
goal4: normal
106.0723,SymptomsCheck,True
160.1783,HeartRateCheck,True
172.4626,TemperatureCheck,True
188.7932,RespiratoryRateCheck,True
287.9937,CallDoctor,True
310.066,SymptomsCheck,True
380.478,TemperatureRegister,True
418.2461,CallDoctor,True
```

Figure 3.51: Example of Data Log (Identification of a Possible Sepsis Case phase).

One feature of this serious game is the data logging of the player's actions during gameplay. In Figure 3.51 is presented an example of the player's data log file for the *Identification of a Possible Sepsis Case* game's phase. A log consists of the personal data of the player, namely his or her name and ID, the player's confidence level about the serious game goals asked about during the Briefing (3.4.1), and the procedures carried out during the game experience. Each time a player executes a procedure, the game logs it and includes information about it, including when it was performed (timestamp), the procedure identification name, and if it was correctly done (boolean). The logged data was used for the serious game evaluation.

It was used CSV format, since it is easy to read and can be easily imported to, for example, Microsoft Excel for the data analysis. The logged data was used for the serious game evaluation as explained in 4.

3.7.4 Clinical Cases

Hospital emergency departments are a complex system where rules the uncertainty. This is, it is impossible to predict what kind of patient will appear next, what are his or her complaints, if the patient is a male or female, his or her age, and so on.

Therefore, all emergency department healthcare professionals, namely nurses and physicians, must be prepared to deal with every kind of patients with an infinity of possible situations.

Sepsis Fast Track Serious Game tries to deal with the variety of patient's conditions providing twelve distinct clinical cases. All the clinical cases were created by healthcare professionals in order to comprise the most situations that can happen regarding to sepsis.

It was defined three main types of clinical cases, based on the protocol 3.3, that are resumed in Table 3.5.

Type	**Possible Case?**	**Confirmed?**
A	×	×
B	✓	×
C	✓	✓

Table 3.5: Clinical Cases Types

Type A is a clinical case where at triage the player must not active the Sepsis Fast Track, because the patient does not have symptoms or does not have at least two SIRS.

Another defined clinical case, *Type B* also includes a positive identification of a sepsis case in the triage, but it is not confirmed by a physician in the *Sepsis Case Confirmation and Therapy* phase.

The last clinical case that was defined, *Type C*, was the one where the patient has a positive identification of a sepsis case in the triage, namely because of his or her complaints and at least two SIRS, and also has a positive confirmation of the sepsis. In this clinical case, a patient may need, or not, vasopressores or a fluid challenge, represented in step 4 of the Sepsis Fast Track algorithm. Table 3.6 presents the possible sub-types of clinical case *Type C*.

Every clinical case can be played by a nurse, though only nine can be played by a physician. Since,

Type	Fluid Challenge?	Vasopressors?
C1	×	×
C2	✓	×
C3	×	✓
C4	✓	✓

Table 3.6: Clinical Cases Type C variations.

four of the defined clinical cases cannot be identified as a possible sepsis case, meaning that they do not reach the *Sepsis Case Confirmation and Therapy* phase.

Each clinical case is composed by clinical case properties, patient's personal data, and medical data for both *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation and Therapy* phases. These properties include the following:

Clinical Case Properties: Clinical Process ID, Sepsis Positive Identification, Sepsis Positive Confirmation.

Patient's Personal Data: Name, Age, Weight, Birth Date, Gender.

Patient's Medical Data for *Identification of a Possible Sepsis Case* phase: Complaints, Symptoms, Temperature, Heart Rate, Respiratory Rate.

Patient's Medical Data for *Sepsis Case Confirmation and Therapy* phase: Clinical History, Exclusions, Glasgow Comma Scale, Systolic Blood Pressure, Diastolic Blood Pressure, Urine Flow Rate, Central Venous Pressure, Physical Exam Result, Lactate, Complementary Exams Needed, Complementary Exams Results, Arterial Blood Gas Report, Venous Blood Gas Report.

The patient's medical data for *Sepsis Case Confirmation and Therapy* phase may vary over time, according to the player's actions. Namely Glasgow Comma Scale, Systolic and Diastolic Blood Pressure, Urine Flow Rate, Central Venous Pressure, Physical Exam Result, Lactate, Arterial and Venous Blood Gas Report. Therefore, multiple values for the mentioned items were defined to by according to the current patient's condition.

All the clinical cases are presented in the Appendix B. New clinical cases can be easily added as described in the section 3.7.2.

3.8 Summary

This chapter described the Sepsis Fast Track serious game, a serious game for teaching and training professionals about the Sepsis Fast Track protocol.

We have started by describing the *Learners and Context*. This serious game is targeted at healthcare professionals working in hospitals' emergency departments, namely nurses and physicians. It was developed to be used as an on-the-job training tool with the aim of teaching the Sepsis Fast Track protocol.

Secondly, we described the Sepsis Fast Track protocol issued by the Portuguese Directorate-General of Health. This protocol is represented by an algorithm that consists of a sequence of steps that need to be followed in order to diagnose a sepsis case, confirm it, and treat the patient. The Sepsis Fast Track

algorithm is divided into two main phases, *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation and Therapy*.

The game play was described as made up of the following main phases, namely *Main Menu*, *Clinical Cases Choice*, *Briefing*, *Game Experience* composed by *Identification of a Possible Sepsis Case* and *Sepsis Case Confirmation and Therapy*, and *Debriefing*. *Game Experience* is the phase in which players play the serious game, which, depending on their role, can be *Identification of a Possible Sepsis Case* for nurses or *Sepsis Case Confirmation and Therapy* for physicians. *Debriefing* is the following game play phase during which players will review their procedures during the *Game Experience*, resulting in learning outcomes.

In terms of the development of the *Game Experience*, several *Game Mechanics* were designed and have been described in this chapter. These game mechanics are based on the real interactions of healthcare professionals in relation to the Sepsis Fast Track protocol. Each set of game mechanics corresponds to an in-game medical procedure that will affect the patient's condition and lead to further evaluation and/or therapy.

The next topic described in this chapter was *Game Environment* which was designed with the goal of increasing the player's immersion, allowing the players to have in-game experiences which are most similar to those in the real world. We have described several elements that compose both game's phases and with which players can interact, namely avatars, medical equipment and the IT system.

Along with the *Game Environment* we presented the *User Interface*. The user interface is composed by an Information/Options Head-up Display (HUD) and a Score, Lives and Real-time Feedback HUD.

Finally, we described the *Implementation* of this serious game. We presented this by using a layer view composed of three layers, namely the Presentation Layer which is responsible for presenting the serious game world to the player, the head-up displays (HUD) and to gather the player's interaction with the game world, the Player Interactions which is a module responsible for the interactions between the player and the game world, and the Data Layer which includes all the data of the serious game. Each layer is composed of several modules that were also described.

In the next chapter we shall describe the evaluation of the serious game, its results and present some further discussion.

Chapter 4

Evaluation

4.1 Introduction

The main goal of the Sepsis Fast Track serious game evaluation was to assess its impact on the real world work practices of Emergency Department healthcare professionals, namely nurses and physicians.

As described previously, the Sepsis Fast Track serious game is divided into two main phases, namely the *Identification of a Possible Sepsis Case* played by nurses and the *Sepsis Case Confirmation and Therapy* played by physicians, each one with its own specific learning and training outcomes. Therefore, the evaluation study was also divided into two main phases. The following sections describe the evaluation phases that were done.

4.2 Identification of a Possible Sepsis Case Evaluation

The *Identification of a Possible Sepsis Case* evaluation phase of Sepsis Fast Track serious game consisted of understanding how the game impacted the actual work practices of Emergency Department nurses after playing it in an evaluation session. The following subsections describe the methodology, the results, and a discussion about them.

4.2.1 Evaluation Methodology

This study was done over the course of three days on-site at the hospital facilities. It included all 43 Emergency Department nurses in the hospital responsible for the triage of patients. The evaluation study of this serious game phase was integrated in a training session (outside the scope of Sepsis Fast Track) that included all the nurses of the hospital emergency department. Therefore, it would be possible to measure the impacts of the game, not only individually but holistically throughout the emergency department.

Figure 4.1 presents a research flowchart with the methodology that was used to accomplish this study.

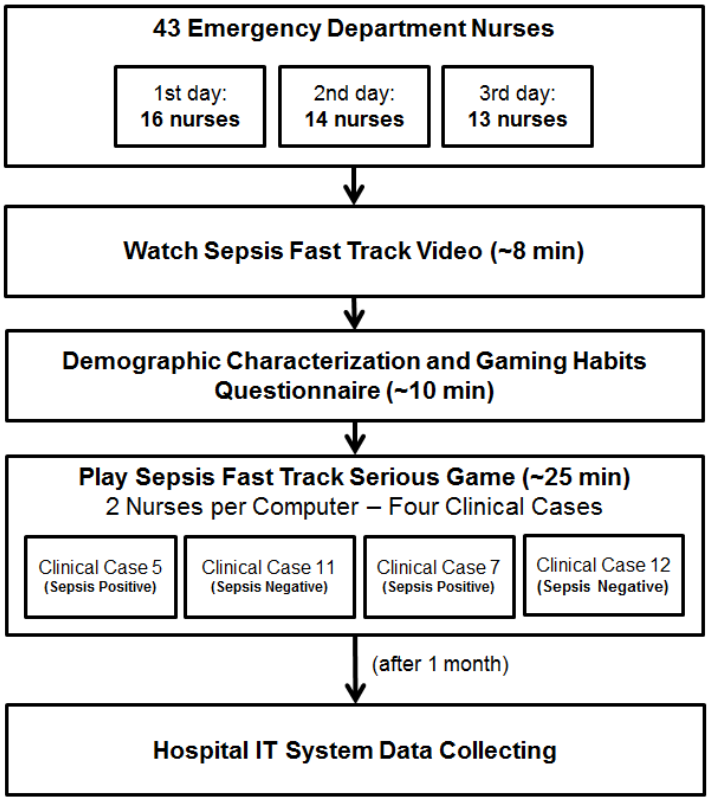


Figure 4.1: Evaluation Research Flowchart - Identification of a Possible Sepsis Case Phase.

The study started by showing a Sepsis Fast Track informational video, approximately 8 minutes long, that was done by the physicians and nurses that also participated in this serious game development. Afterwards the nurses answered to a questionnaire with two goals, a demographic characterization and their gaming habits.

Then the nurses were divided into groups of two, for each group was assigned a computer for playing four clinical cases. They started playing clinical cases 5 and 11, and then played 7 and 12. Clinical cases 5 and 7 are positive sepsis cases, and 11 and 12 are negative cases. This variety allowed the players to deal with different situations, and know the procedures to each one.

All the played clinical cases were logged, in order to understand the procedures executed by the nurses, and in particular the errors that they committed along the gameplay.

This evaluation sessions occurred in the first days of February, in March we returned to the hospital to collect data regarding to the Sepsis Fast Track. This data was logged by the hospital IT system, and includes informations such as the number of patient's admissions and the number of Sepsis Fast Track activations. Allowing us to understand if there was any improvement regarding to the number of possible sepsis cases identification.

4.2.2 Demographic Characterization and Gaming Habits

As stated before, this study was conducted with 43 nurses of the hospital emergency department, and each one answered to a questionnaire. The goal of the questionnaire was to gather demographic in-

formation, the nurses gaming habits, and if they already had previous Sepsis Fast Track training. The questionnaire that was used can be seen in Appendix A.

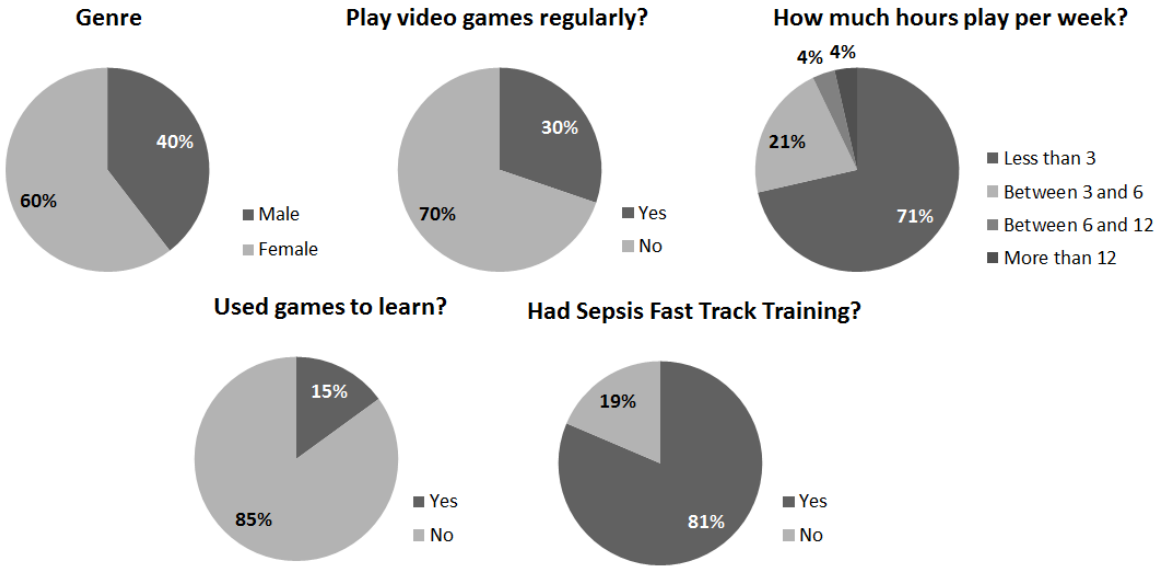


Figure 4.2: Demographic characterization and gaming habits of emergency department nurses.

Figure 4.2 shows several graphs, result of statistical analysis of the questionnaires answers.

The group of 43 triage nurses was composed of 26 females and 17 males with an average age of 35.07 (sd $\approx$ 6.63) years old. Regarding their professional experience, the triage nurses had an average of 12 years (sd $\approx$ 6.61) of previous experience working in an emergency department.

13 of the 43 triage nurses played video games regularly, but the majority played less than three hours per week. Only 6 nurses had already used serious games to learn; they referred to examples such as the ACLS Trainer, Israel catastrophe game, and Resuscitation! serious games.

35 of the 43 nurses already had Sepsis Fast Track training; all those training courses had been in a traditional class setting.

4.2.3 Results

The evaluation of the Sepsis Fast Track serious game focused on two aspects: the analysis of the in-game data logging and the hospital IT system logs.

4.2.3.1 In-game Data Logs

As referred in 3.7.3 Sepsis Fast Track serious game is able to log every procedure that a player performs while playing the game. Therefore, it is possible to analyse which procedures were performed by the nurses and the mistakes that they committed during the gameplay.

All the nurses played four clinical cases, two nurses per computer. Two cases had criteria to validate the Sepsis Fast Track (clinical cases 5 and 7), and two cases did not have the criteria to validate the

Sepsis Fast Track (clinical cases 11 and 12).

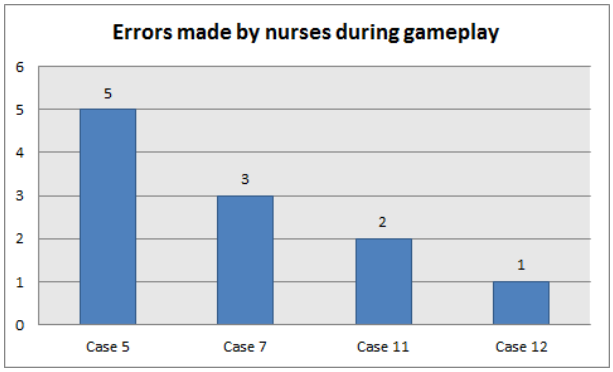


Figure 4.3: Number of errors made by nurses playing four clinical cases.

Figure 4.3 shows the number of errors made by the nurses while playing the four clinical cases and Table 4.1 presents the procedure where the mistake occurred.

Procedure	Case 5	Case 7	Case 11	Case 12
Symptoms Check	0	0	0	0
Temperature Check	0	0	0	0
Respiratory Rate Check	0	**1**	0	0
Heart Rate Check	0	0	0	0
Register Data (IT System)	**1**	**2**	**2**	0
Sepsis Alert Activation (IT System)	**1**	0	0	0
Send Patient to Waiting Room	N/A	0	N/A	**1**
Call Physician responsible for Sepsis Fast Track	**3**	N/A	0	N/A
Total	**5**	**3**	**2**	**1**

Table 4.1: Number of errors made by nurses playing four clinical cases

The first procedure that the player should do is the *Symptoms Check* that allows him or her to know the patient's complaints and see if they match with any of the symptoms that may suggest a sepsis case, none of the nurses at any clinical cases committed an error.

Temperature Check, *Respiratory Rate Check*, and *Heart Rate Check* procedures should be made after *Symptoms Check* and can be done in any order. These procedures allow the player to know if the patient has criteria for systemic inflammatory response syndrome (SIRS). Only a nurse committed an error doing the *Respiratory Rate Check* at clinical case 7.

Afterwards, the player should *Register Data* on the IT system. This data must include the values of previous patient's analysis, namely the patient complaints, temperature, respiratory rate, and heart rate. If any of these information is registered wrong, the game logs this action as an error. Five nurses committed errors while registering the data on the IT system, one in clinical case 5 and two nurses at clinical cases 7 and 11.

Send Patient to Waiting Room is a procedure the only applies to the clinical cases with patients that do not have criteria to activate the Sepsis Fast Track. One nurse made an error while doing this action in clinical case 12, which means that he or she tried to finish the clinical case without doing all the required evaluation procedures.

Call Physician responsible for Sepsis Fast Track is a procedure the only applies to the clinical cases with criteria to activate the Sepsis Fast Track. Three errors were committed in clinical case 5, which means, as in previous action, that the players tried to finish the clinical case without checking all the required criteria.

4.2.3.2 Hospital IT System Logs

After one month of the evaluation study with the emergency department nurses, we returned to the hospital to collect the hospital IT system logs. In respect to the nurses' evaluation, these logs reveal information about the number of patient admissions in the emergency department and the number of Sepsis Fast Track activations. The purpose of having this information was to assess whether there had been any impact regarding the activation procedures by nurses.

The hospital IT system logs that we were provided with included data from 2011 up to February 2014.

Figure 4.4 presents the patient's admissions in emergency department per month, and Figure 4.5 presents the number of Sepsis Fast Track activations made by nurses of the emergency department. As shown in these graphs, the number of the Sepsis Fast Track activations is clearly lower than the number of patient's admissions. Although, we thought that they could be related. Figure 4.6 presents the percentage of the Sepsis Fast Track activations related to the number of patients admissions. This graph presents a comparison between the years 2011 to 2014 across the months, this representation allowed us to understand if there was any improvement in nurses work practices after the evaluation study.

Analysing the graph shown in Figure 4.6, the average number of activations was 0.26%, the minimum occurred in May 2011 with a percentage of 0.01%, and the maximum occurred in February 2013 with 0.75%. The evaluation study sessions with the nurses occurred in the beginning of February 2014, which was the second highest month in terms of Sepsis Fast Track activations per patient admissions, with a percentage of 0.70%.

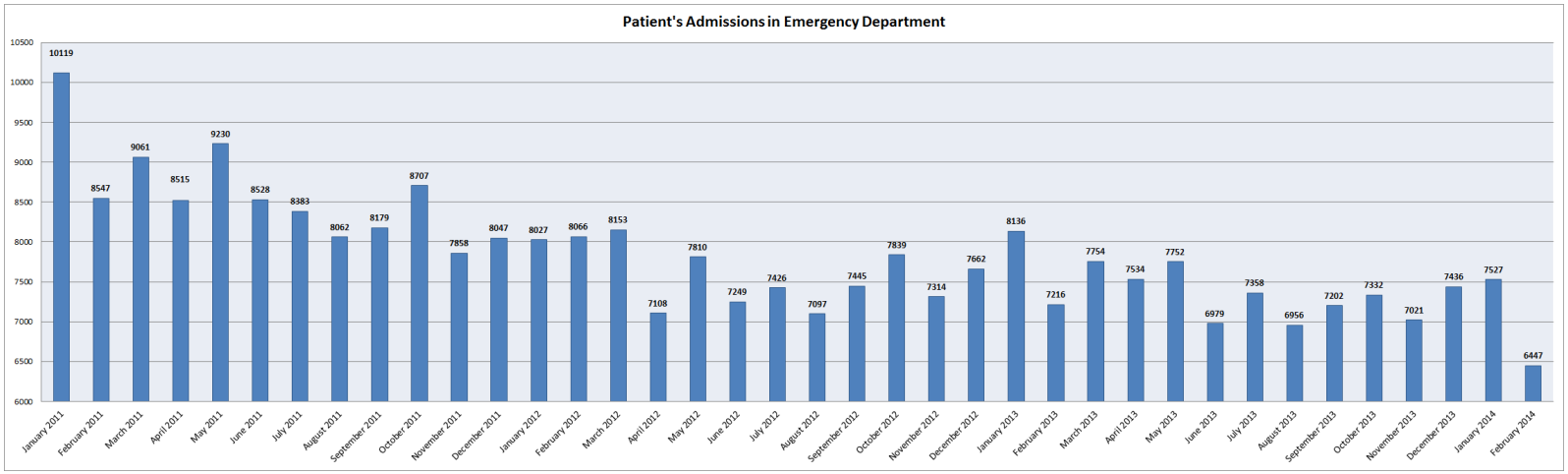


Figure 4.4: Patient's Admissions in Emergency Department.

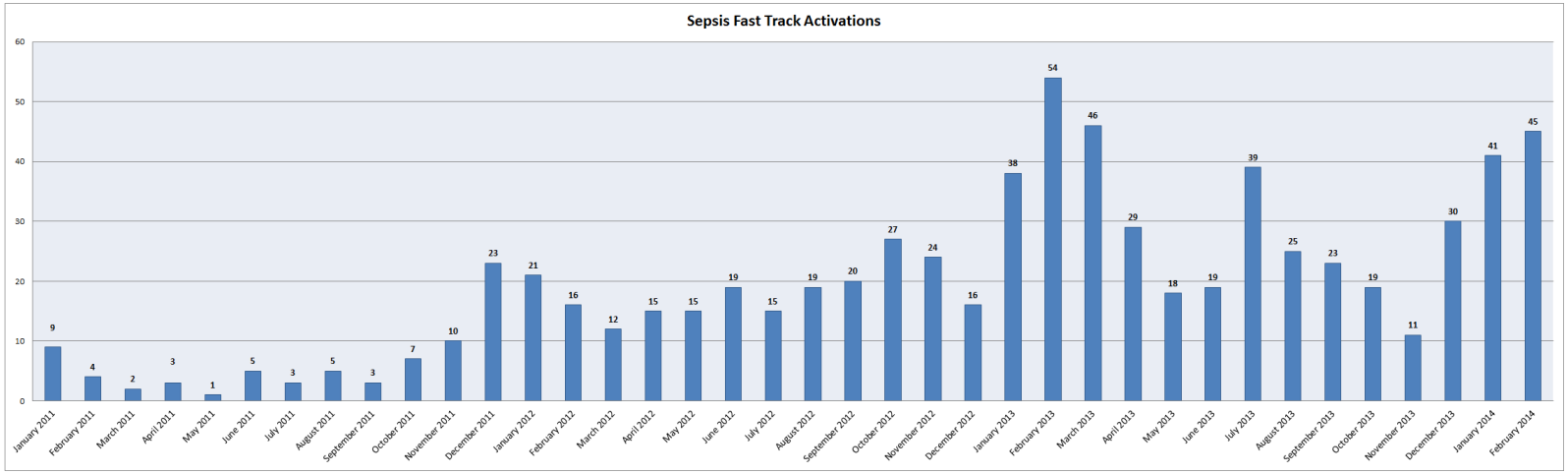


Figure 4.5: Sepsis Fast Track Activations.

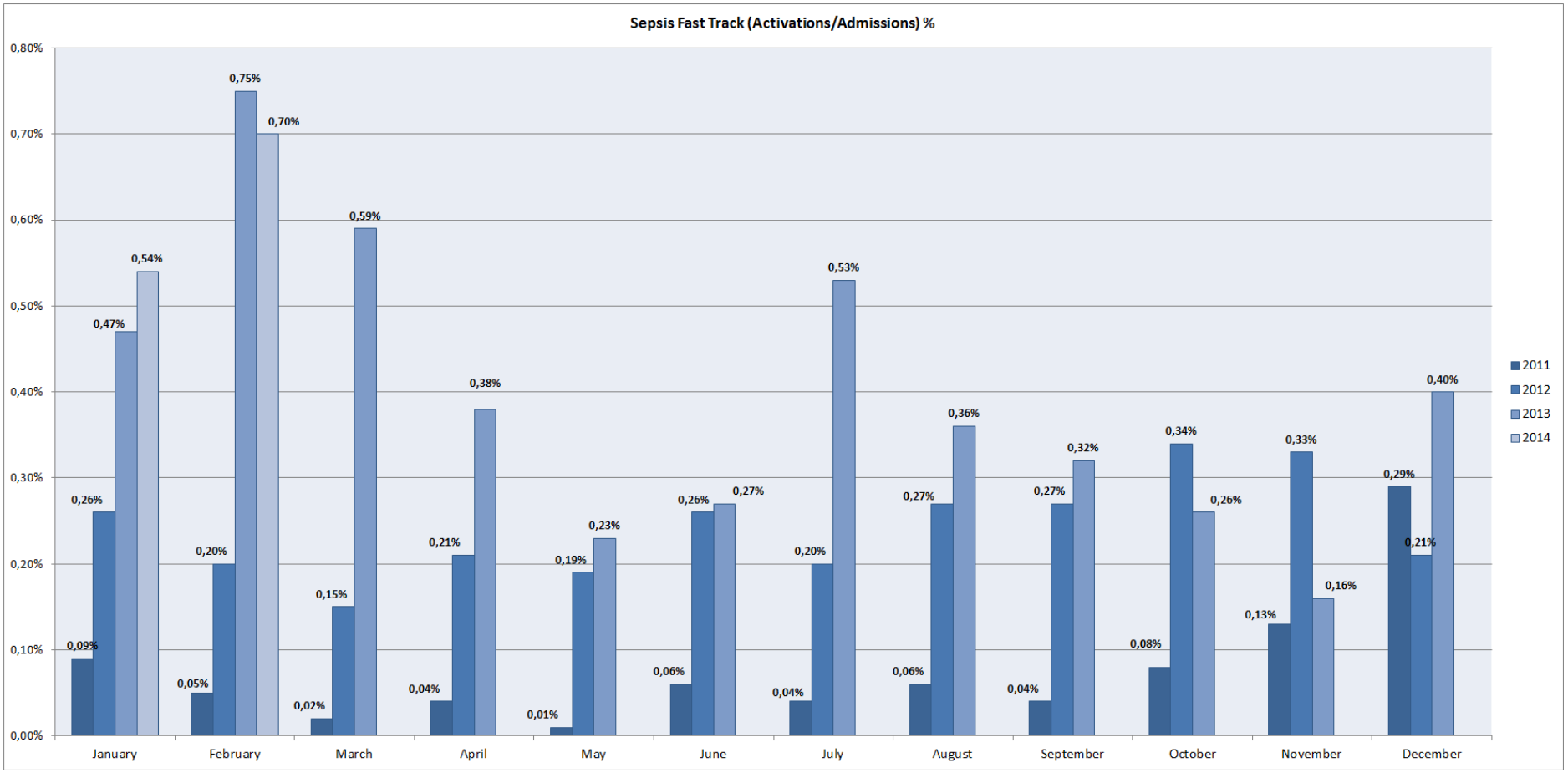


Figure 4.6: Percentage of Sepsis Fast Track activations per patients admissions.

4.2.4 Discussion

Since we are dealing with healthcare data, there is an unpredictability factor that may affect the results, more specifically, the seasonality and the dynamics of infectious diseases, sepsis in particular Altizer et al. (2006), Danai et al. (2007). Therefore, the results presented in the previous section may not be very conclusive, although we thought that some analysis could be made.

Analysing the in-game data logs, despite the difference between the number of errors across several clinical cases is not very substantial, there are noticeable improvements when comparing both types of clinical cases with each other. Comparing clinical case 7 with case 5 (positive sepsis case) and case 11 with 12 (negative sepsis case), there was an improvement. Overall, the nurses committed two errors less and one error less, after playing the other clinical case. This may indicate that the nurses were better trained after playing a clinical case, as they had been made aware of some areas they had failed in during the first playing time.

The most failed procedure was *Register Data (IT System)* (with a total of 5 errors in the first three played clinical cases), mostly because the nurses forgot to activate the Sepsis Fast Track alert. However, by the fourth case, all the nurses performed this procedure correctly, suggesting that they learnt which information needs to be registered and how to activate the alert.

Upon analysing the results of the IT system logs in terms of the percentage of Sepsis Fast Track admissions, it was found that February 2014 (the month when this study was carried out), was the second best month in the period of 2011 to 2014. This may indicate that the evaluation sessions, where all the emergency department nurses played the serious game, resulted in a tangible improvement in their working practices. However, we cannot conclude that by simply analysing the data of Sepsis Fast Track activations, since there is a variance every month due to the previously mentioned unpredictable factor.

For a better Sepsis Fast Track serious game evaluation, it would be necessary to perform more evaluation sessions in order to compare the values over a longer period of time. This would reduce the impact of unpredictability and seasonality of patient infections and other diseases, allowing us to more accurately draw conclusions about the efficiency and efficacy of these serious games.

Nevertheless, during an informal talk with the nurses after they had played the game, almost every participant said that they enjoyed playing it and preferred this learning method in comparison to traditional methods. They stated that the interaction and the possibility of assessing a patient in a practical way would allow them to better assimilate the protocol requirements and necessary procedures.

In conclusion, the results of this evaluation study are promising. However, with the current data, both from in-game and IT system logs, there is no concrete way to prove that Sepsis Fast Track serious game had a positive impact on emergency department nurses work practices. Nevertheless, we can conclude that the serious game did not have a negative impact on the working practices of these nurses.

4.3 Sepsis Case Confirmation and Therapy Evaluation

The *Sepsis Case Confirmation and Therapy* evaluation phase of the Sepsis Fast Track serious game was intended to understand how the game impacted the work practices of Emergency Department physicians. The following subsections describe how the evaluation study was carried out, its results, and a further discussion.

4.3.1 Evaluation Methodology

This evaluation study was conducted over the course of a week at the hospital facilities. It was composed of 15 Emergency Department physicians: 11 attending physicians and 4 interns. The attending physician team of the hospital Emergency Department is composed by 15 physicians, four of them did not participated in this evaluation study because they were not present at the hospital during the evaluation week, they were on holiday or on sick leave.

Unlike the evaluation study with the nurses, this study included interviews and watching each physician playing the game individually. This was mainly done because the *Sepsis Case Confirmation and Therapy* game's phase is more complex and the players may require some help during their first gameplay. Also, it was done to allow a much closer study of the physicians interaction with the serious game and their individual opinions about it, since the physicians team is smaller than the nurses team,.

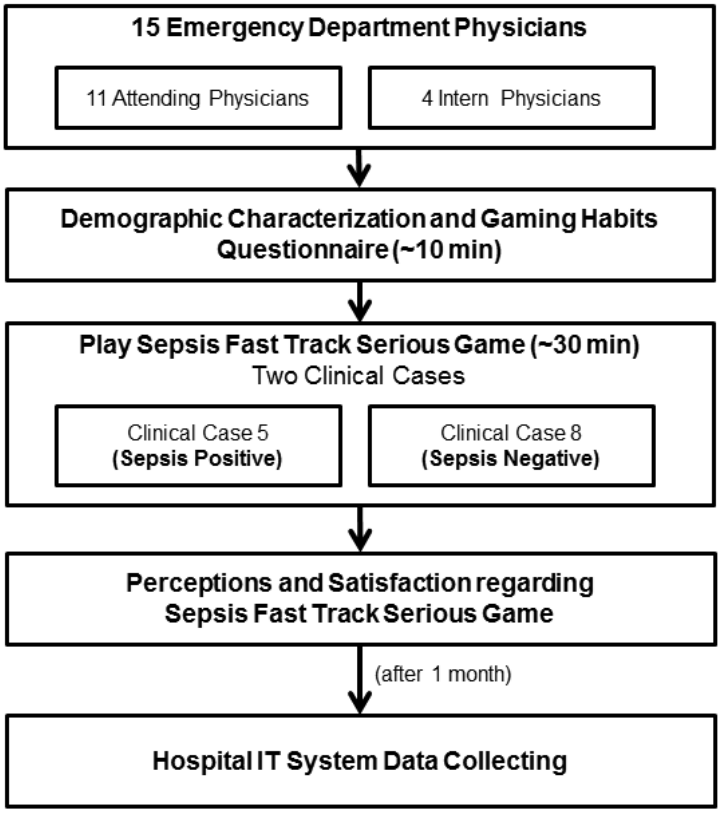


Figure 4.7: Evaluation Research Flowchart - Sepsis Case Confirmation and Therapy Phase.

Figure 4.7 presents a research flowchart with the methodology that was used to accomplish this

study.

It started with a questionnaire with two goals, a demographic characterization and the gaming habits of the physicians.

Afterwards, each physician was asked to play two clinical cases. Namely, the clinical case 5, a positive sepsis case, and the clinical case 8, a negative sepsis case. Along with the serious game play the interviews were done.

This evaluation sessions occurred in the last week of January of 2014, in March of 2014 we returned to the hospital to gather the data regarding to the Sepsis Fast Track. This data is logged by the hospital IT system, in addition to the referred data in the previous section, includes informations such as the number of Sepsis Fast Track forms that were filled out. Therefore, it was possible to understand if the serious game had impact on the confirmation of sepsis cases and further medical therapies after this evaluation session.

4.3.2 Demographic Characterization and Gaming Habits

The evaluation study of the physicians started with the same questionnaire that was used with the evaluation study of the nurses, presented in Appendix A. Also, the goal of this questionnaire was to get a demographic characterization, perceive the physicians gaming habits and to know if they had previous Sepsis Fast Track training.

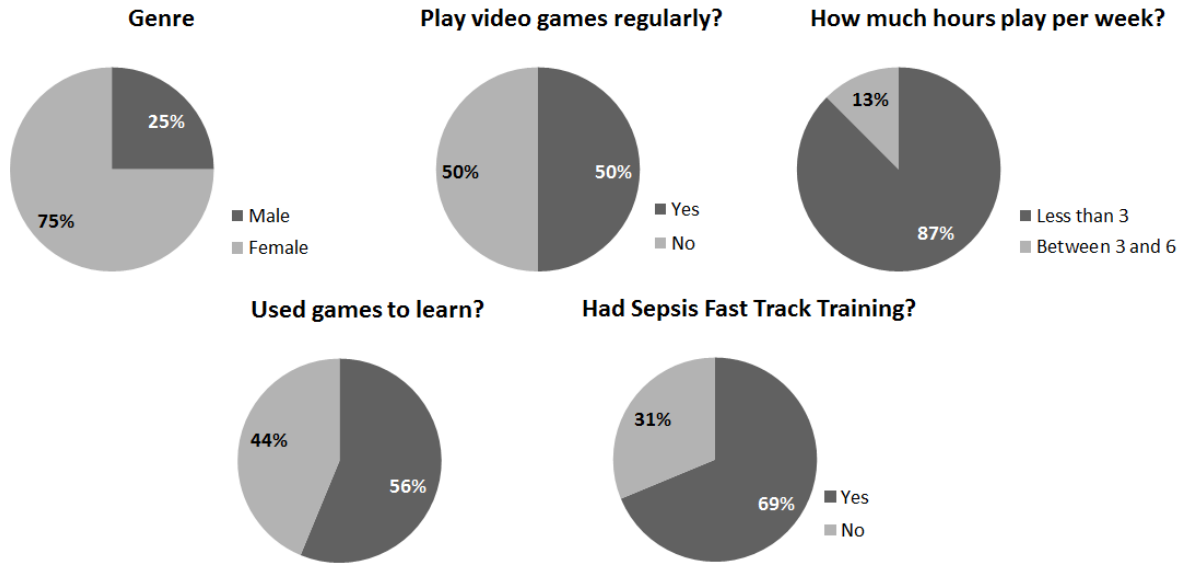


Figure 4.8: Demographic characterization and gaming habits of Emergency Department physicians.

The group of 15 physicians was composed of 11 females and 4 males with an average age of 36.81 years old. In terms of their professional experience, the physicians had an average of 6.63 years of previous experience working in an emergency department. Half of them played video games regularly, although most of them played less than 3 hours per week. Seven physicians had already used serious games and eleven, all attending physicians, had previous Sepsis Fast Track training.

Did you agree that the game helps you understand the importance of the sepsis fast track protocol?
Did the feedback given during the game help you understand what you had to do next and learn during the game?
What are your impressions about how the debriefing is structure and the information that is shown? Do you think it help you understand what you did wrong and why?
Did you felt that the game helps you to systematize the protocol steps (medical acts and therapeutics)?
Did you felt in the role of a physician?
Did you think the game is intuitive? Is easy to understand what you have to do and how you have to do it?
Did you like playing the game? Do you think is useful?

Table 4.2: Examples of Questions That Guide the Interviews

4.3.3 Results

The results of the evaluation of the Sepsis Fast Track serious game for the physicians focused on three aspects: the interviews conducted during the gameplay, the analysis of the in-game data logging, and the hospital IT system logs.

4.3.3.1 Interviews Results

The interviews were done while the physicians were playing the Sepsis Fast Track serious game, providing us with their opinions about it and helping us understand if it could help teaching and training of the Sepsis Fast Track protocol. The questions used to guide the interviews are presented in Table 4.2.

Attending Physicians

As referred in 4.3.2, all the attending physicians already had previous Sepsis Fast Track training. Therefore, they were aware of its goals and procedures in order to confirm a sepsis case and begin therapy.

Most of them became upset when they made a mistake, causing them to lose lives and points.

"*I didn't register the lactate value?? Yes, i did!!*"

"*Why did i lost points?? This is not how its done in real life!!*"

When an error occurs, feedback is provided, allowing the player to know which error was committed and which procedure should have been done instead. This also served as a bridge between how they normally perform in real life and how they should achieve their objectives in the serious game.

"*I'm always confused what to do first in the game because usually we do everything at the same time. But yes i understand the feedback and is correct. This is how things should be done.*"

"*Is different to be in a multitasking environment, which we don't have here in the game. Theoretically the protocol has an order that should be respected, but in real life we do everything at the same time. Because we have that habit in real life we try to do the same in the game.*"

Regarding the debriefing, some physicians felt that it was too long and did not pay adequate attention to it. On the other hand, some physicians agreed that it was important to understand why the game requires the performance of some procedures instead of others.

The majority of the attending physicians stated that this serious game was a good tool to teach and refresh the Sepsis Fast Track protocol, namely to systematise its procedural sequence. They also suggested that this game would be more suitable for intern physicians.

"*Yes, i agree that this game is suitable to teach and refresh the sepsis fast track protocol. It's seems very effective to systematize the things we have to do which i find very important.*"

"*Playing the game is a good training. It helps people to get their ideas in order about the protocol.*"

"*Yes, i liked to play the game. But for us (attending physicians) that already have the protocol systematize seems a bit trivial. On the other hand, interns could benefit very much by training with this game.*"

Regarding the player immersion, most of the physicians said that they did not feel immersed in the role of a real physician, nor did they consider the patients as real ones. They also forgot which procedures had already been done and repeated some of them. However, they did not seem to care much about it, saying *"oh, it's okay. Is just a game."*.

In general they said that they enjoyed playing the game, but most of them said that they would not play it voluntarily.

All the attending physicians pointed out the differences between the ways they needed to examine the patients in the game vs. patient examinations in real life. For instance, in real life, the patient's vital signs are always visible, opposed to the game, where players need to click on the vital signs monitor to check the levels.

Interns

The intern physicians that participated in these evaluation sessions had very little experience working in an emergency department and none of them had ever applied the Sepsis Fast Track protocol in a practical way by attending to a real sepsis patient. However, they already had theoretical contact with the Sepsis Fast Track protocol.

Contrary to the attending physicians, the interns were more tolerant when they made errors while playing the serious game. When they received negative feedback, they quickly figured out what they had done wrong and what they were supposed to do instead. They all stated that the feedback was an important feature, because it helped them to know what to do next.

> "*ok, i didn't know we had to do this first. I never had to do this with a real patient. When something like this happens we always call a more experience physician*."

All the interns agreed that this serious game helped them to know more about the Sepsis Fast Track protocol, particularly which procedures need to be made and in which order. They commented on the importance of the multiple types of information that the serious game provides, such as the in-game feedback and the debriefing presentation when they concluded the clinical case.

> "*yes, i think the game helps to systematize the protocol steps, specially because it gives feedback during the game and we can study the sepsis fast track protocol during the debriefing phase*."

In general, all the intern physicians enjoyed playing the game and felt that it was intuitive. Some of them wanted to play more clinical cases and even asked if this serious game was available so they could play it at home.

> "*I really liked to playing the game but i would have liked to play more clinical cases. Can we play this game at home?*"

4.3.3.2 In-game Data Logs

As referred in 3.7.3 Sepsis Fast Track serious game is able to log all the actions that a player do while playing the game. Therefore, is possible to understand which medical procedures were made by the physicians and the mistakes that they committed during the gameplay. These errors may be for example realize a procedure out of order, repeat an unnecessary procedure, or choose wrong values for medical drugs administration.

All the physicians that participated in this evaluation study played only two clinical cases, due to time restrictions. We chose clinical case 8 (Appendix B) because is one of the *complete* clinical cases, this is, it is a clinical case where every step of the Sepsis Fast Track protocol must be performed. Therefore, it would be possible to evaluate the *Sepsis Case Confirmation and Therapy* game's phase in a comprehensive manner. Although physicians also played clinical case 5 (Appendix B), it is not consider in this study because it is a very small case which results are negligible.

Table 4.3 shows the number of physicians that committed an error at a particular medical procedure in clinical case 8. In this table are present all the medical procedures that a physician needs to do according to the Sepsis Fast Track protocol as referred in 3.3.2.

In Step 2 of the protocol, all the physicians executed correctly the *Confirm Suspicion* which is the first procedure that must be made. To perform this procedure correctly the physician should ask the patient his or her complaints and certify that the SIRS identified by the nurse are confirmed.

Medical Procedure	**Attending** (11 physicians)	**Interns** (4 physicians)	**Total** (15 physicians)
Step 2			
Confirm Suspicion	0	0	0
Hipoperfusion?	0	0	0
Without Exclusion Criteria?	0	0	0
VVS Activation (IT System)	6	1	7
Step 3a and 3b			
Hemocultures?	1	2	3
Complementary Exams?	1	3	4
Administer Antibiotic Therapy	4	2	6
Fluids Quantity	3	4	7
Contact ICU	5	3	8
Step 4 (CVP $>$8mmHg)			
Reassess Patient Condition	7	3	10
Insert Central Venous Catheter	6	3	9
Examine Central Venous Pressure (CVP)	6	3	9
Administer Fluid Therapy	8	3	11
Step 4 (MAP $>$65mmHg)			
Reassess Patient Condition	2	0	0
Reassess CVP	5	0	5
Reassess Urine Flow Rate	3	0	3
Administer Vasopressors	7	0	7
Step 4 (ScVO2 $>$70%)			
Reassess Patient Condition	0	0	0
Reassess CVP	0	0	0
Request Blood Venous Gas Exam	0	0	0
Contact ICU	0	0	0
Total	**74**	**30**	**104**

Table 4.3: Number of errors made by physicians playing clinical case 8

Hipoperfusion? procedure was also correctly done by all physician, which require measure the patient's arterial blood pressure in the vital signs monitor and perform an arterial blood gas exam to check the patient's lactate.

Also, the *Without Exclusion Criteria?* procedure was properly done by all physicians, to perform this procedure the physicians had to check the patient's chart in order to check if he or she had any exclusion criteria that preclude the application of the Sepsis Fast Track protocol.

The only procedure that was incorrectly done by physicians in Step 2 of protocol was *VVS Activation (IT System)* which requires the physicians to register the patient's data and validate the Sepsis Fast Track in the IT system. 6 of the 11 attending physicians and 1 of the 4 intern physicians did not performed this procedure correctly.

In Steps 3a and 3b errors occurred in all medical procedures.

Hemocultures? was performed incorrectly by 1 attending physician and 2 intern physicians. This procedure is a requirement of the protocol and is done by asking the nurse to collect the hemocultures from the patient, allowing further blood analysis.

Complementary Exams was performed incorrectly by 1 attending physician and 3 intern physicians. It consists in request specific exams according to the patient conditions, allowing a more accurate diag-

nosis. The complementary exams request should be done at the hospital IT system. In this particular clinical case the physicians should have requested an abdominal X-ray, in addition to the standard sepsis complementary exams.

Administer Antibiotic Therapy is the most crucial medical procedure of the Sepsis Fast Track protocol. It was performed incorrectly by 4 attending physician and 2 intern physicians. The antibiotic must be administered to a sepsis infected patient within 1 hour. Although all the physicians administered it in a timely manner, it was not done in a correct order, e.g. hemocultures must be performed before the antibiotic administration so the blood tests results is not affected.

The *Fluids Quantity* was erroneously chosen by 3 attending physicians and all of the intern physicians. The protocol refers that any patient that has sepsis must be administered fluids, which the recommended one is crystalloids at an infusion rate between 30ml/Kg and 40 ml/Kg in the first 3 hours. The fluids administration contributes to reduce the patient's hypoperfusion.

Contact ICU is the last procedure that physicians should do in Step 3 of the protocol. 5 attending physicians and 3 intern physicians did not executed this procedure correctly. Contacting intensive care unit (ICU) should be made in order to refer the patient to a specialized department where he or she can get constant and close monitoring and support. Although this serious game informs the player that ICU is currently full, as happens a lot of times in a real hospital, the physicians should always contact it.

Like in the previous step, in the first iteration of the Step 4 (CVP $>$8mmHg) errors occurred in every procedure.

Reassess Patient Condition was not correctly performed by 7 attending physicians and 3 intern physicians. When entering the Step 4 one in-game hour passes, though the physicians should reassess the patient's condition in order to check if there was any change on its state for better or for worse. The physician should check patient's arterial blood pressure, physical condition, and optionally the urine flow rate.

After reassessing the patient, the physicians should *Insert Central Venous Catheter*, which was not correctly executed by 6 attending physicians and 3 intern physicians. The insertion of a central venous catheter allows the physician to perform more medical procedures. Particularly in a sepsis case it is important since it is the only way to measure the central venous pressure (CVP).

After the central venous catheter, the physicians should *Examine Central Venous Pressure*, which was incorrectly done, like in the previous procedure, by 6 attending physicians and 3 intern physicians. This procedure allows the physician to know which is the patient's central venous pressure (CVP), reflecting the amount of blood returning to the heart and the ability of the heart to pump the blood into the arterial system. The value of CVP should be at least 8 mmHg, if not the following procedure should be made.

Administer Fluid Therapy must be performed to increase the CVP to at least 8 mmHg. In clinical case 8, at this point, the value of CVP was lesser than the reference value, so the physicians should administer more fluids to the patient. 8 attending physicians and 3 did not this procedure correctly.

In the second iteration of the Step 4 (MAP $>$65mmH) only attending physicians committed errors at every procedures, all the intern physicians performed the procedures correctly.

This iteration starts after 30 minutes from the conclusion of the previous on. Therefore, *Reassess Patient Condition* must be performed, with the same objectives. Now, only 2 attending physicians did this procedure incorrectly.

In addition to reassess the general patient's condition, the physicians should also *Reassess CVP*. Which objective is to guarantee that the additional administration of fluid therapy had a good impact on patient's CVP. 5 attending physicians performed this procedure incorrectly.

During the *Reassess Patient Condition* procedure, the physicians had to check the patient's mean arterial pressure (MAP). In this particular case the MAP is less than the reference value of 45 mmHg, therefore the physician should perform the *Administer Vasopressors* procedure to increase it. 7 attending physicians did not performed it correctly.

The last iteration of the Step 4 (ScVO2 $>$70%), also occurs after 30 minutes (in-game) of the previous iteration. Therefore *Reassess Patient Condition* and *Reassess CVP* must be performed. In order to examine the patient's ScVO2, the physicians should *Request Blood Venous Gas Exam*. In clinical case 8, the patient's ScVO2 is greater than 70%, therefore no more medical procedures had to be done. This clinical case ends contacting again the intensive care unit, *Contact ICU* procedure. All the physicians, both attending and intern, executed every procedure correctly.

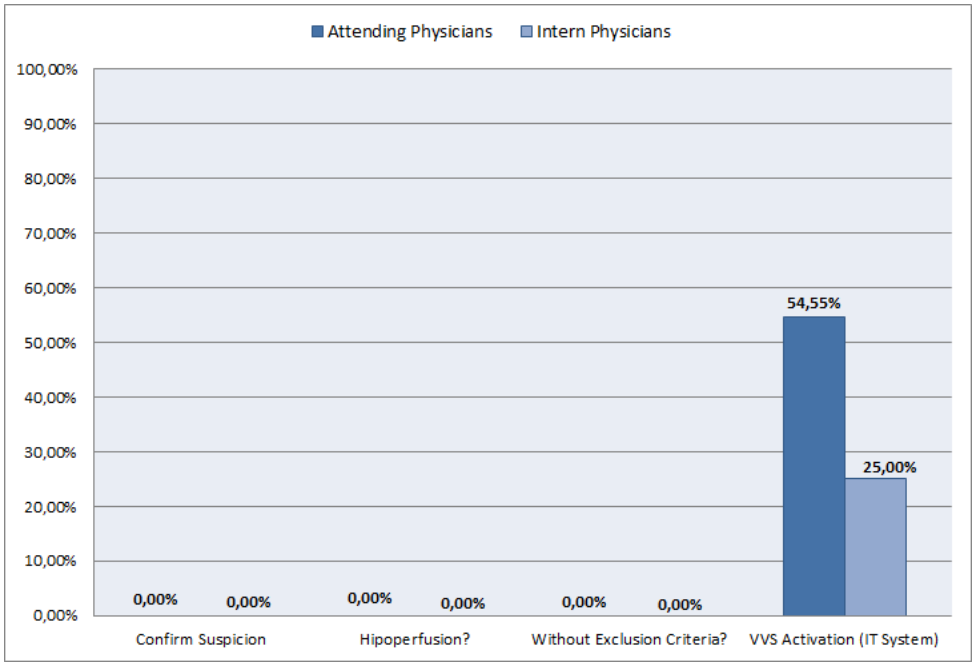


Figure 4.9: Comparison between the percentage of errors made by Attending and Intern physicians in Step 2.

Figures 4.9, 4.10, 4.11, and 4.12 present several graphs comparing the percentage of errors made by the attending physicians and intern physicians throughout the clinical case, specifying every procedure. Globally, the attending physicians made 28.03% of errors, and the interns made 31.25%.

Overall, the performance of the attending physicians was better. However, in Step 2, intern physicians performed better doing the *VVS Activation (IT System)* procedure, and in Step 4, (MAP $>$65 mmHg), the interns executed all the procedures without errors, as opposed to the attending physicians, who

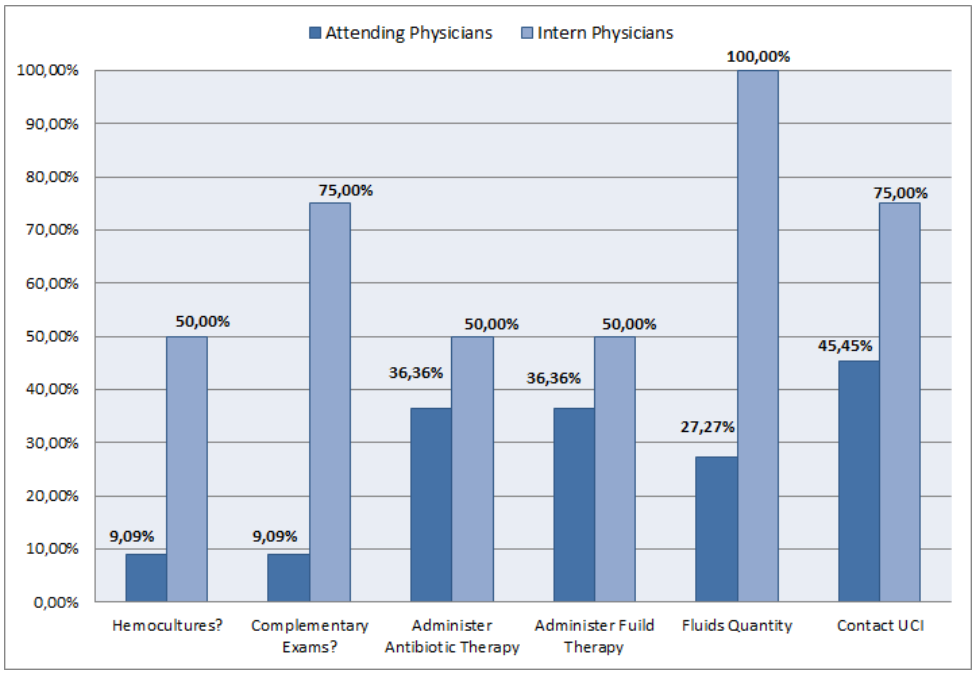


Figure 4.10: Comparison between the percentage of errors made by Attending and Intern physicians in Step 3a and 3b.

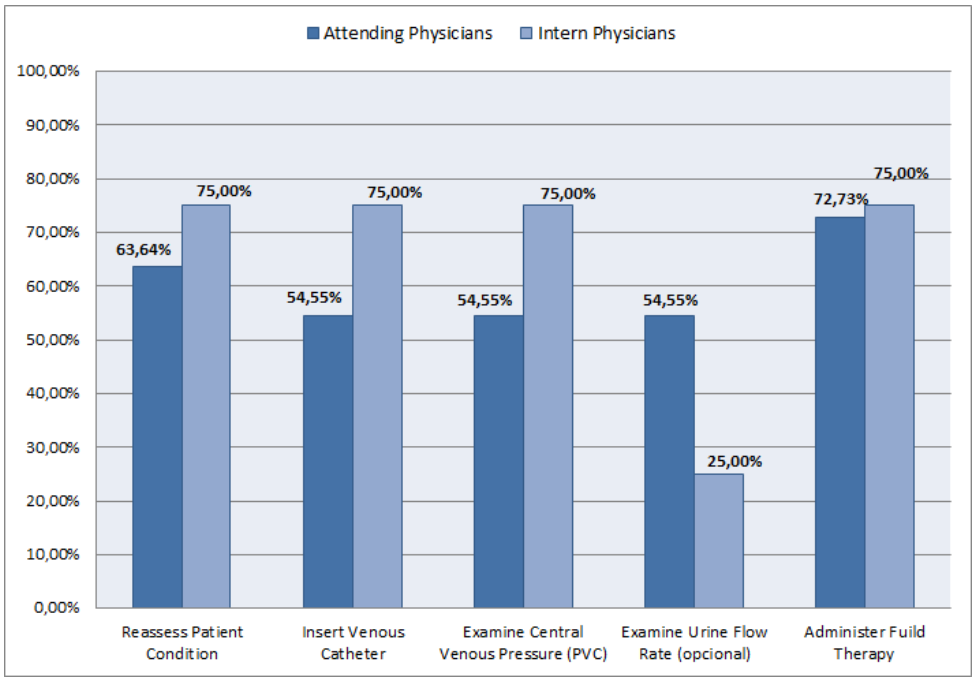


Figure 4.11: Comparison between the percentage of errors made by Attending and Intern physicians in Step 4 (CVP $>$8 mmHg).

committed errors. In Step 4 (ScVO2 $>$70%), all the physicians executed the procedures correctly.

4.3.3.3 Hospital IT System Logs

The Sepsis Fast Track serious game evaluation study was done during January 2014, after almost two months we returned to the hospital to get the IT system logs. In terms of the physician evaluation, the

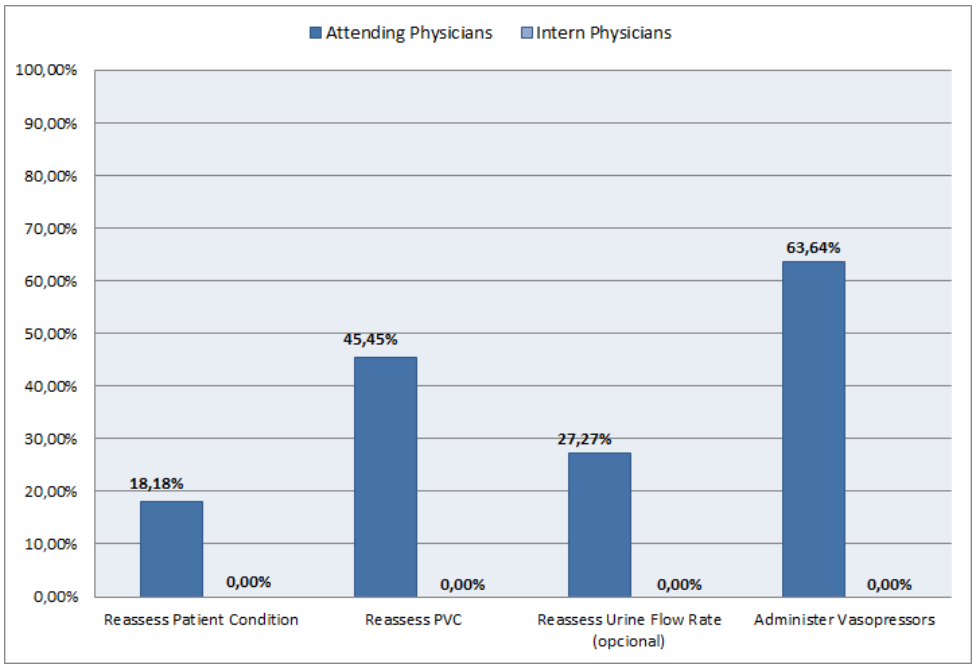


Figure 4.12: Comparison between the percentage of errors made by Attending and Intern physicians in Step 4 (MAP $>$65 mmHg).

IT system logs show information about the Sepsis Fast Track forms that were filled out by physicians.

After a nurse identifies a possible sepsis case and refers the patient to the physician responsible for the Sepsis Fast Track, the physician should register the patient's data concerning the sepsis case. This may include medical condition of the patient and the validation, or not, of the Sepsis Fast Track.

Analysing this information, it would be possible to know if there had been any impact on physicians' work practices regarding the registration of the sepsis forms. The registration of these forms is important for better hospital management and ultimately for patient care quality.

The hospital IT system logs that we were provided with included data from 2011 up to February 2014.

Figures 4.13 and 4.14 present graphs for each month, comparing the number of Sepsis Fast Track activations, made by nurses, and sepsis forms registration, made by physicians, across the years. Figure 4.15 presents a graph with a percentage of forms registered per activations, for each month from January 2011 to February 2014.

Analysing the graphs, we can conclude that only two months had an optimal form registration level: December 2012 and November 2013. Also, both of those months had very low rates of Sepsis Fast Track activations.

Only an average of 35.63% of the total Sepsis Fast Track activations resulted in form registration.

The evaluation of the physicians occurred in the beginning of January 2014, the percentage of form registration for January and February of 2014 are 58.33% and 30.43%, respectively. January is 22.70% above average, while February is 5.2% below the average.

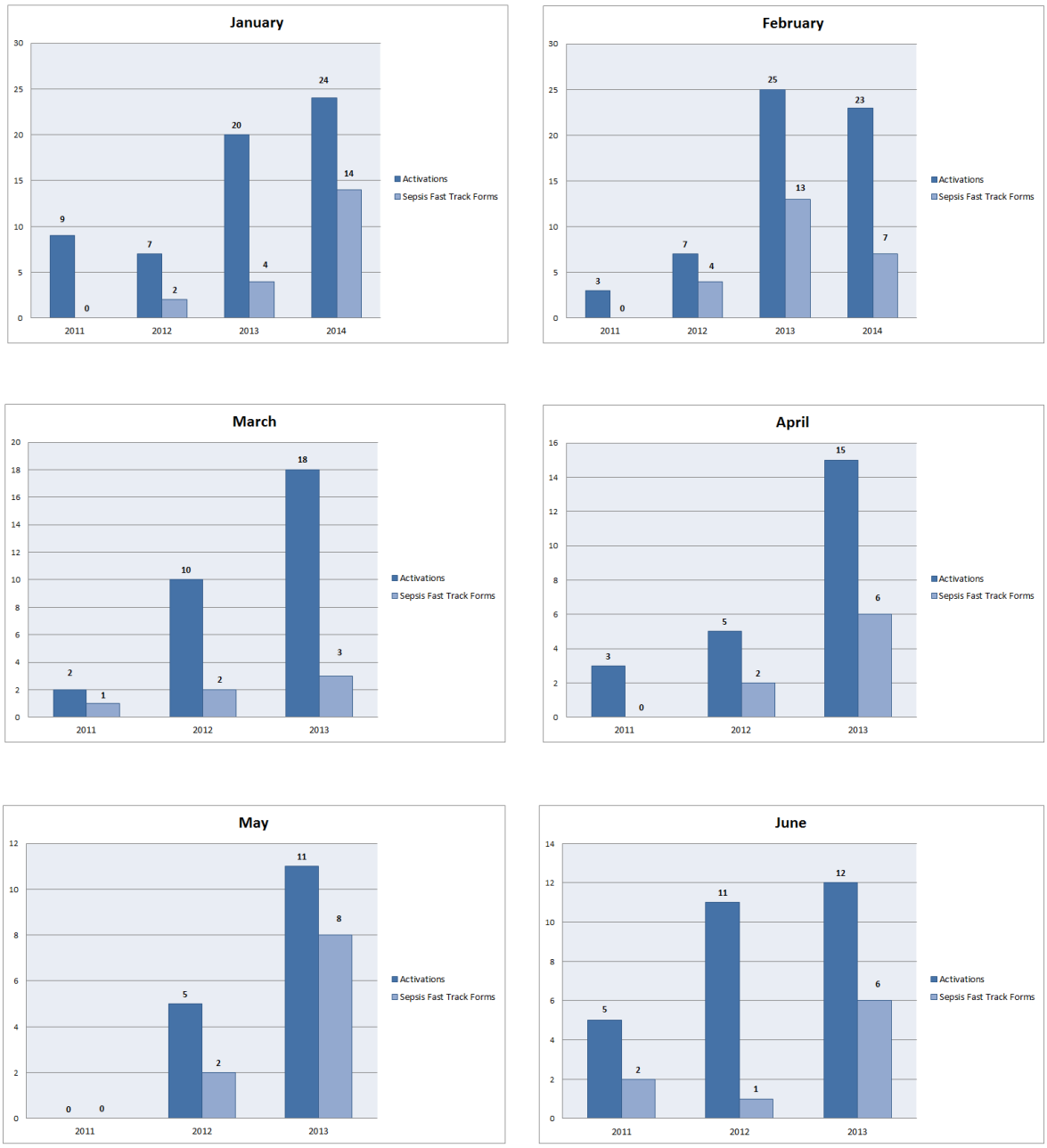


Figure 4.13: Percentage of Sepsis Fast Track activations and forms per month (January-June).

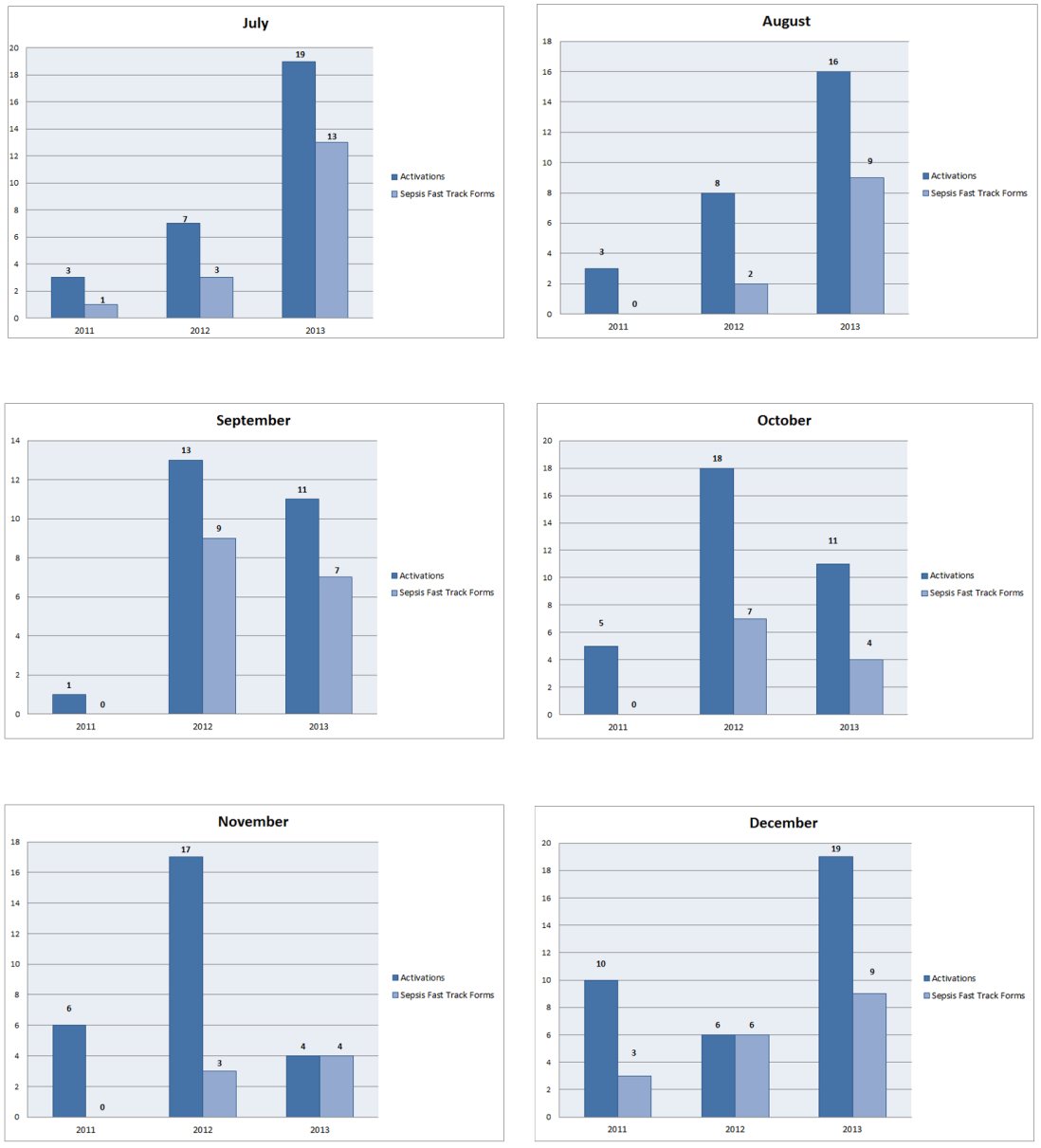


Figure 4.14: Percentage of Sepsis Fast Track activations and forms per month (July-December).

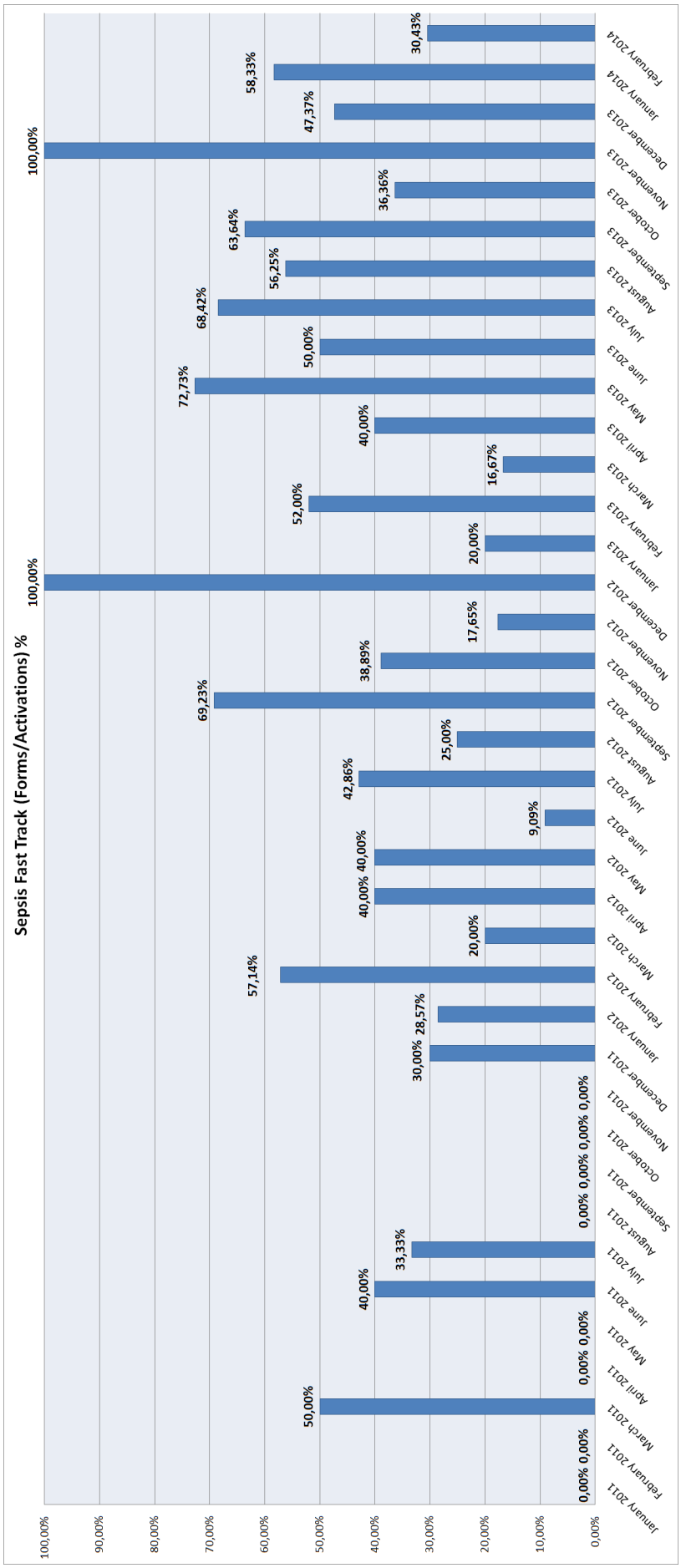


Figure 4.15: Percentage of Sepsis Fast Track forms per activations.

4.3.4 Discussion

The evaluation of the *Sepsis Case Confirmation and Therapy* game phase is based on the same main goals as the previous phase - evaluating the impact on physicians' working practices. Additionally, we interviewed each physician in order to hear his or her opinion and measure of satisfaction with the game.

As in the *Identification of a Possible Sepsis Case* evaluation study with the nurses, the results of this evaluation do not conclusively demonstrate the efficiency of the Sepsis Fast Track serious game regarding the improvement in physicians working practices. However, some assumptions can be made.

During the interviews, every physician referred to the importance of the in-game, real-time feedback and the debriefing that was implemented in the game. They stated that the feedback facilitated easier gameplay; suggesting procedures that should be done and even losing a "life" were good forms of feedback. They commented on the debriefing phase, which is where they could understand which errors they committed and why. They pointed out that the inclusion of the Sepsis Fast Track algorithm in the debriefing allowed them to get a broader view of the issue and also provided them with a better understanding of the procedural sequence.

We noticed some differences between the attending and the intern physicians while playing the game. In general attending physicians already have a way to do things because of their experience diagnosing and treating patients in the emergency department and which in many situations differs from the proposed in medical treatment protocols as is the case of Sepsis Fast Track protocol. Contrarily to the interns, most attending physicians refereed the inability to do multiple procedures while playing the serious game. We also noticed that attending physicians where they make more mistakes is when reassessing the patient current condition.

Analysing the in-game data logs, we can observe that the attending physicians performed better, but by quite a small margin, 3.22%. This can be explained by the fact that attending physicians have already mastered many of the necessary *mechanics* for a proper patient diagnosis and further treatment, without the need to follow the Sepsis Fast Track protocol to the letter, as the game requires. Moreover, during the evaluation sessions, the attending physicians generally seemed to concentrate less and did not take the game seriously, in comparison to the interns. This could be because the attending physicians are not as open to this new learning method and still see video games solely as a source of entertainment. This can also explain the hospital's IT system logs, which did not reveal any improvements regarding the physicians' working practices.

From the results, it seems that this serious game would be more suitable for intern physicians than for attending physicians. Also, by analysing the in-game data logs, it is possible to conclude that the attending physicians performed better than the intern physicians (even in a small percentage), indicating that the interns need to better trained on the Sepsis Fast Track. However, this serious game may be a way to teach the attending physicians new changes to the protocol procedures. Regarding the lack of proper form documentation in the IT system, particularly of the Sepsis Fast Track form, we don't think that this serious game would improve it substantially. Other approaches, such as the 'gamification' of the hospital IT system, would have potentially better benefits.

We also conclude that some changes could to be made to this serious game regarding the player's

immersion. As pointed out by some physicians, they did not view the in-game patient as a real patient, resulting in errors and a lack of full attention to what the game was teaching and training. Virtual reality is coming back as trend, which could be a possibility for improving the player's sense of immersion.

For a better analysis of this serious game, more evaluation sessions need to be conducted. That would make it possible to analyse this game in a more comprehensive manner, comparing the results not only with a unique evaluation session, but also with other ones within a longer period of time.

4.4 Summary

The *Sepsis Fast Track* serious game evaluation was divided into two main phases, one with emergency department nurses and other with physicians, corresponding to the two serious game phases. The main goal of this evaluation was to assess the serious game impacts on the healthcare professionals working practices.

The evaluation of the *Identification of a Possible Sepsis Case* game's phase was done during three days with 43 nurses. The nurses started watching a Sepsis Fast Track video, answered to a demographic characterization questionnaire and played four clinical cases.

The evaluation of the *Sepsis Case Confirmation and Therapy* game's phase was done during a week with 15 physicians, 11 attending and 4 interns. The physicians started answering a demographic characterization questionnaire and played one clinical case. The evaluation sessions with the physicians were carried on individually, and along with the gameplay an interview was carried on.

The results of these evaluation sessions were not conclusive regarding to the main goal, the improvement in emergency department healthcare professionals work practices. Although, the results were not negative, and according to the interviews with the physicians and the feedback that we received, this serious game has potential to be a teaching and training tool for the Sepsis Fast Track protocol.

In order to conclude if this serious game impacts in any way in the healthcare professionals working practices, more evaluations sessions need to be made.

Chapter 5

Conclusions

5.1 Conclusions

In this paper, we presented a serious game entitled Sepsis Fast Track serious game for clinical education. It was developed to teach and train healthcare professionals in hospital emergency departments, namely nurses and physicians, about the Sepsis Fast Track protocol. This serious game was based on the protocol issued by the Portuguese Directorate-General of Health Direcção-Geral da Saude (2010) based on the Surviving Sepsis Campaign guidelines Dellinger et al. (2008), which aims to regulate and spread awareness of implementation procedures of the Sepsis Fast Track in Portuguese hospitals.

The development was conducted together with healthcare professionals, which facilitated the requirements analysis. Moreover, during the game development, several meetings were held to ensure that the serious game was being developed according to the algorithm described in the Sepsis Fast Track protocol. Since we are dealing with medical information, procedures, equipment, and language, it was very important support.

We analysed several serious games developed for medical education, namely Septris serious game which was developed in order to teach in a practical way the identification and application of sepsis guidelines. Since Septris is available to play it online, we tested and think that it lacks in some aspects, namely:

- There is not any in-game briefing explaining the game objectives and learning goals.
- The game starts right away, without a tutorial, being very confuse for the first time.
- There is not any help menu.
- It is almost ”text on screen”, not being immersive at all.
- The user interface was designed for mobile platforms, not being user friendly when used in a personal computer.
- When a patient dies or survives there is a very slight feedback.

- It is limited to only eight clinical cases, and they must all played, not being possible to choose only one case.
- There is not trace of actions realized during the gameplay.
- There is not a debriefing for the overall performance during the game.

All the above features were implemented in Sepsis Fast Track serious game, which we think that are essential for the better user experience and further learning outcomes.

In order to evaluate the impacts of this serious game on emergency department healthcare professionals' working practices, an evaluation study was done in the hospital facilities. This study was divided into two phases, one with 43 nurses that played four clinical cases (*Identification of a Possible Sepsis Case*) and another with 15 physicians playing one clinical case and being interviewed (*Sepsis Case Confirmation and Therapy*).

In both evaluation phases, the players' actions during the gameplay were logged in order to evaluate their performance. In addition, after one month, we returned to the hospital to gather the IT system data logs, in order to understand if there had been an improvement in healthcare performance regarding the Sepsis Fast Track.

The hospital's IT system data logs were not sufficient to assess the serious game efficiency. Because of the unpredictability factor that exists when dealing with healthcare, the data related to the number of Sepsis Fast Track activations was significantly variable over the analysed months.

The physicians mentioned the importance of the in-game real-time feedback and the debriefing procedure. Both nurses and physicians said that they enjoyed playing the game. Most of the nurses and the intern physicians stated that they preferred this method of learning as compared to the traditional ones. They explained that the interaction that the game allows facilitates enhanced learning, rather than listening to a person teaching and explaining them the protocol in a traditional academic setting.

In conclusion, we think that the Sepsis Fast Track serious game has a lot of potential to be used as a real training tool for the Sepsis Fast Track protocol. However, more studies need to be conducted in order to understand if it is consistently efficient and effective as a training tool.

5.2 Future Work

As mentioned in Chapter 4, the evaluation results were not totally conclusively. Therefore, more evaluation studies need to be done in order to understand the efficiency of Sepsis Fast Track serious game regarding the improvement on healthcare professionals working practices.

Currently, a website with education content is being designed at the São Francisco Xavier hospital. We were proposed to integrate this serious game in the hospital's intra-net. Therefore, in order to integrate this serious game in a website, it will need to compiled to web platform and to be tested (currently, it is tested with Windows and MacOS platforms). Since it was developed using a multi-platform game engine, Unity3D, it will be probably made without a lot of effort.

In order to engage the players and add a better challenging factor to this game, implementing a scoreboard listing the players with the highest scores, would be an improvement.

Other improvements that can be done are related to the game's presentation. The game's GUI was not designed by a graphic designer and it would greatly improve if it would be done. Some 3D models can also be improved, namely in detail. Nevertheless, the existing avatars' animations are currently very limited, they should be redesigned and new ones have to be created. Improving these aspects would greatly increase the players' immersion, resulting in better results.

Appendix A

Questionnaire for Demographic Characterization

Caracterização da Amostra

Nome: _____ Idade: _____

sexo: F____ M____

Instruções

Por favor responda a todas as perguntas.

Parte I: Hábitos de Jogo

1) _____ **Joga habitualmente videojogos?**

   a. sim
   b. não

2) _____ **Com que idade jogou pela primeira vez videojogos e em que contexto?**

   Idade:

   Contexto: (ex. escola, casa)

3) _____ **Quanto tempo joga videojogos por semana?**

   a. Menos de 3 horas
   b. 3 a 6 horas
   c. 9 a 12 horas
   d. Mais de 12 horas

4) _____ **Qual é o seu género de jogo preferido?**

   a. Jogos de luta (ex. Street fighter)
   b. Jogos de estratégia (ex. Civilization)
   c. Jogos de plataformas (ex. Mario Bros)
   d. Jogos de FPS (ex. Unreal tournment, Quake)
   e. Jogos de aventura (ex. Monkey Island, Zelda)
   f. Jogos de Role Playing (ex. Final Fantasy, World of Warcraft)
   g. Jogos de simulation (ex. FlightGear)
   h. Jogos casuais (ex. Angry Birds)
   i. Outro: (por favor dê um jogo como exemplo)

5) _____ **Em que tipo de sistema prefere jogar?**

a. PC/Mac
b. Smartphone/Tablet
c. Consola (ex. PS3, Xbox, Wii)
d. Handheld (ex. Nintendo DS, PSP)

Parte II: Conhecimentos Prévios

1) _____ **Já alguma vez teve formação sobre o "Transporte do doente crítico"?**

a. sim
b. não

2) _____ **Se sim, qual foi o método pedagógico utilizado?**

a. Aula "clássica"
b. Simulação
c. Outro:

3) _____ **Já alguma vez tinha usado jogos para aprender (jogos sérios, simulações)?**

a. Sim. Nome do jogo:_____
b. não

4) _____ **Se sim, em que contexto?**

a. Aula "clássica"
b. Em casa
c. Outro:

Appendix B

Clinical Cases

Clinical Case 1

ID	1			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	True			
Patient Personal Details				
Name	Luis Santana			
Age	52			
Weight	70			
Birth Date	06/02/1961			
Genre	Masculino			
Patient Details				
Clinical Process ID	123456789			
Complaints	Ando há 3 dias com tosse, deito expectoração escura que é difícil de soltar e canso-me muito, às vezes sinto que o ar não entra. Hoje então nem consegui ir trabalhar.			
Symptoms	Tosse + (dispneia ou dor pleurítica) [a]			
Temperature	38.7			
Heart Rate	110			
Respiratory Rate	24			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	90	80	88	120
Diastolic Blood Pressure	50	46	52	60
Urine Flow Rate	0	15	25	200
Central Venous Pressure	6	6	12	12
Exclusions	-			
Clinical History	Fumador			
	00h00	**01h00**	**01h30**	**02h00**
Glasgow Comma Scale	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.
Physical Exam	Mucosas coradas, desidratadas. Sinais de má perfusão periférica com tempo de preenchimento capilar de 4 segundos. Taquipneico com tiragem. Auscultação pulmonar com fervores na base direita.	Mucosas coradas, desidratadas. Sinais de má perfusão periférica com tempo de preenchimento capilar de 4 segundos. Taquipneico com tiragem. Auscultação pulmonar com fervores na base direita.	Mucosas coradas, desidratadas. Sinais de má perfusão periférica com tempo de preenchimento capilar de 4 segundos. Taquipneico com tiragem. Auscultação pulmonar com fervores na base direita.	Mucosas coradas, desidratadas. Sem sinais de má perfusão periférica. Eupneico, sem tiragem. Auscultação pulmonar com fervores na base direita.
Lactate	5	6	4	3
Complementary Exams	RX Tórax			
Exams Results				
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.35	7.38	7.39	7.39
pCO2	32	33	35	35
pO2	61	65	74	74
ctHb	Random	Random	Random	Random
Hct	Random	Random	Random	Random
sO2	90%	91%	94%	94%
FO2Hb	Random	Random	Random	Random

FMetHb	Random	Random	Random	Random
FCOHb	Random	Random	Random	Random
FHHb	Random	Random	Random	Random
K+	Random	Random	Random	Random
Na+	Random	Random	Random	Random
Ca2+	Random	Random	Random	Random
Lac	5	6	4	3
tCO2(B)	Random	Random	Random	Random
Base(Ecf)	Random	Random	Random	Random
HCO3-(P,st)	21	19	21	21
HCO3-(P)	20	22	23	23
AnionGap,K+	Random	Random	Random	Random

Clinical Case 2

ID	2			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	False			
Patient Personal Details				
Name	Mónica Abrantes			
Age	28			
Weight	61			
Birth Date	16/05/1985			
Genre	Feminino			
Patient Details				
Clinical Process ID	241225431			
Complaints	Ando com uma dor nas costas já há 3 dias, ontem comecei com febre e vomito tudo.			
Symptoms	Dor lombar + (disúria ou polaquiúria) [b]			
Temperature	39			
Heart Rate	112			
Respiratory Rate	28			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	88			
Diastolic Blood Pressure	54			
Urine Flow Rate	80			
Central Venous Pressure	9			
Exclusions	Gravidez [a]			
Clinical History	Grávida 28 semanas			
Glasgow Comma Scale	A paciente está acordada, cumpre ordens e responde.			
Physical Exam	Mucosas coradas, desidratadas com prega cutânea.AC sons ritmicos, sem sopros.AP MV mantido bilateralmente sem ruidos adventícios.Murphy renal presente à esquerda.			
	00h00	**01h00**	**01h30**	**02h00**
Lactate	5			
Complementary Exams	Ecografia Renal: rins normodimensionados com normal diferenciação parenquimosinusal, ligeira uretero-hidronefrose esquerda, sem litíase observável. Sem liquido ou colecçoes peri-renais. Bexiga em fraca replecção impedindo avaliação adequada			
Exams Results	Leucócitos 22.000x10e9/L, PCR 31 mg/L, urina II: leucócitos +++ e nitritos +, β-HCG 80000 mIU/mL			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.33			
pC02	30			
p02	90			
ctHb	Random			
Hct	Random			
sO2	100%			

FO2Hb	Random			
FMetHb	Random			
FCOHb	Random			
FHHb	Random			
K+	Random			
Na+	Random			
Ca2+	Random			
Lac	9			
tCO2(B)	Random			
Base(Ecf)	Random			
HCO3-(P,st)	22			
HCO3-(P)	21			
AnionGap,K+	Random			

Clinical Case 3

ID	3			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	False			
Patient Personal Details				
Name	Fábio Martins			
Age	34			
Weight	75			
Birth Date	06/11/1979			
Genre	Masculino			
Patient Details				
Clinical Process ID	215336478			
Complaints	Há meia-hora atrás, assim de repente, comecei a sentir uma pontada aqui nas costas e desde então falta-me o ar e tenho tosse.			
Symptoms	Tosse + (dispneia ou dor pleurítica) [a]			
Temperature	36.3			
Heart Rate	111			
Respiratory Rate	34			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	100			
Diastolic Blood Pressure	56			
Urine Flow Rate	20			
Central Venous Pressure	9			
Exclusions	-			
Clinical History	Fumador			
Glasgow Comma Scale	O paciente está acordado, cumpre ordens e responde.			
Physical Exam	Mucosas coradas, hidratadas.Taquipneico com tiragem.Menor expansão torácica à direita.Murmúrio vesicular diminuido à direita.			
	00h00	**01h00**	**01h30**	**02h00**
Lactate	2			
Complementary Exams	RX Tórax: pneumotórax à direita			
Exams Results	Leucocitos 16.000x10e9/L			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.58			
pC02	18			
p02	56			
ctHb	Random			
Hct	Random			
sO2	84%			
FO2Hb	Random			
FMetHb	Random			

FCOHb	Random			
FHHb	Random			
K+	Random			
Na+	Random			
Ca2+	Random			
Lac	2			
tCO2(B)	Random			
Base(Ecf)	Random			
HCO3-(P,st)	22			
HCO3-(P)	21			
AnionGap,K+	Random			

Clinical Case 4

ID	4			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	False ???			
Patient Personal Details				
Name	Nélia Fortes			
Age	44			
Weight	90			
Birth Date	08/07/1979			
Genre	Feminino			
Patient Details				
Clinical Process ID	195523647			
Complaints	Ando com tosse seca e a sentir-me cansada há alguns dias, hoje começou a faltar-me o ar.			
Symptoms	Tosse + (dispneia ou dor pleurítica) [a]			
Temperature	37.3			
Heart Rate	125			
Respiratory Rate	40			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	78			
Diastolic Blood Pressure	44			
Urine Flow Rate	40			
Central Venous Pressure	12			
Exclusions	-			
Clinical History	Insuficiência venosa periférica, Obesidade, Fumadora			
Glasgow Comma Scale	A paciente está acordada, cumpre ordens e responde.			
Physical Exam	Mucosas coradas, hidratadas. Ingurgitamento venoso jugular. Taquipneica com tiragem e cianose.AC sons taquicardicos. AC MV mantido bilateralmente sem ruidos adventícios. Edema do MID.			
	00h00	**01h00**	**01h30**	**02h00**
Lactate	6			
Complementary Exams	Angio-TC pulmonar: documenta-se tromboembolismo pulmonar envolvendo os ramos principais de ambas as artérias pulmonares			
Exams Results	Leucocitos 16.000x10e9/L, D-dimeros >5 mcg/mL			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.58			
pC02	28			
p02	51			
ctHb	Random			
Hct	Random			
sO2	86%			
FO2Hb	Random			

FMetHb	Random			
FCOHb	Random			
FHHb	Random			
K+	Random			
Na+	Random			
Ca2+	Random			
Lac	5			
tCO2(B)	Random			
Base(Ecf)	Random			
HCO3-(P,st)	15			
HCO3-(P)	14			
AnionGap,K+	Random			

Clinical Case 5

ID	5			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	False			
Patient Personal Details				
Name	Maria Conceição			
Age	28			
Weight	58			
Birth Date	05/01/1985			
Genre	Feminino			
Patient Details				
Clinical Process ID	195523647			
Complaints	Doi-me muito a barriga e perdi muito sangue pela vagina. Sinto-me muito fraca, há pouco desmaiei e tudo.			
Symptoms	Dor abdominal ou icterícia [c]			
Temperature	37.3			
Heart Rate	115			
Respiratory Rate	16			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	70			
Diastolic Blood Pressure	38			
Urine Flow Rate	0			
Central Venous Pressure	5			
Exclusions	-			
Clinical History	Saudável			
Glasgow Comma Scale	A paciente está acordada, cumpre ordens e responde.			
Physical Exam	Mucosas coradas, desidratadas.Eupneica.AC sons taquicardicos.AP murmúrio vesicular mantido bilateralmente sem ruidos adventicos.Abdómen pouco depressivel, com defesa generalizada e dor à descompressão.			
	00h00	**01h00**	**01h30**	**02h00**
Lactate	2			
Complementary Exams	Ecografia abdominal e pélvica: massa extra-uterina hiperecogénica compatível com gravidez ectópica			
Exams Results	Hb 6.8 g/dL, leucocitos 18.000x10e9/L, PCR 12 mg/mL, β-HCG 1000 mIU/mL			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.42			
pCO2	37			
pO2	90			
ctHb	Random			
Hct	Random			
sO2	98%			
FO2Hb	Random			

FMetHb	Random			
FCOHb	Random			
FHHb	Random			
K+	Random			
Na+	Random			
Ca2+	Random			
Lac	2			
tCO2(B)	Random			
Base(Ecf)	Random			
HCO3-(P,st)	23			
HCO3-(P)	22			
AnionGap,K+	Random			

Clinical Case 6

ID	6			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	True			
Patient Personal Details				
Name	Carlos Mota			
Age	23			
Weight	77			
Birth Date	05/09/1990			
Genre	Masculino			
Patient Details				
Clinical Process ID	195523647			
Complaints	Há 2 dias que me muito a cabeça aqui atrás na nuca e tenho febre, acho que estou cada vez pior.			
Symptoms	Cefaleias + vómitos [e]			
Temperature	39			
Heart Rate	110			
Respiratory Rate	24			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	115	108	110	114
Diastolic Blood Pressure	55	50	52	56
Urine Flow Rate	20	50	80	220
Central Venous Pressure	11	11	10	10
Exclusions	-			
Clinical History	Saudável			
	00h00	**01h00**	**01h30**	**02h00**
	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.
Physical Exam	Mucosas coradas, desidratadas. Taquipneico. Auscultação cardio-pulmonar sem alterações. Lesões púrpura nos membros inferiores. Rigidez da nuca.	Mucosas coradas, desidratadas. Taquipneico. Auscultação cardio-pulmonar sem alterações. Lesões púrpura nos membros inferiores. Rigidez da nuca.	Mucosas coradas, desidratadas. Taquipneico. Auscultação cardio-pulmonar sem alterações. Lesões púrpura nos membros inferiores. Rigidez da nuca.	Mucosas coradas, desidratadas. Taquipneico. Auscultação cardio-pulmonar sem alterações. Lesões púrpura nos membros inferiores. Rigidez da nuca.
Lactate	5	4	3	2
Complementary Exams	Punção lombar			
Exams Results	Leucocitos 20.000x10e9/L, plaquetas 110.000x10e9/L, PCR 14.0 mg/dL, punção lombar: turvo, leucócitos 500/mm3 com predomínio Polimorfonucleares, glicose 30 mg/dL, proteínas 100mg/dL			

Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.46	7.48	7.45	7.44
pC02	33	34	36	35
p02	92	94	92	94
ctHb	Random	Random	Random	Random
Hct	Random	Random	Random	Random
sO2	98%	98	97	98
FO2Hb	Random	Random	Random	Random
FMetHb	Random	Random	Random	Random
FCOHb	Random	Random	Random	Random
FHHb	Random	Random	Random	Random
K+	Random	Random	Random	Random
Na+	Random	Random	Random	Random
Ca2+	Random	Random	Random	Random
Lac	5	4	3	2
tCO2(B)	Random	Random	Random	Random
Base(Ecf)	Random	Random	Random	Random
HCO3-(P,st)	23	25	24	25
HCO3-(P)	22	21	22	23
AnionGap,K+	Random	Random	Random	Random

Clinical Case 7

ID	7			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	True			
Patient Personal Details				
Name	Teresa Silva			
Age	41			
Weight	59			
Birth Date	13/10/1972			
Genre	Feminino			
Patient Details				
Clinical Process ID	125469855			
Complaints	Ontem depois do jantar comecei a ter uma dor muito forte na barriga que ainda não passou e vomito tudo, não aguento nada no estômago.			
Symptoms	Dor abdominal ou icterícia [c]			
Temperature	38.2			
Heart Rate	113			
Respiratory Rate	24			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	88	98	100	110
Diastolic Blood Pressure	46	50	55	60
Urine Flow Rate	20	20	80	150
Central Venous Pressure	8	9	9	11
Exclusions	-			
Clinical History	Saudável			
	00h00	**01h00**	**01h30**	**02h00**
Glasgow Comma Scale	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.
Physical Exam	Mucosas coradas, desidratadas.	Mucosas coradas, desidratadas.	Mucosas coradas, desidratadas.	Mucosas coradas, desidratada

	Taquipneica sem tiragem ou cianose. AP murmúrio vesicular diminuído na base direita. Abdómen com dor à palpação e defensa no hipocôndrio direito.	Taquipneica sem tiragem ou cianose. AP murmúrio vesicular diminuído na base direita. Abdómen com dor à palpação e defensa no hipocôndrio direito.	Eupneica. AP murmúrio vesicular diminuído na base direita. Abdómen com dor à palpação e defensa no hipocôndrio direito.	s. Eupneica. AP murmúrio vesicular diminuído na base direita. Abdómen com dor à palpação e defensa no hipocôndrio direito.
Lactate	2	3	1	1
Complementary Exams	Ecografia abdominal distensão da vesícula biliar com espessamento das paredes, líquido perivesicular e cálculos no infundíbulo			
Exams Results	Leucocitos 24.000x10e9/L, PCR 24.0 mg/dL, fosfatase alcalina 460 U/L, GGT 400 U/L			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.31	7.33	7.35	7.36
pC02	32	35	36	40
p02	84	86	85	88
ctHb	Random	Random	Random	Random
Hct	Random	Random	Random	Random
sO2	94%	95%	94%	95%
FO2Hb	Random	Random	Random	Random
FMetHb	Random	Random	Random	Random
FCOHb	Random	Random	Random	Random
FHHb	Random	Random	Random	Random
K+	Random	Random	Random	Random
Na+	Random	Random	Random	Random
Ca2+	Random	Random	Random	Random
Lac	2	3	1	1
tCO2(B)	Random	Random	Random	Random
Base(Ecf)	Random	Random	Random	Random
HCO3-(P,st)	16	18	19	22
HCO3-(P)	15	19	20	21
AnionGap,K+	Random	Random	Random	Random

Clinical Case 8

ID	8
Sepsis Positive Identification	True
Sepsis Positive Confirmation	True
Patient Personal Details	
Name	José Murtosa
Age	78
Weight	80
Birth Date	26/08/1935
Genre	Masculino
Patient Details	
Clinical Process ID	225336457
Complaints	Desde há 3 dias que me dói a barriga e tenho diarreia. Hoje já devo ter tido umas 10 dejecções.
Symptoms	Dor abdominal ou icterícia [c]
Temperature	38.2
Heart Rate	120
Respiratory Rate	34

	00h00	01h00	01h30	02h00
Systolic Blood Pressure	70	80	90	98
Diastolic Blood Pressure	34	42	48	52
Urine Flow Rate	0	0	30	100
Central Venous Pressure	6	6	9	9
Exclusions	-			
Clinical History	Hipertensão arterial, DPOC tabágica, internamento recente por pneumonia			
	00h00	**01h00**	**01h30**	**02h00**
Glasgow Comma Scale	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.	O paciente está acordado, cumpre ordens e responde.
Physical Exam	Mucosas descoradas, desidratadas. Taquipneico sem tiragem ou cianose. Auscultação cardio-pulmonar sem alterações. Abdómen distendido, doloroso à palpação de forma generalizada.	Mucosas descoradas, desidratadas. Taquipneico sem tiragem ou cianose. Auscultação cardio-pulmonar sem alterações. Abdómen distendido, doloroso à palpação de forma generalizada.	Mucosas descoradas, desidratadas. Taquipneico sem tiragem ou cianose. Auscultação cardio-pulmonar sem alterações. Abdómen distendido, doloroso à palpação de forma generalizada.	Mucosas descoradas, desidratadas. Taquipneico sem tiragem ou cianose. Auscultação cardio-pulmonar sem alterações. Abdómen distendido, doloroso à palpação de forma generalizada.
Lactate	6	5	3	1
Complementary Exams	RX abdomen tangencial: distensão de ansas intestinais com níveis hidro-aéreos			
Exams Results	Leucocitos 30.000x10e9/L, PCR 22.0 mg/dL, creatinina 3,5 mg/dL, Pesquisa toxina de Clostridium *difficile* nas fezes positiva			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.18	7.22	7.28	7.31
pC02	22	22	24	29
p02	68	70	71	74
ctHb	Random	Random	Random	Random
Hct	Random	Random	Random	Random
sO2	92%	93%	93%	93%
FO2Hb	Random	Random	Random	Random
FMetHb	Random	Random	Random	Random
FCOHb	Random	Random	Random	Random
FHHb	Random	Random	Random	Random
K+	Random	Random	Random	Random
Na+	Random	Random	Random	Random
Ca2+	Random	Random	Random	Random
Lac	6	5	3	1
tCO2(B)	Random	Random	Random	Random
Base(Ecf)	Random	Random	Random	Random
HCO3-(P,st)	8	9	11	14
HCO3-(P)	7	10	12	14
AnionGap,K+	Random	Random	Random	Random

Clinical Case 9

ID	9			
Sepsis Positive Identification	True			
Sepsis Positive Confirmation	false			
Patient Personal Details				
Name	Beatriz Fernandes			
Age	68			
Weight	80			
Birth Date	26/08/1935			
Genre	Feminino			
Patient Details				
Clinical Process ID	265441993			
Complaints	Falta-me muito o ar, o oxigénio já não faz nada e tenho mais tosse, com expectoração verde.			
Symptoms	Tosse + (dispneia ou dor pleurítica) [a]			
Temperature	34.6			
Heart Rate	117			
Respiratory Rate	44			
	00h00	**01h00**	**01h30**	**02h00**
Systolic Blood Pressure	68	72	80	80
Diastolic Blood Pressure	34	38	44	42
Urine Flow Rate	0	0	0	0
Central Venous Pressure	9	9	12	15
Exclusions	Não candidato a técnicas de suporte de orgãos			
Clinical History	Neoplasia do pulmão em estádio IV, DPOC tabágica sob oxigenoterapia domiciliária			
Glasgow Comma Scale	O paciente está acordado, cumpre ordens e responde.			
Physical Exam	Caquéxia. Mucosas descoradas, desidratadas.Taquipneica, com tiragem e cianose.Auscultação pulmonar com diminuição do murmúrio à esquerda.Roncos e sibilos dispersos lateralmente.			
	00h00	**01h00**	**01h30**	**02h00**
Lactate	8	12	>14	>14
Complementary Exams	RX Tórax			
Exams Results	Anemia, leucocitose, pcr elevada, ldh 3000			
Patient Blood Gas Report				
	00h00	**01h00**	**01h30**	**02h00**
pH	7.30			
pC02	74			
p02	58			
ctHb	Random	Random	Random	Random
Hct	Random	Random	Random	Random
sO2	86%			
FO2Hb	Random	Random	Random	Random
FMetHb	Random	Random	Random	Random
FCOHb	Random	Random	Random	Random
FHHb	Random	Random	Random	Random
K+	Random	Random	Random	Random
Na+	Random	Random	Random	Random
Ca2+	Random	Random	Random	Random
Lac	9			
tCO2(B)	Random	Random	Random	Random
Base(Ecf)	Random	Random	Random	Random
HCO3-(P,st)	38			
HCO3-(P)	37			
AnionGap,K+	Random	Random	Random	Random

Clinical Case 10

ID	10
Sepsis Positive Identification	false
Sepsis Positive Confirmation	false
Patient Personal Details	
Name	Vera Santos
Age	34
Weight	
Birth Date	
Genre	Feminino
Patient Details	
Clinical Process ID	
Complaints	-
Symptoms	Doí-me a cabeça e o corpo todo e tenho febre desde ontem.
Temperature	37.8ºC
Heart Rate	92
Respiratory Rate	18

Clinical Case 11

ID	11
Sepsis Positive Identification	false
Sepsis Positive Confirmation	false
Patient Personal Details	
Name	Artur Fontes
Age	27
Weight	
Birth Date	
Genre	Masculino
Patient Details	
Clinical Process ID	
Complaints	-
Symptoms	Estou muito mal, não consigo respirar e doí-me o peito.
Temperature	36.6
Heart Rate	122
Respiratory Rate	38

Clinical Case 12

ID	12
Sepsis Positive Identification	false
Sepsis Positive Confirmation	false
Patient Personal Details	
Name	Célia Pinheiro
Age	58
Weight	
Birth Date	
Genre	Feminino
Patient Details	
Clinical Process ID	
Complaints	-
Symptoms	Estou com uma dor aqui nos rins desde há 2 dias e arde muito quando urino.
Temperature	37.2
Heart Rate	102
Respiratory Rate	18

Bibliography

Abt, C. (1987). *Serious Games*. University Press of America.

Adams, E. and Dormans, J. (2012). *Game mechanics: advanced game design*. New Riders.

Altizer, S., Dobson, A., Hosseini, P., Hudson, P., Pascual, M., and Rohani, P. (2006). Seasonality and the dynamics of infectious diseases. *Ecology letters*, 9(4):467–484.

Alvarez, J. (2007). *Du jeu vidéo au serious game: approches culturelle, pragmatique et formelle*. PhD thesis, Toulouse 2.

Angus, D. C., Linde-Zwirble, W. T., Lidicker, J., Clermont, G., Carcillo, J., and Pinsky, M. R. (2001). Epidemiology of severe sepsis in the united states: analysis of incidence, outcome, and associated costs of care. *Critical care medicine*, 29(7):1303–1310.

Balay, S., Buschelman, K., Eijkhout, V., Gropp, W. D., Kaushik, D., Knepley, M. G., McInnes, L. C., Smith, B. F., and Zhang, H. (2004). PETSc users manual. Technical Report ANL-95/11 - Revision 2.3.0, Argonne National Laboratory.

BreakAway (2007). Pulse!! serious game.

Bruner, J. S. (1961). The act of discovery. *Harvard educational review*.

Campaign, S. S. (2006). Surviving sepsis campaign.

Chen, H., Wigand, R. T., and Nilan, M. S. (1999). Optimal experience of web activities. *Computers in human behavior*, 15(5):585–608.

Cook, D. A., Hatala, R., Brydges, R., Zendejas, B., Szostek, J. H., Wang, A. T., Erwin, P. J., and Hamstra, S. J. (2011). Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *Jama*, 306(9):978–988.

Corti, K. (2002). Game-based learning a serious business application.

Costikyan, G. (2002). I have no words & i must design: Toward a critical vocabulary for games. In *CGDC Conf.*

Crookall, D. (1995). A guide to the literature on simulation/gaming. *Simulation and gaming across disciplines and cultures: ISAGA at a watershed*, pages 151–177.

Crookall, D. and Saunders, D. (1989). Towards an integration of communication and simulation. *Communication and simulation: From two fields to one theme*, pages 3–29.

Csikszentmihaly, M. (1990). Flow: The psychology of optimal experience.

Csikszentmihalyi, M. (2000). *Beyond boredom and anxiety*. Jossey-Bass.

Czikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. *Praha: Lidové Noviny. Cited on page*.

Danai, P. A., Sinha, S., Moss, M., Haber, M. J., and Martin, G. S. (2007). Seasonal variation in the epidemiology of sepsis*. *Critical care medicine*, 35(2):410–415.

De Freitas, S. and Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers & Education*, 46(3):249–264.

de Wit-Zuurendonk, L. and Oei, S. (2011). Serious gaming in women's health care. *BJOG*, 118:17–21.

Dellinger, R. P., Levy, M. M., Carlet, J. M., Bion, J., Parker, M. M., Jaeschke, R., Reinhart, K., Angus, D. C., Brun-Buisson, C., Beale, R., et al. (2008). Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2008. *Intensive care medicine*, 34(1):17–60.

Dellinger, R. P., Levy, M. M., Rhodes, A., Annane, D., Gerlach, H., Opal, S. M., Sevransky, J. E., Sprung, C. L., Douglas, I. S., Jaeschke, R., et al. (2013). Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock, 2012. *Intensive care medicine*, 39(2):165–228.

Direcção-Geral da Saude (2010). Criação e implementação da via verde de sepsis (vvs).

Djaouti, D. (2011). *Serious Game Design: considérations théoriques et techniques sur la création de jeux vidéo à vocation utilitaire*. PhD thesis, Toulouse 3.

Driskell, J. E. and Johnston, J. H. (1998). Stress exposure training. *Making decisions under stress: Implications for individual and team training*, pages 191–217.

Durkin, K. (2010). Videogames and young people with developmental disorders. *Review of General Psychology*, 14(2):122.

Elliot, A. J. and Harackiewicz, J. M. (1994). Goal setting, achievement orientation, and intrinsic motivation: A mediational analysis. *Journal of personality and social psychology*, 66(5):968.

Engel, C. E. (1997). Not just a method but a way of learning. *The challenge of problem-based learning*, 2:17–27.

Finneran, C. M. and Zhang, P. (2003). A person–artefact–task (pat) model of flow antecedents in computer-mediated environments. *International Journal of Human-Computer Studies*, 59(4):475–496.

Foreman, J., Gee, J. P., Herz, J., Hinrichs, R., Prensky, M., and Sawyer, B. (2004). Game-based learning: How to delight and instruct in the 21st century. *Educause Review*, 39:50–67.

Garris, R., Ahlers, R., and Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & gaming*, 33(4):441–467.

Graafland, M., Schraagen, J. M., and Schijven, M. P. (2012). Systematic review of serious games for medical education and surgical skills training. *British Journal of Surgery*, 99(10):1322–1330.

Han, P. K., Klein, W. M., and Arora, N. K. (2011). Varieties of uncertainty in health care a conceptual taxonomy. *Medical Decision Making*, 31(6):828–838.

Heinrichs, W. L., Youngblood, P., Harter, P. M., and Dev, P. (2008). Simulation for team training and assessment: case studies of online training with virtual worlds. *World Journal of Surgery*, 32(2):161–170.

Hoffman, D. L. and Novak, T. P. (1996). Marketing in hypermedia computer-mediated environments: conceptual foundations. *The Journal of Marketing*, pages 50–68.

HumanSim (2009). Zero hour: America's medic serious game.

HumanSim (2011). Pivotal decision serious game.

in Learning Inc., I. (2010). Clinispace serious game.

Institute of Medicine (2001). Crossing the quality chasm: A new health system for the 21st century. *Washington, DC: National Academies Press.*

Jameson, A., Pierce, N. A., and Martinelli, L. (1998). Optimum aerodynamic design using the Navier–Stokes equations. In *Theoretical and Computational Fluid Dynamics*, volume 10, pages 213–237. Springer-Verlag GmbH.

Kato, M. P. (2010). Video games in health care: Closing the gap. *Review of General Psychology*, 14(2):113–121.

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, 8(1):13 – 24.

Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology*, 38(3):394–404.

Knight, J. F., Carley, S., Tregunna, B., Jarvis, S., Smithies, R., de Freitas, S., Dunwell, I., and Mackway-Jones, K. (2010). Serious gaming technology in major incident triage training: A pragmatic controlled trial. *Resuscitation*, 81(9):1175–1179.

Kohn, K., Corrigan, J., and Donaldson, M. (1999). To err is human: Building a safer health system. *Washington, DC: National Academies Press.*

Kolb, D. A. et al. (1984). *Experiential learning: Experience as the source of learning and development*, volume 1. Prentice-Hall Englewood Cliffs, NJ.

Lederman, L. C. (1992). Debriefing: Toward a systematic assessment of theory and practice. *Simulation & Gaming*, 23(2):145–160.

Lederman, L. C. and Fumitoshi, K. (1995). Debriefing the debriefing process: A new look. *Simulation and gaming across disciplines and cultures. London: Sage Publications*.

Marshall, J. C., Dellinger, R. P., and Levy, M. (2010). The surviving sepsis campaign: a history and a perspective. *Surgical infections*, 11(3):275–281.

Marta, A. C., Mader, C. A., Martins, J. R. R. A., van der Weide, E., and Alonso, J. J. (2007). A methodology for the development of discrete adjoint solvers using automatic differentiation tools. *International Journal of Computational Fluid Dynamics*, 21(9–10):307–327.

Marta, A. C., Shankaran, S., Holmes, D. G., and Stein, A. (2009). Development of adjoint solvers for engineering gradient-based turbomachinery design applications. In *Proceedings of the ASME Turbo Expo 2009: Power for Land, Sea and Air*, number GT2009-59297.

Martins, J. R. R. A., Alonso, J. J., and Reuther, J. J. (2004). High-fidelity aerostructural design optimization of a supersonic business jet. *Journal of Aircraft*, 41(3):523–530.

Maslow, A. H. (1963). *The creative attitude*. Psychosynthesis Research Foundation.

Michael, D. and Chen, S. (2006). *Serious games: games that educate, train and inform*. Thomson Course Technology.

Nocedal, J. and Wright, S. J. (1999). *Numerical optimization*. Springer.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the horizon*, 9(5):1–6.

Randel, J. M., Morris, B. A., Wetzel, C. D., and Whitehill, B. V. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation & Gaming*, 23(3):261–276.

Rendas, A. B., Fonseca, M., Pinto, P. R., et al. (2006). Toward meaningful learning in undergraduate medical education using concept maps in a pbl pathophysiology course. *Advances in Physiology Education*, 30(1):23–29.

Ribeiro, C., Antunes, T., Monteiro, M., and Pereira, J. (2013). Serious games in formal medical education: An experimental study. In *Games and Virtual Worlds for Serious Applications (VS-GAMES), 2013 5th International Conference on*, pages 1–8.

Rollings, A. and Adams, E. (2003). *Andrew Rollings and Ernest Adams on game design*. New Riders.

Sabri, H., Cowan, B., Kapralos, B., Porte, M., Backstein, D., and Dubrowskie, A. (2010). Serious games for knee replacement surgery procedure education and training. *Procedia-Social and Behavioral Sciences*, 2(2):3483–3488.

Sawyer, B. (2007). The ”serious games” landscape. In *Instructional & Research Technology Symposium for Arts, Humanities and Social Sciences, Camden*.

Schreuder, H., Oei, G., Maas, M., Borleffs, J., and Schijven, M. (2011). Implementation of simulation in surgical practice: minimally invasive surgery has taken the lead: the dutch experience. *Med Teach*, (33):105–120.

Sociedade Portuguesa de Cuidados Intensivos and Ordem dos Médicos (2010). Transporte de doentes críticos - recomendações.

Stanford University, S. o. M. (2011). Septris serious game.

Susi, T., Johannesson, M., and Backlund, P. (2007). Serious games: An overview.

TruSim (2008). Triage trainer serious game.

VirtualHeroes (2007). 3diteams serious game.

Wexley, K. N. and Latham, G. P. (2001). Developing and training human resources in organizations (prenticee hall series in human resources) author.

Witmer, B. and Singer, M. (1994). Measuring immersion in virtual environments. *US Army Res. Inst., Alexandria, VA, Tech. Rep*, 1014.

Wittgenstein, L. (1953). *Philosophical investigations*. Oxford: Basil Blackwell.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer*, 38:25–32.