

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

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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 every 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.

Training of emergency department healthcare professionals is essential, and should be attended regularly 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 often considered as out-dated for the younger generation, the so-called "digital natives". The usage of serious games is a trend that has been considered when discussing new tools for teaching and training in various fields, including healthcare. Several research works on the impact of applying such technologies in healthcare, stating that serious games could provide new approaches and opportunities have been published.

This paper presents the Sepsis Fast Track serious game. It is a serious game developed to teach and train nurses and physicians working in hospital Emergency Departments on the Sepsis Fast Track protocol. An evaluation study carried out with the healthcare professionals is also presented. The main goal of which was to evaluate the impact of serious games on professional working practices.

I. 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 every hour that passes without the appropriate antibiotic therapy, 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 [1] based on the Surviving Sepsis Campaign guidelines [2]. The Sepsis Fast Track may facilitate the identifications of these cases and as a result reduce the in-hospital levels of mortality and morbidity.

To guarantee that healthcare professionals are update and aware of the Sepsis Fast Track protocol, including its procedures and when to be performed, professionals are required to participate in training sessions. These training sessions

should occur frequently, not only to refresh their knowledge, but also to teach healthcare professionals any changes that may occur in the Sepsis Fast Track protocol, which is updated every three years. Currently, the Sepsis Fast Track training program uses traditional teaching methods, such as watching videos and attending workshop classes with PowerPoint slide presentation.

Serious games are gaining interest as a powerful tool to educate and train people [1]. It is based on experiential learning paradigm, fostering active participation through actions creating motivation and satisfaction. Recently the field of medicine has also recognized the potential of serious games for clinical education. Several authors [2], [3], [4] have conducted systematic reviews regarding the usage of serious games for clinical education. Moreover, the application of serious games for learning and training is also expanding; in the last decade, several studies on the impact of the application of such technologies in healthcare have stated that serious games may be a useful approach and provide opportunities [5], [6].

Section II describes background work related to serious games in clinical education. Section III presents the sepsis fast track serious game and the game design considerations. Section IV describes the evaluation study conducted whereas the results are presented in section V and detailed discussed in Section VI. We finalize with conclusions and future work (Section VII).

II. SERIOUS GAMES FOR CLINICAL EDUCATION

Clinical education is clearly much more than acquiring knowledge. It has a social responsibility component. It needs to train competences like time-critical decision-making, dealing with risk and uncertainty, communication with peers, patients and relatives, to deal with error and failure and problem-solving techniques. In sum, it must enable doctors to know, to put knowledge successfully into practice and to develop appropriate behaviors in order to accomplish their mission. "But how this goal can best be accomplished, given the time constraints faced by physicians, has challenged the profession and medical educators since the early 1900s" [7].

Recently, healthcare professionals, namely physicians and medical students, have become a target group for serious

games. These games appear to have a number of characteristics to answer the aforementioned current challenges [5]. Serious games are potentially powerful tools for training, as they are able to create immersive simulation environments and can easily be accessed at almost any time from almost any place. The player can train at his/her own pace and can be evaluated as well, which makes it possible to integrate the games into a learning curriculum or a crediting system.

This trend has resulted in the development of several serious games aiming at clinical education. For example, the Critical Transport serious game which was designed to teach healthcare students the recommendations for the transport of critically ill patients [6]. It is composed of two main scenes, one where the player has to evaluate ten parameters regarding the patient's condition, and another where the player must choose the correct team and equipment for the transport of the patient. The evaluation study carried out showed a positive impact on player's knowledge [6].

Another example is Pulse!! serious game designed for training healthcare professionals in clinical skills [8]. It uses proprietary 3D and game technology by BreakAway's¹ to recreate a lifelike, interactive, virtual environment in which civilian and military healthcare professionals can practice clinical skills in order to better respond to injuries sustained during catastrophic incidents, such as combat or bioterrorism.

3DiTeams is a multiplayer serious game for clinical education and team training [9]. It is a first-person game developed using the Unreal Engine. The training is based on the DoD Patient Safety Program and Agency for Healthcare Research and Quality (AHRQ) TeamSTEPPS curriculum.

Clinispace serious game [10] 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. It is targeted to medical students, and allow them to train procedures just like they would in real life, such as washing their hands, performing tests and talking to patients.

Finally, a serious game was developed in 2011 by Stanford University - School of Medicine entitled Septris [11] which provides a practical approach to the application of the sepsis fast track protocol procedures. Septris serious game runs in a web browser and 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.

III. SEPSIS FAST TRACK SERIOUS GAME

The Sepsis Fast Track serious game was developed together with emergency department healthcare professionals,

including both nurses and physicians. In order to ensure that all the information and procedures in the game are correct and according to the guidelines provided by the Portuguese Directorate-General of Health, we used a co-creative design approach involving both nurses and physicians. As opposed to the Septris serious game, 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 similar to the real world. The underlying idea was to facilitate the player's interactions with the virtual environment in order to augment the possibility of transferring the knowledge acquired during gameplay to real working practices. Therefore, before starting the development of this project's, several observation sessions were conducted, as well as photography sessions documenting the hospital's Emergency Department facilities and equipment.

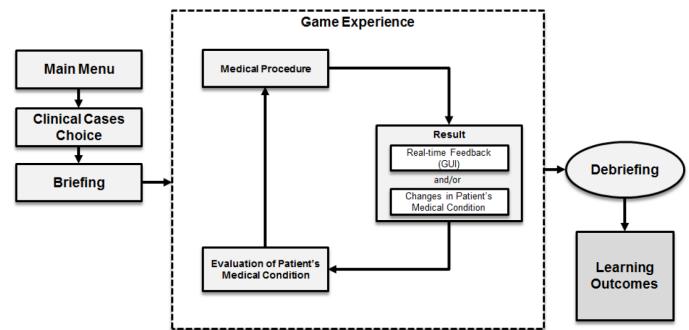


Fig. 1. Sepsis Fast Track serious game stages.

In Figure 1 the stages that compose this serious game are presented. When a player starts the Sepsis Fast Track serious game, he/she is prompted with the Main Menu, where he/she must identify him/herself using his/her name and personnel hospital number. The player must also select if he/she is a nurse or a physician, which will allow him/her to play the respective serious game phase. 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 [12]. 1) Briefing: In the briefing phase the main objectives are described in detail, allowing the player to understand what the serious game about and its main pedagogical goals. There are four pedagogical goals; for each one, the player must choose his/her confidence level concerning their knowledge about this topic. 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.

2) Game Experience: After the briefing, the player is prompt to choose which clinical cases he/she wishes to play. Once the clinical cases are chosen the game experience begins. According to the role of the player a specified game's phase begins, either Identification of a Possible Sepsis Case for nurses (see Figure 2) or Sepsis Case Confirmation and Therapy

¹<http://www.breakawaygames.com>

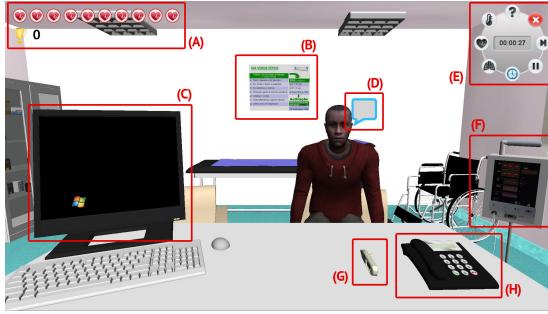


Fig. 2. Identification of a Possible Sepsis Case Game Experience.

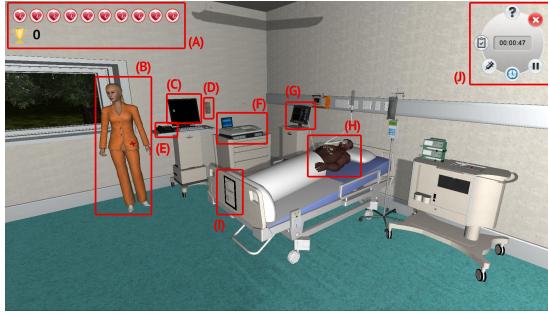


Fig. 3. Sepsis Case Confirmation and Therapy Game Experience.

for physicians (see Figure 3). Each game phase occurs in a particular part of the Emergency Department. Therefore, each phase has its own game environment. 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. Figure 3 presents the elements that the player has available for the patient's evaluation, including Score and Lives HUD (A), Sepsis Poster (B), IT System (C), Phone book (D), Phone (E), Blood Gas Analyser (F), Vital Signs Monitor (G), Thermometer (H), and Phone (I).

The Sepsis Case Confirmation and Therapy phase takes place after the triage and is performed by a physician in an observation room. Figure 3 presents all the elements that the player has available during this phase: Score and Lives HUD (A), Nurse (B), IT System (C), Phone book (D), Phone (E), Blood Gas Analyser (F), Vital Signs Monitor (G), Patient (H), Patient's chart (I), and Information/Options HUD (J). All the interactions with the elements of the game are accomplished through point-and-click.

3) The debriefing is the last phase of the gameplay and is a very important part of the serious game, as it functions as a link between the game experience and the learning outcomes [13]. In the debriefing, the players have the opportunity to analyse how he/she performed during the game. If a player performed a procedure incorrectly, it is shown in the debriefing, along with the right procedure and an explanation of why it is the right choice.

In order to make this serious game more challenging and by consequence more motivating and engaging, the designers decided to measure the player's performance and present it

in a Score and Lives HUD. The number of available Lives decreases whenever a player makes an error, either major or minor, depending on which procedure the mistake occurred in. Real-time Feedback is an important game feature and is also presented to the player. This feedback allows the player to know if the procedure that he/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/she won. If a procedure is incorrectly performed, in addition to that information, the player is advised on the correct procedure and is informed about the lives that he/she lost.

The development of the game experience phase was based on both the Problem-based Gaming Model [14] and the Input-Process-Outcome Game Model [13], as shown in Figure 1. It consists of three main modules that form a cyclic process. During gameplay, the player interacts with the game environment, executing medical procedures that may have impact on the environment and/or on the medical condition of the patient. Depending on the procedure and when it is conducted, the impact can be positive or negative. This information is provided on the user interface, letting the player know if the procedure was correctly performed, and if not, what he/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.

IV. EVALUATION

The main goal of the Sepsis Fast Track serious game evaluation was to assess its impact on the 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, each with its own specific learning and training outcomes. Therefore, the evaluation study was also divided into two main phases, detailed in the following sub-sections.

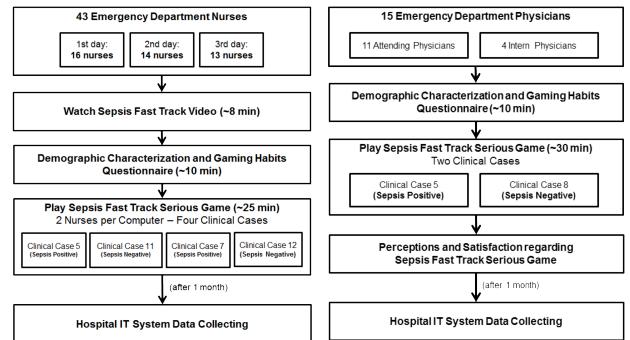


Fig. 4. Research flowchart: nurses (left) and physicians (right)

A. Identification of a Possible Sepsis Case

The Identification of a Possible Sepsis Case evaluation phase aimed at understanding if and how the game impacted the work practices of Emergency Department nurses after

playing the Sepsis Fast Track serious game in an evaluation session.

This study was done over the course of three days on-site at the hospital facilities. It included all 43 Emergency Department nurses responsible for the triage of patients. Figure 4 presents a research flowchart with the methodology that was followed in this study. 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, specifically the ACLS Trainer, Israel catastrophe game, and Resuscitation! serious games. 35 of the 43 nurses already had previous Sepsis Fast Track training in a traditional class setting.

B. Sepsis Case Confirmation and Therapy

The Sepsis Case Confirmation and Therapy evaluation phase was intended to understand how the game impacted the work practices of Emergency Department physicians as well as understanding their perceptions, expectations and satisfaction regarding the Sepsis Fast Track serious game and its suitability to teach this medical procedure both to attending and intern physicians.

This 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 intern 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 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. Every game session was individual and a part from the physician or inter only two researchers were present to help with possible questions or doubts about the game.

V. EVALUATION RESULTS

A. Identification of a Possible Sepsis Case

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. For this group interviews were not part of the study because of time restrictions as it involved all the nurses of the emergency department.

1) In-game Log Data: Sepsis Fast Track serious game is able to log every procedure (medical act and therapeutics) 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 5 shows the number of errors made by the nurses while playing the four clinical cases.

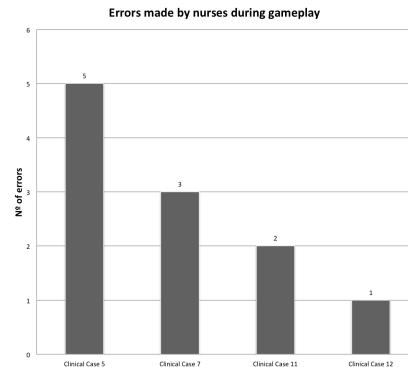


Fig. 5. Number of errors made by nurses playing four clinical cases.

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. 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%.

B. Sepsis Case Confirmation and Therapy

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.

1) Interview Results: As explained previously each doctor was asked to think-aloud while playing the game and these comments were recorded together with the semi-structured interviews and were later transcribed and analysed. The questions used to guide the semi-structured interviews are described in Table I.

The physicians that participated in this study had already had previous contact with the pedagogical content in a workshop class and in attending sepsis patients while working in the Emergency Department. Thus all aware of the importance and goal of the Sepsis Fast Track protocol.

In general all the physicians showed very little tolerance in losing lives and points during the game. In fact, some were so

TABLE I
EXAMPLES OF QUESTIONS USED TO COLLECT PHYSICIANS PERCEPTIONS,
EXPECTATIONS AND SATISFACTION REGARDING THE SEPSIS FAST TRACK
SERIOUS GAME

Do 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 structured and the information is shown? Do you think it help you understand what you did wrong and why?
Did you feel that the game helps you to systematize the protocol steps (medical acts and therapeutics)?
Did you feel in the role of a physician?
Did you think the game is intuitive? Is it easy to understand what you have to do and how you have to do it?
Do you like playing the game? Do you think it is useful?

upset that they actually screamed and hit their hands on the table.

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

"Why did I lose points?? This is not how it's done in real life!"

In this respect the feedback served both to help them understand what to do next but also to bridge the gap between what they do in the real environment and what they are expected to do inside the virtual environment.

"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 it is correct. This is how things should be done."

"It 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."

The opinions about the debriefing diverged among physicians. Some felt that it was very long and what we observed was that they didn't pay much attention to the information being shown. They were more in a hurry to finish and go back to work. Others agreed that it was very well structured and did help them understand why they were penalized in some of their decisions and also helped them remember some particularities about the protocol (e.g. which is the recommended vasopressor, the recommended value for the mean arterial pressure, etc.).

In general all the physicians agreed that the game was suitable to teach and refresh the Sepsis Fast Track protocol. In particular some said that it helps to systematize the protocol

sequence. Nevertheless, the physicians that had more professional experience all expressed that they felt that the game is more suited for intern physicians and not for those already having a vast practical experience in diagnosing and treating sepsis patients.

"Yes, I agree that this game is suitable to teach and refresh the Sepsis Fast Track protocol. It 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 about the protocol in order."

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

When asked if they felt in the role of a real physician while playing the game most of them said that they didn't feel and in fact during the game several physicians forgot what they had already done and sometimes repeated certain actions (e.g. give antibiotic or vasopressors twice) and in this situations they always said *"oh, it's okay. It is just a game."*

They all liked to play the game but when asked if they would play it voluntarily, most of them said no, that they didn't have time and when they did have time they rather prefer to rest or dedicate it to their personal matters.

Finally, the comment common to all the physicians had to do with the way they had to examine the patient in the virtual environment. In the serious game they have to click on the respective medical equipment (e.g. ECG monitor) or patient and nurse to have access to the information needed to make a decision. They found this was not intuitive because when treating a patient they are used to have all the information accessible around them. While administering a therapeutic or observing a patient they can also see the ECG monitor values or the amount of fluids currently being given to the patient among other relevant information.

The intern physicians that participated in this study had all very little experience working in an ED and all came from different hospitals. They all had had some contact with the pedagogical content but always from a theoretical point of view, none had experienced treating sepsis patients. In this regard, all agreed that the game helped having a clearer idea of what the protocol was about, its respective importance in patient care quality and how it had been implemented in that particular hospital.

In general, the intern physicians were a lot more tolerant when they did failures in virtual environment and more comfortable to ask for help instead of starting to question what and why certain information was shown and a particular decision should have been made. In general while receiving a negative feedback they needed time to understand why. However, they all agreed that the feedback was very important because it helped them to understand what to do next, what they did wrong and right.

"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 experienced physician."

The opinion expressed regarding the ability of the serious game support in systematizing the protocol steps (medical acts and therapeutics), was very positive, specifically when combining the information given during gameplay (in-game feedback) and during the debriefing phase. Both during gameplay and in the debriefing phase the intern physicians took notes in their personal notebooks about the Sepsis Fast Track protocol and also tried to discuss what they did versus what they should have actually done.

"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."

Finally, in general they all found that the game was intuitive and were very happy to have the opportunity to play the game. They also showed an interest to play more clinical cases and if it would be possible to have the game available to play 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?"

2) *In-game Log Data:* All the physicians that participated in this evaluation study played only two clinical cases, due to time restrictions. We chose clinical case 8 because is one of the *complete* clinical cases, this is, it is a clinical case where every step of the Sepsis Fast Track protocol (medical acts and therapeutics) 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, it is not consider in this study because it is a very small case which results are negligible.

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, ($\text{MAP} > 65 \text{ mmHg}$), the interns executed all the procedures without errors, as opposed to the attending physicians, who committed errors.

Table II presents the percentage of errors made by attending and intern physicians at a particular step of the protocol, while playing clinical case 8.

3) *Hospital IT System Logs:* In terms of the physician evaluation, the 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. By 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.

TABLE II
NUMBER OF ERRORS MADE BY PHYSICIANS PLAYING CLINICAL CASE 8

Medical Procedure	Attending (11 physicians)	Interns (4 physicians)
Step 2		
Confirm Suspicion	0%	0%
Hipoperfusion?	0%	0%
Without Exclusion Criteria?	0%	0%
VVS Activation (IT System)	54,5%	25%
Step 3a and 3b		
Hemocultures?	9%	50%
Complementary Exams?	9%	75%
Administer Antibiotic Therapy	36,4%	50%
Fluids Quantity	27,3%	100%
Contact ICU	45,5%	75%
Step 4 (CVP >8mmHg)		
Reassess Patient Condition	63,6%	75%
Insert Central Venous Catheter	54,5%	75%
Examine Central Venous Pressure (CVP)	54,5%	75%
Administer Fluid Therapy	72,7%	75%
Step 4 (MAP >65mmHg)		
Reassess Patient Condition	18,2%	0%
Reassess CVP	45,5%	0%
Reassess Urine Flow Rate	27,3%	0%
Administer Vasopressors	63,6%	0%
Step 4 (ScVO2 >70%)		
Reassess Patient Condition	0%	0%
Reassess CVP	0%	0%
Request Blood Venous Gas Exam	0%	0%
Contact ICU	0%	0%
Total	32%	35,7%

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

VI. DISCUSSION

The analysis of the in-game log data, think-aloud and semi-structure interviews has led to interesting observations and has also raised pertinent questions. These observations and questions concern the design of serious games as well as how should be used in clinical education. Moreover, it also allowed to have an insight in the decision-making strategies of both attending and intern physicians.

After analysing the in-game logo data and hospital IT system logs for the nurses, we have realized that the results are quite inconclusive. From the in-game log data we can infer that they improve their performance the more they play the game. Nevertheless, the hospital IT system logs didn't provide the required information to established a clear connection between game performance and work practices improvements. More

data should be capture in future studies, such as, knowledge tests over a long period of time (longitudinal study).

To evaluate the decision-making strategies of both attending and intern physicians we have also collected in-game log data. The in-game log data consisted in the timestamp and sequence of decisions that the attending and intern physicians made while playing each clinical case of the Sepsis Fast Track serious game, both right and wrong decisions.

Our in-game log analysis showed that although attending physicians had previous training in the Sepsis Fast Track protocol and also practical experience in diagnosing and treating sepsis patients their performance wasn't in general superior to the intern physicians. We believe that this result is related to several factors. First, in general physicians carry out the protocol based on previous experience, often including many years diagnosing and treating patients in the Emergency Department requiring to handle situations differently than the Sepsis Fast Track protocol prescribes. In addition, most physicians stated the game did not allow multitasking like in real life. We also noticed that they did more mistakes while reassessing the patient current condition. In the real environment they are used to have all the relevant information visible and easily accessible. Therefore, having to specifically interact with medical equipment and characters in the virtual environment was not intuitive. This opinion was both shared by attending and intern physicians.

The log data also allowed identifying weaknesses in physicians' current knowledge and mistakes in their current practice regarding the Sepsis Fast Track protocol. This information is very interesting as it identifies training needs and generates useful data to better plan future clinical education for this group of professionals.

Another factor described in Section V-B1 was the fact that the physicians didn't feel in the role of a real physician in the virtual environment. From these results we believe that regarding fidelity, clinical case data and patient condition should evolve as close as possible to reality in order to improve game experience and to motivate the player to do the right things. In terms of interactivity, the physicians need to interact with the environment around them more closely to what they are used to do. Unnecessary actions (e.g. clicking objects) distract them and induce them into unnecessary errors because it is not how the real environment works. A virtual environment collapses when the game world is inconsistent with player's expectations [15], [16].

Therefore, our understanding is that interactivity and fidelity are critical factors when designing serious games for clinical education. Specifically, these factors need to be very well balanced in order to create an immersive virtual environment adapted to the physicians expectations where they can learn from experience as they do in the real world. Balancing these factors might also mean including other aspects of the real environment, such as, side-tracks, meaning, issues to distract physicians from following the steps of the protocol. This raises an interesting question regarding serious game design: Should serious games design start from theory/knowledge or from

practice (of the domain)? What are the pros and cons?

After a thorough analysis of the interview and think-out loud results we have noticed that attending physicians are more averse to error than intern physicians. Their reactions were very emotional (e.g. feeling angry and revolted) and it seemed very important to them that we (the people conducting the study) understand and believed that they didn't make a mistake that it was some how a problem with the game and not them. Even though we had clearly stated before the game session that they were not being evaluated, that it would be okay to make mistakes, their attitude throughout the game session didn't change and also they went back to this subject after finishing the game. Although it seemed a rather unexpected reaction, since the apparatus of the training involved a virtual environment (no real patients) and also no formal assessment, this reaction is apparently common and has been reported in [17], [18], [19].

Some of the factors that have been pointed-out as a justification to this reaction are related to the physicians holding themselves to high standards of excellence in providing patient care, and patients and other healthcare workers expecting them to be error-free [18]. Due to this expectations, physicians have a very particular reaction to the possibility of committing an error. Specifically, they struggle between deciding what to do and the fear that anyone might find out [17], [19]. We also believe that their competitive nature, encouraged and stimulated throughout medical school, contributes to this behaviour. Specifically, we have also observed that after the gaming session physicians would compare scores between each other and even would ask us if they had been the worse so far.

From the experience derived from this study and also with the Critical Transport serious game [6] we are led to believe that feedback, both in-game, as well as post-game (debriefing) should perhaps be better integrate with the fun aspect of games in general. In particular, both feedback and assessment have to take into account both the pedagogical content being taught as well as to whom it is being taught. In-game feedback has to provide information both to help the player to improve his current strategy (single-loop learning versus double-loop learning) as well as motivate him to continually being engaged in the game activity. Combining these two effects during game play helps increase the probability of learning to occur.

A. Limitations

Although the use of games is not entirely new, the use of games for training and education is an area under development. Although, there is evidence that games can be effective learning tools, there are still open questions that need to be addressed. One of such is: what are players actually learning and what aspects of games (e.g. feedback, debriefing) contribute to attain the intended learning outcomes? Another central concern is related to the level of acceptance of this educational tool and what are target players expectations. Our study have attempt to address both concerns. As it is an initial study, more research is required to better understand what do

physicians expect from this educational tool, what is the level of acceptance and how these tools can impact work practices. In particular, a bigger and more diverse sample needs to be tested. It should include more nurses, attending and intern physicians working in different hospitals. This will allow us to undertake a quantitative analysis and correlate relevant information such as gaming habits and professional experience to both satisfaction as well as level of acceptance. Also, knowledge pre, post and retention-tests should be included in order to assess learning efficacy, as well as interviews to every participant of the study (including nurses). Finally, hospital IT system data is not enough to clearly understand the impacts of these study, specifically the number of correctly identified cases of sepsis both for nurses and physicians and interns. Therefore, a different approach should be considered, such as, devising simulated real-world scenarios to test if both nurses and doctors improved their ability to clearly identify sepsis cases, at different intervals after having played several clinical cases of the serious game.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we report an exploratory study that aimed understanding healthcare professionals perceptions and satisfaction regarding the Sepsis Fast Track serious game and its suitability to teach the Sepsis Fast Track protocol. Moreover, in-game log data were analysed in order to understand how previous knowledge influences decision-making strategies comparing attending and intern physicians.

In general, both attending and intern physicians agreed that the Sepsis Fast Track is a useful education tool to organize and systematize the Sepsis Fast Track procedures. Nevertheless, experienced physicians stated that it would be a more useful tool for interns and not for physicians with many years of practical experience.

Both nurses and physicians mentioned the importance of the in-game real-time feedback and the debriefing procedure and they stated that they had enjoyed playing the game. Most of the nurses and the intern physicians expressed that they preferred this method of learning as compared to the traditional one. They explained that the interaction that the game allows provides a more rich learning experience as compared to listening to a person teaching and explaining the protocol in a traditional classroom setting.

Regarding decision-making strategies, analysing the in-game log data showed that experienced physicians didn't have a better performance than doctors in training. Factors that may explain this result are that experienced physicians make decisions based on their previous experience, inability to perform multitasking as a limitation of the very game, and not being completely in-role. Log data also showed which were the particular steps of the protocol each physicians had more difficulties with. This information could be useful to continuing medical education programs according to the actual training needs of their target. Also, it raises an interesting question regarding serious game design: should serious game

design start from theory/knowledge or from practice (of the domain)?

Finally, these results point to future experiences that include using different versions of the same game, where realism and interactivity is adapted to fit physicians expectations to enhance their motivation and measure if this influences both the level of acceptance as well as the level of knowledge gain and retention.

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REFERENCES

- [1] K. Durkin, "Videogames and young people with developmental disorders," *Review of General Psychology*, vol. 14, no. 2, p. 122, 2010.
- [2] M. Graafland, J. M. Schraagen, and M. P. Schijven, "Systematic review of serious games for medical education and surgical skills training," *British Journal of Surgery*, vol. 99, no. 10, pp. 1322–1330, 2012. [Online]. Available: <http://dx.doi.org/10.1002/bjs.8819>
- [3] L. de Wit-Zuurendonk and S. Oei, "Serious gaming in women's health care," *BIOG*, vol. 118, pp. 17–21, 2011.
- [4] M. P. Kato, "Video games in health care: Closing the gap," *Review of General Psychology*, vol. 14, no. 2, pp. 113–121, 2010.
- [5] C. Ribeiro, M. Monteiro, S. Corredoura, F. Candeias, and J. Pereira, *Games in Higher Education: Opportunities, Expectations, Challenges and Results in Medical Education*. IGI Global, 2012, ch. New Pedagogical Approaches in Game Enhanced Learning: Curriculum Integration.
- [6] C. Ribeiro, T. Antunes, M. Monteiro, and J. Pereira, "Serious games in formal medical education: An experimental study," in *Games and Virtual Worlds for Serious Applications (VS-GAMES), 2013 5th International Conference on*, Sept 2013, pp. 1–8.
- [7] P. Manning, "Continuing medical education 1906-1975: How the past influences the present," *Almanac, Alliance for CME*, vol. 27, no. 12, 2005.
- [8] BreakAway, "Pulse!! serious game," 2007. [Online]. Available: <http://www.breakawaygames.com/serious-games/solutions/healthcare/>
- [9] VirtualHeroes, "3diteams serious game," 2007. [Online]. Available: <http://www.virtualheroes.com/projects/3diteams/>
- [10] I. in Learning Inc., "Clinispace serious game," 2010. [Online]. Available: <http://www.clinispace.com/>
- [11] S. o. M. Stanford University, "Sepris serious game," 2011. [Online]. Available: <http://med.stanford.edu/sepris/>
- [12] D. A. Kolb *et al.*, *Experiential learning: Experience as the source of learning and development*. Prentice-Hall Englewood Cliffs, NJ, 1984, vol. 1.
- [13] R. Garris, R. Ahlers, and J. E. Driskell, "Games, motivation, and learning: A research and practice model," *Simulation & gaming*, vol. 33, no. 4, pp. 441–467, 2002.
- [14] K. Kiili, "Foundation for problem-based gaming," *British Journal of Educational Technology*, vol. 38, no. 3, pp. 394–404, 2007.
- [15] R. Held and A. Hein, "Movement-produced stimulation in the development of visually guided behavior," *J Comp Physiol Psychol*, pp. 872–876, 1963.
- [16] F. Varela, *The Embodied Mind*. MIT Press, 1991.
- [17] A. W. Wu, "Medical error: the second victim," *British Medical Journal*, vol. 320, no. 7237, pp. 726–727, Mar. 2000.
- [18] A. D. Waterman, J. Garbutt, E. Hazel, W. C. Dunagan, W. Levinson, V. J. Fraser, and T. H. Gallagher, "The emotional impact of medical errors on practicing physicians in the united states and canada," *Joint Commission Journal on Quality and Patient Safety*, vol. 33, no. 8, pp. 467–476, 2007.
- [19] S. D. Scott, L. E. Hirschinger, K. R. Cox, M. McCoig, J. Brandt, and L. W. Hall, "The natural history of recovery for the healthcare provider second victim after adverse patient events," *Quality and Safety in Health Care*, vol. 18, no. 5, pp. 325–330, 2009.